

THE TOOLS OF THE RADAR SYSTEM ENGINEER

by

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A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MECHANICAL ENGINEER

June 1954

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Date thesis is presented MAY, 1954

Typed by Jane J. Bower

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THE TOOLS OF THE RADAR SYSTEM ENGINEER

THE RELATIONSHIP OF THE SYSTEM ENGINEER TO THE DEVELOPMENT PROGRAM

A project normally proceeds through three phases of engineering. The preliminary design is primarily the development of a sales document to obtain funds authorization for a project; it is an effort to develop the useful value of the product and the estimate of cost. The development program involves primarily model shop type production with fairly complete engineering drawings but with a minimum of tooling; a small number of working models are required for functional test, for tests under extremes of environment and for determination of customers information such as outline and installation details, weight data, and power requirements. The engineering part of the production phase involves engineering for economical quantity production, detailed maintenance and servicing manuals, spare parts stocking and cataloging, and training programs for operators and servicing personnel.

The system engineer contributes to system-wide planning and records and extends the planning in the form of system specifications, drawings, etc.; he reports to the project engineer. He is not responsible for major system decisions; these are the responsibility of the project engineer. He is not responsible for highly technical

decisions; these will be handled by appropriate staff engineers or specialists.

In addition to the system coordination work, the system engineer may be directly responsible for the design of such items as:

- Junction Boxes

- Interconnecting cabling or harnesses

- Cooling system

- Racks, cases or mountings for major units

- Shock or vibration isolation systems

- Standard parts to be used throughout the system.

The system engineer should maintain close liaison between the unit engineers with regard to interconnections; between the unit engineers and the company staff engineers or specialists on technical problems common to several units (probably in cooperation with the project engineer); and between the unit engineers and customer on special requirements as directed by the project engineer.

The project engineer is responsible for scheduling but the system engineer should make sure that the interchange of information, the release of system drawings, design freeze dates, etc. are consistent with the established schedule, and that releases of information meet the customer's requests and report or publication deadlines.

ORGANIZATION OF GRAPHIC MATERIAL

The ability of an engineering group to work together smoothly depends to a considerable degree on the extent they can work separately; if the function and physical requirements of each unit of the system are clearly described, the unit engineer can give his full attention to the development of his unit; otherwise he would have to interrupt his work continually to consider other units. The principal function of the system engineer (with his helpers) is to create the appropriate information and to keep it up to date. This material should be in a form convenient for reference; yet it should be as explicit as needed by the unit engineers. The organization of this information requires the use of considerable ingenuity in the mediums and presentations to be employed. Drawings, written specifications, schematic diagrams, photographs, and models or mockups are all of use; some of the more useful will be discussed in following sections of this paper.

In regard to written material, few engineering groups have adequate secretarial assistance. An experienced secretary of sufficient competence can relieve the engineers of a great deal of work and insure a better job. Certainly any material to be presented in written form should be prepared carefully and brought up to date

frequently. In addition to compliance with any secrecy requirements that may be imposed by reason of military security or otherwise, important documents or specifications should be distributed under control sufficient to enable the revision or replacement of out-of-date material. While the system engineer does not set up the requirements for secrecy and control, he certainly must adhere to them and should cooperate in maintaining and following the necessary "red-tape".

Drafting assistance is almost a necessity for groups involving more than three or four engineers. Pencil drawings are suitable, but the following points contribute to the smooth progress of the job:

1. The pencil lines should be heavy enough to print clearly; semi-legible prints should not be tolerated.
2. The drawing should be signed and dated by the engineer responsible; revision dates and approvals should be shown for each change.
3. Prints should be obtainable by a drawing number (engineering sketch numbers are often used). The central source should be in or close to the group.
4. The classification (if military "security information" if involved) should be marked on the original prior to the first printing.
5. Prints should be distributed under sufficient control to enable them to be replaced when revisions are distributed. (This is frequently combined with the procedure required for "classified" material.)

Most engineers lack training in the technique of presenting material in schematic form. While the basic symbols for radio use are well established in the current ASA bulletin (1), the usage of these symbols is not uniform. The armed services have issued a guide (3) which is of some help on symbols, but little information is available on accepted standards for electrical circuit schematics, and even less is available on the other diagrams discussed.

The layout of a schematic cannot be left to a draftsman; the engineer must supply this since it must express the workings of the circuit rather than the electrical connections (4, p.42) (5, p.19).

TOOLS OF THE SYSTEM ENGINEER

Functional Block Diagram

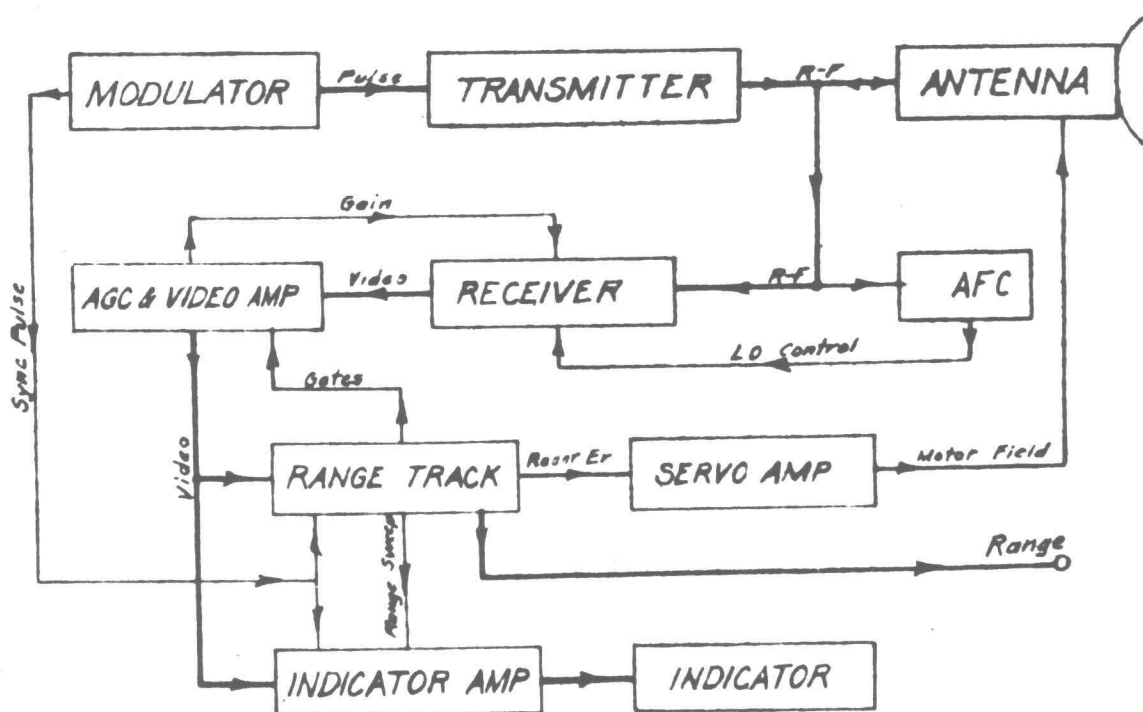
The first step in organizing the engineering team is the development of a simple block diagram showing the functions needed in the system. Figure 1 shows an example of such a diagram. In many cases this diagram will have been inherited from the preliminary design phase of the job; in any event it should represent the plans to be detailed by the development group. It should indicate such major functional units as transmitter, automatic ranging circuits, etc.

Almost from the beginning, the block diagram should be made explicit in regard to the nature of the signal interconnections, at least to the extent of specifying whether dc, r-f, pulse, etc. During the development period, the simple block diagram should evolve into a more elaborate drawing showing:

1. Physical breakdown into major units and subassemblies.
2. Full list of signals in and out of each block.
3. Estimates of power requirements - types and quantities.
4. Estimate of weight, size, cooling requirements, etc.

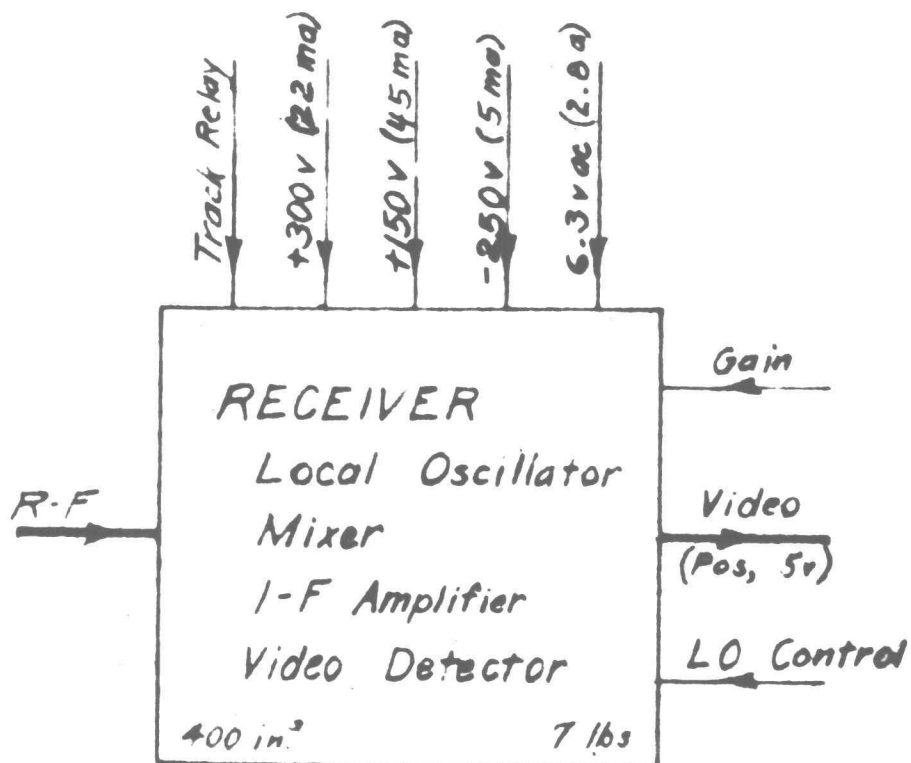
An example of such added information is shown in Figure 2.

At the time that the system block diagram is being expanded, each of the blocks will be broken down into its



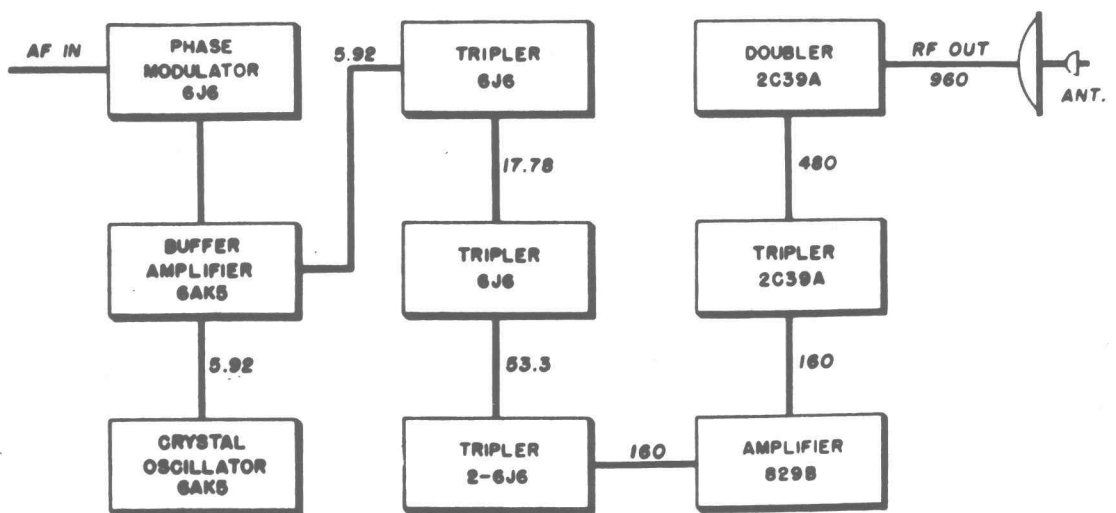
SIMPLE BLOCK DIAGRAM

Fig 1.



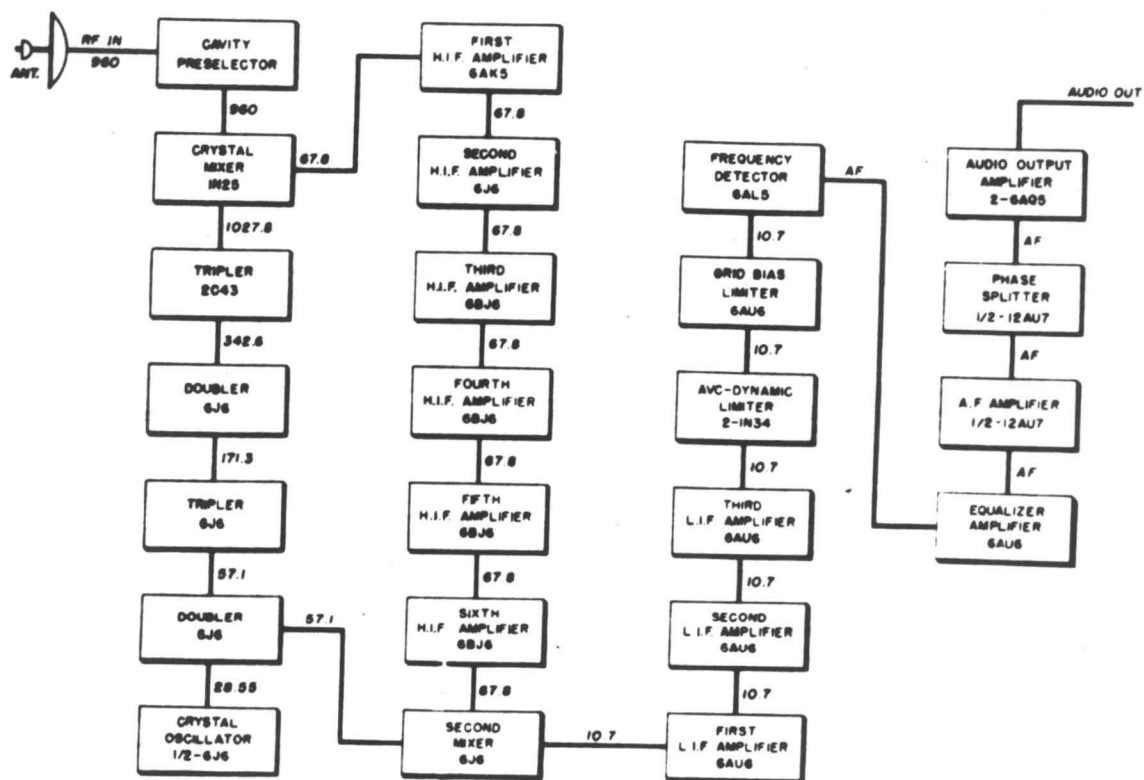
EXAMPLE, MORE COMPLETE
BLOCK DIAGRAM

Fig 2



TRANSMITTER, BLOCK DIAGRAM

Fig 3



RECEIVER, BLOCK DIAGRAM

Fig 4

functional parts and the unit engineer will, very likely, make up his own detailed block diagram for the unit in question. Figures 3 and 4 illustrate such a breakdown. The unit schematic finally takes form as illustrated in Figure 5, and at this time the final system schematics can be undertaken.

Family Tree

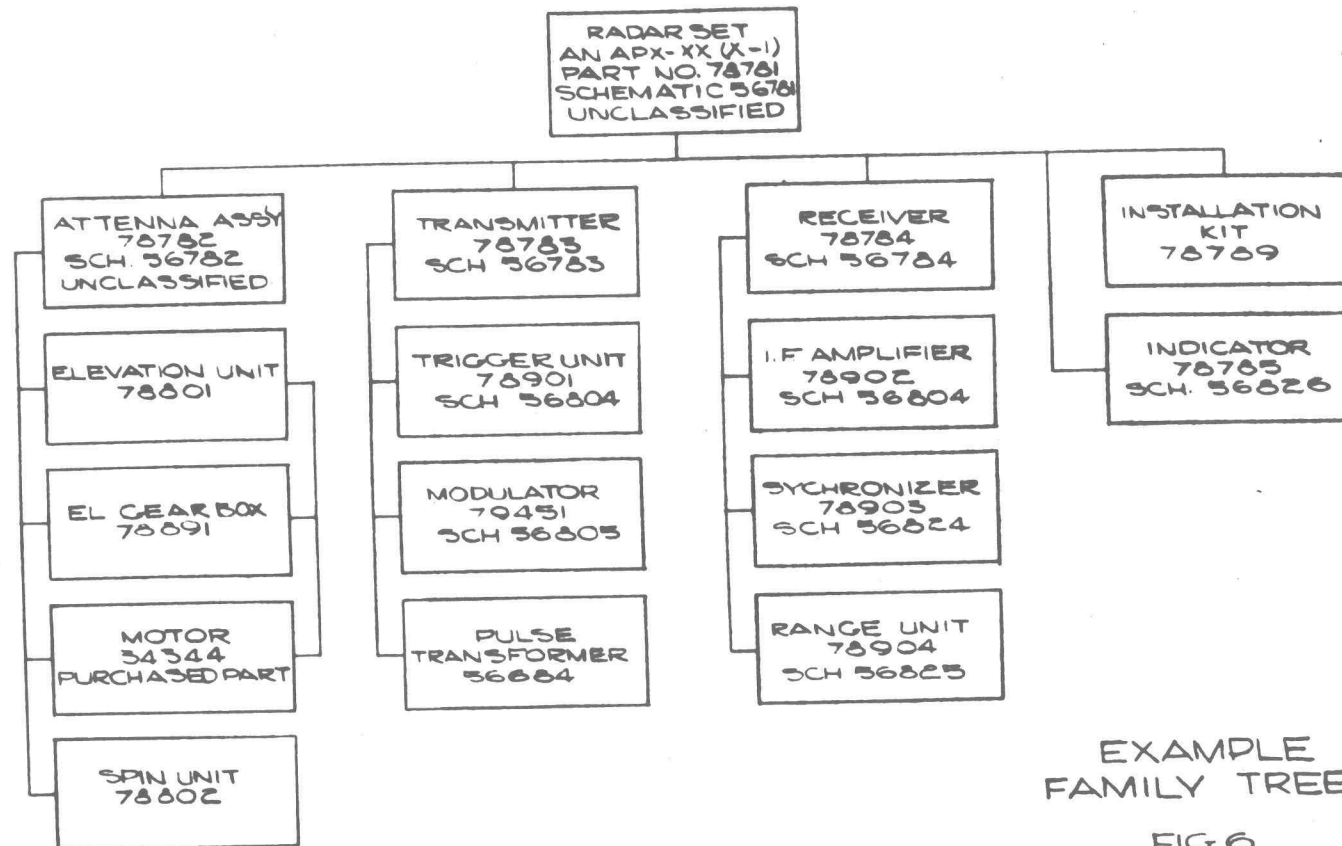
As soon as the physical breakdown in Major Units and replaceable subassemblies is determined, a "Family Tree" drawing is useful in showing the breakdown. An example is shown in Figure 6. Each unit or assembly should be given:

1. Its identifying name and/or nomenclature.
2. The assembly or part number.
3. The number of its functional schematic, if any.
4. The component identification number series, if any. (See Appendix I)
5. Identification as "Purchased Part" if applicable.
6. Classification, if military security requirements are involved.
(If a "Secret" subassembly is used, all higher order assemblies must either omit the classified information or also be classified.)

Detailed System Signal Schematic

Such a comprehensive schematic will usually be undertaken after the system planning has congealed--that is, when a detail schematic is available for each unit of the system. The purposes of such a schematic are to provide a





EXAMPLE
FAMILY TREE

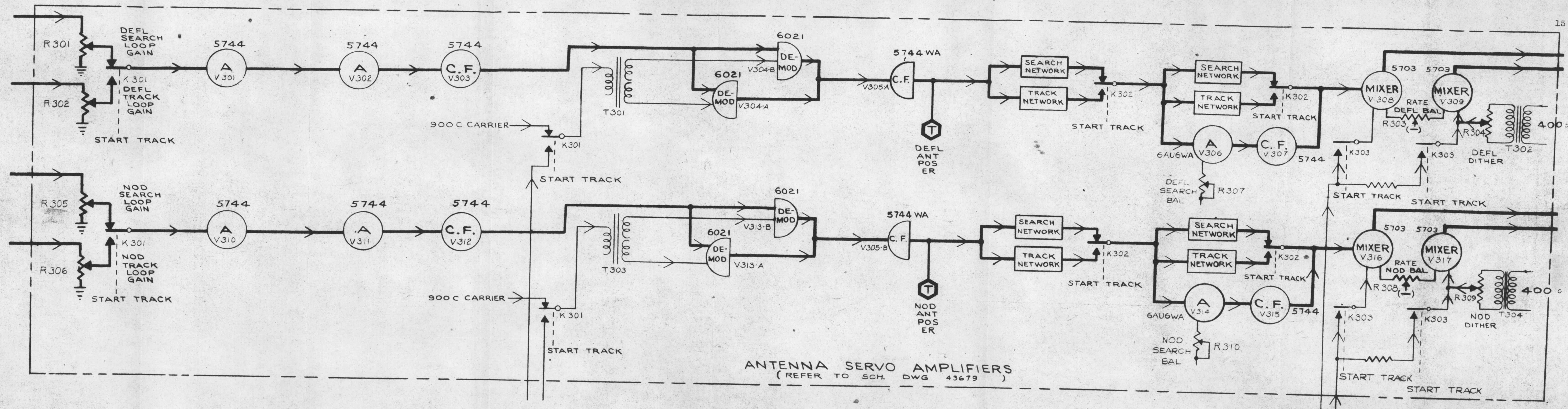
FIG 6

quick reference for important details of the system, to describe the system to informed engineers outside the group, and to provide source material for reports or the instruction book.

An example of a portion of such a schematic is shown in Figure 7. The functional blocks should each represent only one important functional element such as a tube, relay or switch, signal transformer, signal filter, mixing device or network, control, system adjustment, etc. All signals, interlocks, and important feedbacks should be shown to describe the basic function of the components shown. Relays and switches should show how they influence the system operation - not necessarily how the relay or switch is operated. Biasing resistors, bypass capacitors, and anti-parasitic filters are examples of items not as a rule necessary on a signal schematic. Important components should be clearly identified; the code shown in Appendix I is convenient for this purpose (2, pp.4-6).

By means of "dash-line" boxes the physical location of each function can be clearly shown; the box should be identified by its subassembly name and part number and reference should be made to the subassembly schematic drawing number.

Since this diagram is the final "paper buildup" of the system, it will serve to check the major system connections, and should indicate the test points and



ANTENNA SERVO AMPLIFIERS
(REFER TO SCH. DWG 43679)

EXAMPLE, SYSTEM SIGNAL SCHEMATIC
Fig 7

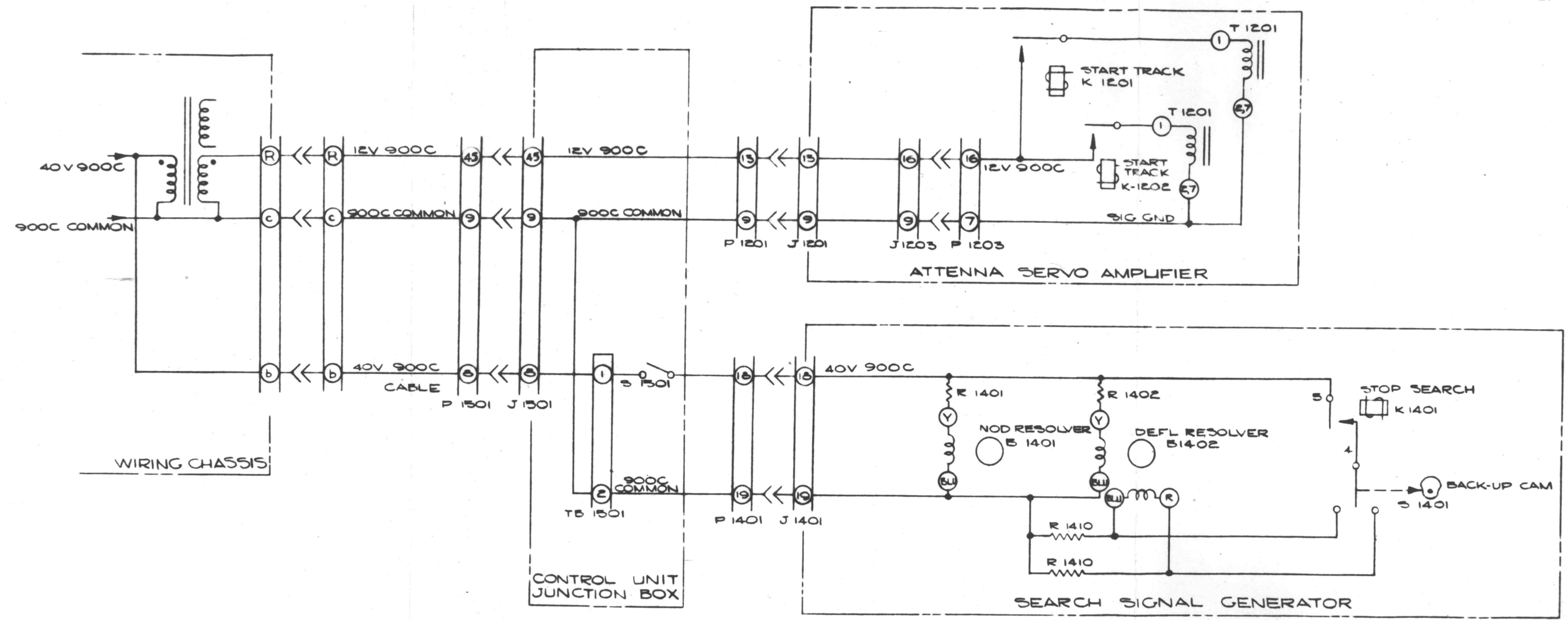
adjustments to be used when the system is coupled together for its composite tests.

Power Distribution Diagram

This diagram should show the origin of each type of power, where it is consumed, the control switching required, the routing of the leads, the currents transmitted, the r-f filters required, permanent meters, voltage regulators and their adjustments, and test jacks for measuring current or voltage. An example is shown in Figure 8.

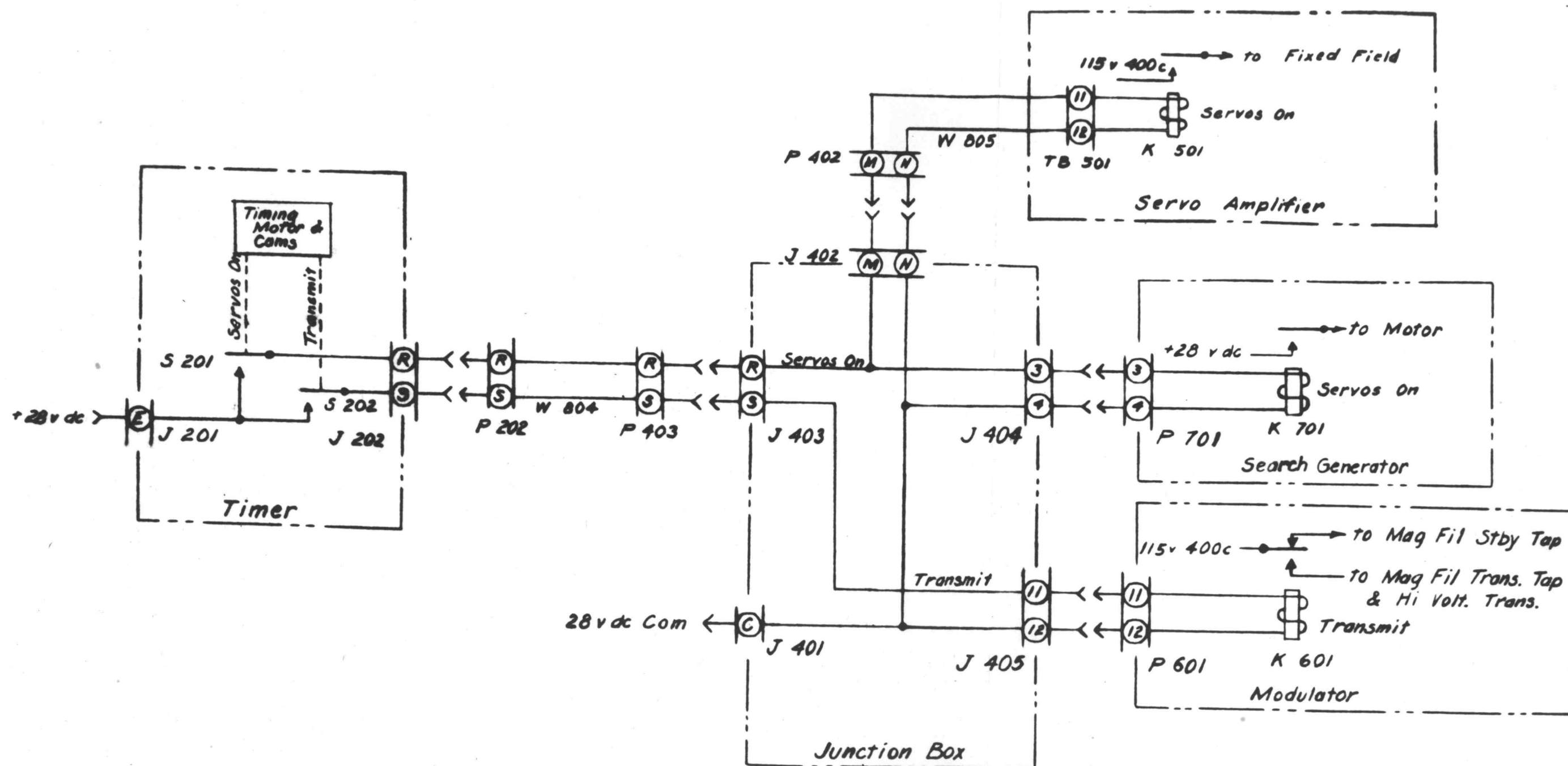
Relay Switching Diagram

The purpose of this diagram is to show what operates the relays--not what the relays switch. An example is shown in Figure 9. Care should be taken to show every interlock clearly. (In this regard, the simplest system is most likely easy to diagram; a needlessly complicated system invites trouble whenever a field crew undertakes to diagnose a switching trouble.) Generally speaking relay coil connections should be drawn out in full; it is also helpful to show all of the contacts for each relay with identifying notes or nomenclature for each pole. The standard symbols for relays show contacts in the energized position regardless of whether or not the relay is energized during "normal" system conditions. Relay coils should be identified clearly. If the "K" number



900C POWER DISTRIBUTION DIAGRAM

Fig 8



RELAY DIAGRAM
"SERVOS ON" & "TRANSMIT"

Fig. 9

nomenclature is used (Appendix I), that will serve to identify the unit or subassembly in which the relay is located.

Servo Loop Diagram

Since many of the components of a servo system will be scattered throughout the system, a diagram similar to the one shown in Figure 10 may be useful to record the details of the data transmission systems and the location of the principal components of the system. Items of interest are:

Types of wiring or transmission line

Location and types of amplifiers, demodulators, etc.

Indication of gain factors, etc.

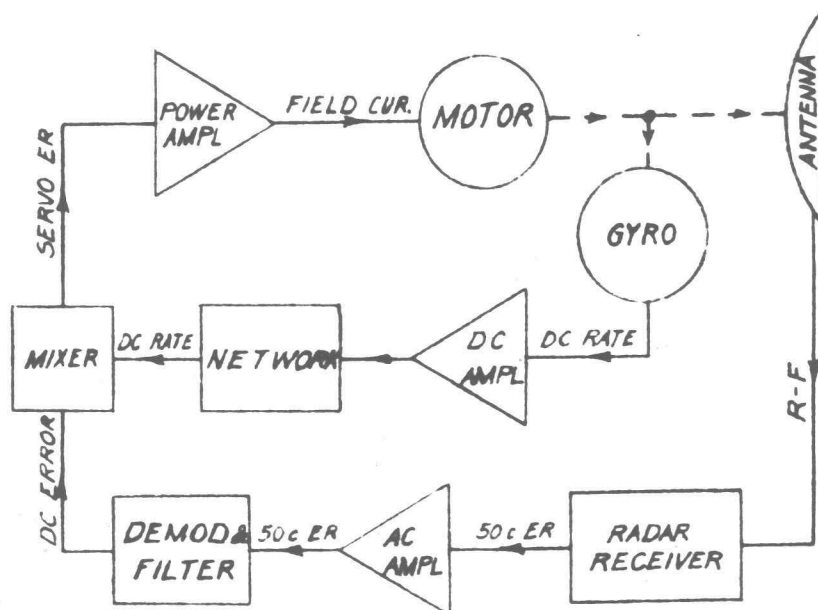
Switching requirements

Networks or filters, with cut-off, pass band, etc.

Routing of signal leads

Data Transmission System

In the case of Selsyn (self synchronous a-c) or resolver data systems, a separate schematic may be worthwhile to show carrier phase correction, limiters, isolation transformers, repeaters (amplifiers), grounding and shielding, or the like. This is especially true if a portion of this system lies outside the limits of the development task.



AZ SERVO LOOP DIAGRAM

Fig. 10

Time Sequence Chart

If the time sequencing of the system is at all complicated or unusual, a chart can be made up showing the portions of the system switched on or off by each step in sequence. In some cases this chart can be combined with relay or switching diagrams. In assigning nomenclature the following points should be observed:

1. Distinguish between a switching "Instant" and the period of operation following, i.e. between "Filaments On" and "Standby".
2. Identify relay control leads, if energized during a period of operation, by the "period" name, i.e. "Search".
3. Identify short duration switching signals by the name of the switching step, i.e. "Stop Search".

Heating or Cooling System Diagram

If the system utilizes elaborate heating or cooling systems, a simple line diagram with suitable notes should be valuable in presenting and recording the basic system. The means of control and the principal specifications should be shown.

Outline Drawings

Perhaps the most neglected of all the system drawings are the outline drawings. In the case of sub-assemblies, the outline drawings provide the information needed by designers of the higher order unit. In the case of the major units, the information is needed for

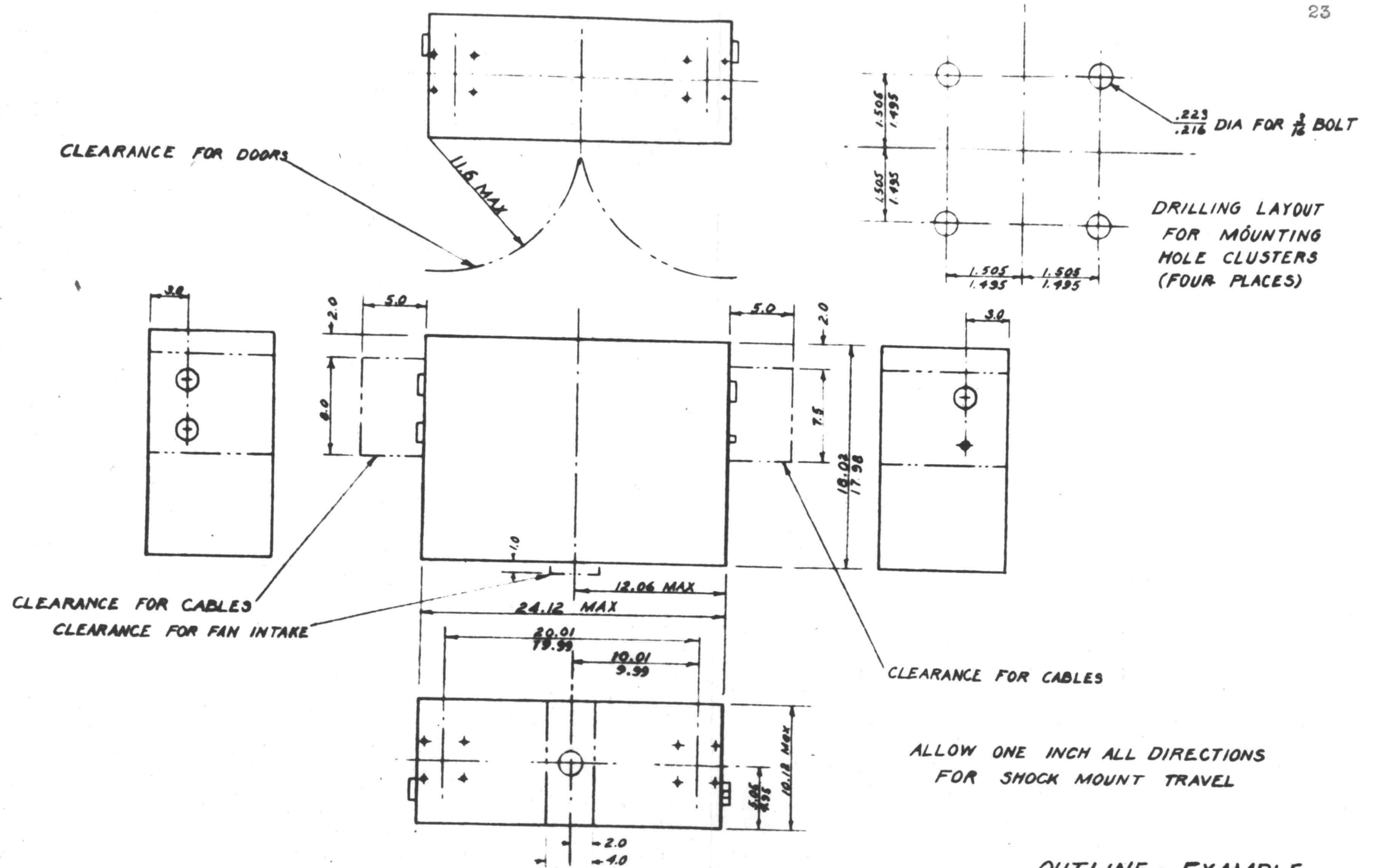
installation studies and drawings and for the customer's information. These drawings should be issued early, in skeleton form, under sufficient control to permit their recall or revision. An example is shown in Figure 11.

The principal requirements of an outline drawing are:

1. At least two views are necessary, three or more if the object is not simple in form.
2. Overall dimensions should be given as maximums with a generous allowance above the largest tolerance accumulation.
3. Mounting hole dimensions should be given in the form of a drilling layout with tolerances and hole diameters specified. Other mounting information should be presented in equally explicit form suitable for the customer's use.
4. Clearances for opening doors, connecting cables, air flow to intakes, travel on shock mountings, access to adjustments, etc., should be both pictured and noted. (These are the most common lacks on outline drawings.)
5. The weight and the location of the center of gravity should be shown.
6. Electrical connectors should be clearly identified, if possible, both by identifying the receptacle and by a "Mates With" note. A cabling drawing may be referenced if the connections are elaborate. If military nomenclature is used, the receptacles should also be identified by the appropriate "J" number (2, p.5).

Cabling and Harness Diagrams

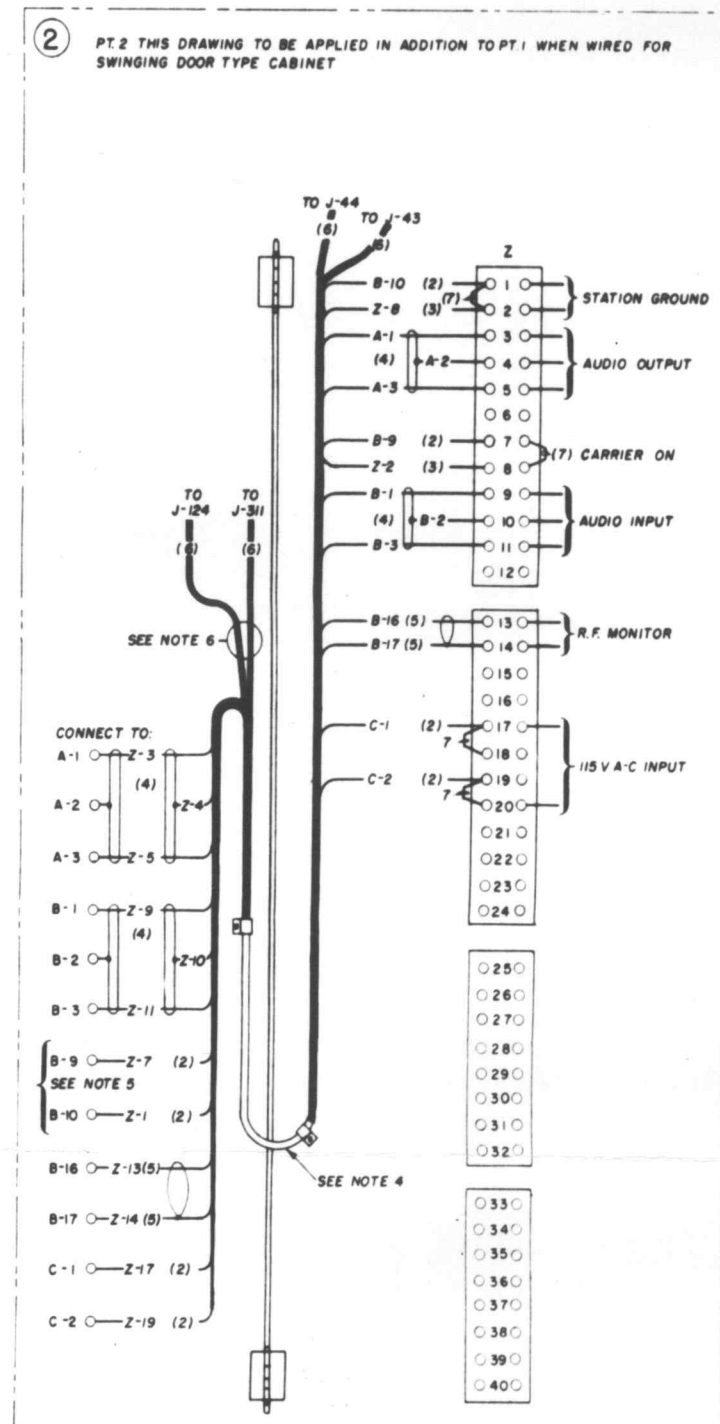
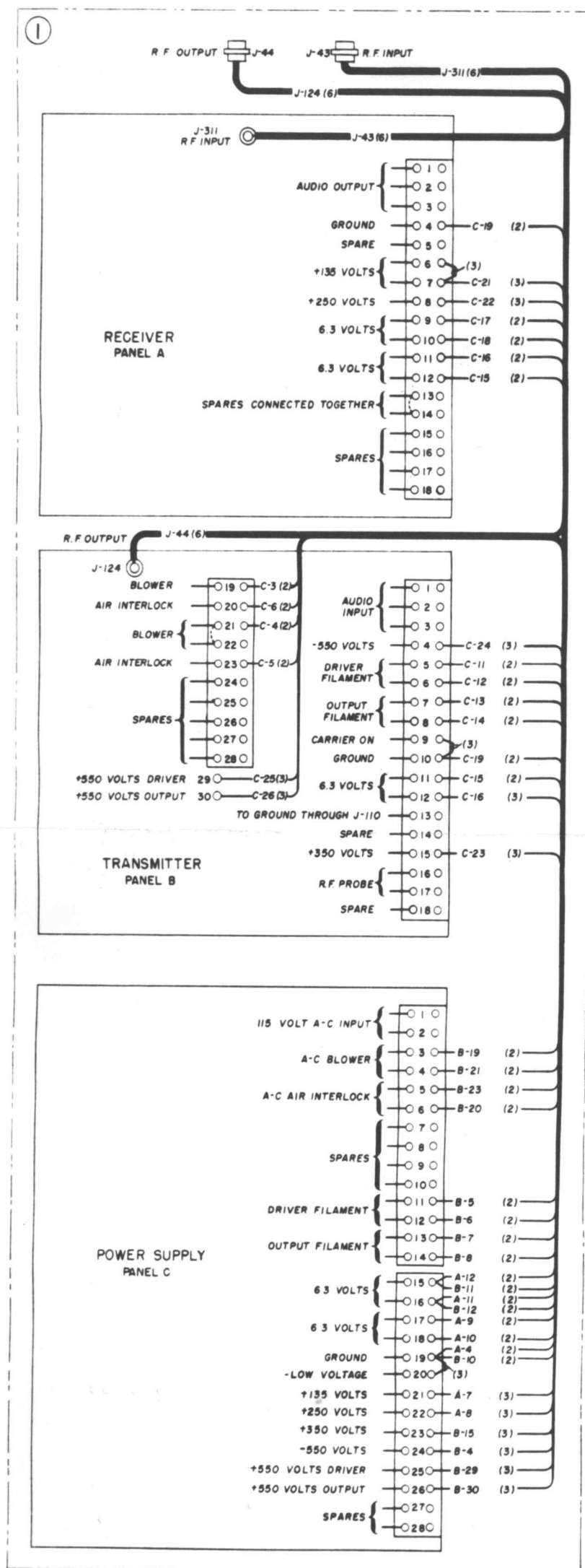
When the time comes to assign plug and pin numbers to the input and output leads from a unit of the system, a



OUTLINE - EXAMPLE

Fig 11

Interconnection Diagram
Fig 12



cabling or harness diagram similar to the example shown in Figure 12 may be employed to record these data. Care should be employed to avoid excessive voltage gradients between adjacent pins and to guard high impedance circuits from ac or noise pickup from adjacent pins. A little common sense early may head off difficulties at a later date.

Whenever possible, leads should be identified by a descriptive name such as "115v 400C" or "Range Voltage". If the diagram is too complex to permit drawing each lead separately, each cable or wire bundle can be drawn as a heavy line; however, each conductor must then be identified also by its destination, for example to "P8104-8", meaning the wire goes to pin 8 in plug P8104.

List of Purchased or Standard Components

For the purpose of achieving reasonable standardization, a preferred parts list should be prepared for semi-standard parts (especially purchased parts) and the design for each unit should be checked by the unit engineer for appropriate use of these semi-standard parts. It is necessary to check these lists against company standard parts lists and in many cases against the customer's preferred parts lists or specifications.

Mockups

Mockups are expensive to make, difficult to keep up to date, and of dubious accuracy. However, many layout problems can be handled best by means of mockups. Such mockups can often be very simple affairs, sometimes at reduced scale. One problem that often comes up is whether a subassembly can be removed through a specified opening. Since it is difficult to determine on the drafting board such factors as hand clearance for releasing fasteners or for juggling the subassembly out through the opening, a full-size mockup of the opening and of the subassembly can be of considerable use.

A full-scale elaborate mockup may be necessary for reasons other than the problems of engineering the equipment; on most projects there is a steady stream of VIP's and the mockup serves to fill the gap in the program when no hardware exists in a form suitable to show off. A good presentation will pay off in two ways: first, it enables the sponsors of the project to follow the planning work; second, the customer's technical staff can better determine how the details of the system should be worked out to make the equipment suitable from their viewpoint. In other words, a good mockup should help to keep the money coming to complete the development and should help to improve the saleability of the equipment.

CONCLUSION

The efforts of the system engineer should be directed toward the following three objectives:

1. The system is to be hooked up on paper before the construction is completed.
2. Coordination in the engineering group is to be facilitated by maintaining convenient reference material.
3. The system plans are to be summarized in a form suitable for evaluation by the customer's representative.

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APPENDIX

*8 May 1953

** 6.3 Alphabetically by letters.

Classes of parts are marked with an asterisk (*) to facilitate designation of parts not specifically included in this list. In case of doubt, a letter or letters already assigned to the part or class most similar in function should be used.

*A	Structural part; mounting (not in electrical circuit and not a socket).	K	Relay (electrically operated contactor or switch).
AR	Amplifier, electron tube or transistor.	L	Choke; inductor; loading coil; relay operating coil; retardation coil; solenoid; tuning coil; winding.
AT	Attenuator; pad, resistive termination.	LS	Loudspeaker; horn; howler; siren; speaker.
*B	Blower; fan; motor; prime mover; resolver; synchro.	*M	Meter; clock; counter (indicating device); elapsed time recorder; gauge; instrument; message register; oscillograph; oscilloscope; thermometer.
BT	Battery.	MG	Motor-generator.
C	Capacitor; capacitance bushing.	MK	Microphone; telephone transmitter.
CB	Circuit breaker.	*MP	Miscellaneous mechanical part such as: bearing; coupling; gear; mechanical interlock; shaft; vibrator rod.
CP	Coupling (aperture, loop, or probe); coaxial or waveguide junction (tee or wye).	MT	Mode transducer.
CR	Crystal detector; crystal diode; crystal unit; crystal, contact or metallic rectifier; selenium cell; varistor, asymmetrical.	N	Chart; nameplate; etc.
D	Dynamotor; converter; inverter.	P	Electrical connector, movable (affixed to the end of a cable, flexible conduit, coaxial line, cord or wire), plug.
DC	Directional coupler.	PS	Power supply, source of power.
DL	Delay line.	PU	Pickup; erasing head; recording head; reproducing head.
DP	Diaphragm.	Q	Transistor.
*DS	Miscellaneous illuminating or indicating device (except meter or thermometer) such as: alarm; annunciator; audible or visual signalling device; bell; buzzer; drop; flasher; pilot, illuminating or signal lamp; telegraph sounder; telephone set ringer; vibrator (indicating).	R	Potentiometer; resistor; rheostat; shunt.
*E	Miscellaneous electrical parts such as: aerial; aluminum or electrolytic cell; antenna; bi-metallic strip; binding post; brush; carbon block; cord tip; counterpoise; dipole antenna; electrical shield; electric contact; gap; individual terminal; insulator; lightning arrester; loop antenna; magnet; protector; resonator; short.	RE	Radio receiver; receiver.
EQ	Equalizer.	RP	Repeater (telephone usage).
F	Fuse; fuse cutout.	RT	Ballast lamp; resistance lamp; thermistor.
FL	Filter.	RV	Symmetrical varistor.
G	Exciter; generator; magnets; rotating amplifier; vibrator (interrupting).	S	Switch (mechanically or thermally operated); contactor; disconnecting device; dial (circuit interrupter); electrical safety interlock; governor switch; interlock; speed regulator; telegraph key; thermal cutout; thermostat.
*H	Hardware; bolts; nuts; screws; etc.	T	Transformer; autotransformer; IF transformer; repeating coil (telephone usage); transformer; waveguide or coaxial taper; induction coil (telephone usage).
HR	Heater (element for thermostats, oven, etc.), heating lamp.	TB	Terminal board; connecting block; group of individual terminals on its own mounting; terminal strip; test block.
HS	Handset.	TC	Thermocouple.
HT	Telephone receiver (not part of handset); headset; hearing aid.	TR	Radio transmitter; transmitter.
HY	Hybrid coil; hybrid junction.	*U	Hydraulic part.
J	Electrical connector, fixed (mounted on a bulkhead, equipment, wall, chassis, rigid conduit, or panel), jack, receptacle.	V	Electron tube; barrier photocell; blocking layer cell; light-sensitive cell; photoconductive cell; phototube.
		VR	Voltage regulator (except an electron tube).
		*W	Cable; cable assembly; coaxial cable; guided transmission path; waveguide; wire; wire assembly.
		X	Socket; fuseholder (see par. 5.1).
		Y	Oscillator (excluding electron tube used in an oscillator); piezoelectric crystal; magnetostriction oscillator.

** Indicates revision. Supersedes page 5 dated 16 April 1952.