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PLAINTIFF'S
EXHIBIT
USX-249

TURBINE-GENERATOR FOUNDATIONS

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DESIGN and CONSTRUCTION RECOMMENDATIONS

GENERAL ELECTRIC COMPANY

SCHENECTADY, NEW YORK

CONSTRUCTION ENGINEERING DEPARTMENT

USHO 002700

FOREWORD

THE design and construction recommendations contained in this booklet are presented to assist purchasers of General Electric equipment in planning foundations for steam-turbine-generator sets.

The conclusion should not be drawn that the structures illustrated are the only ones that may prove successful. These designs, however, have been employed successfully in many installations, and purchasers are invited to study them when making preliminary foundation plans. Such preliminary plans should be submitted to the General Electric Company for review in order that suggestions by G-E engineers may be considered prior to the preparation of the final design.

Although some details have necessarily been omitted from the illustrations, sufficient information is included to indicate the general framing schemes, sizes of the principal members, and reinforcing details of the particular sizes of units shown.

The foundation designs shown here are representative of actual installations, but must not be used for construction purposes. The intention is that they shall serve only as guides in the preparation of plans for a particular turbine-generator installation.

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MACHINE FOUNDATIONS

THE modern, high-speed, high-power machine requires a foundation that is not only sufficiently strong to support the machine and its accessories and hold them in alignment, but one that is also stiff enough in all its elements to prevent the development of resonant vibrations that might render the unit inoperative.

Foundations should be so designed that they will not have an over-all resonance condition corresponding to the speed of the machine; it is suggested, therefore, that the maximum deflection for a particular machine speed should avoid the values given in the table on page 8.

Regardless of the care exercised in the design of a structure, unsatisfactory results will be obtained if the workmanship and materials are of poor quality.

As a result of its experience with various types of foundation structures, General Electric recommends that either the concrete-encased steel or the reinforced-concrete type of foundation be used for the support of turbine-generators. The advantages to be gained by the use of reinforced concrete more than offset the usual reasons advanced for using other types. The idea that the space requirement of reinforced-concrete foundations is excessive is not always justified. Steel framing is not only difficult to design, but the bracing that is usually required with such construction occupies considerable space; it often occurs that such bracing takes up space that was originally intended for pipes and auxiliary equipment. Furthermore, concrete is usually added to steel structures locally to dampen vibrations and eliminate quick expansions and contractions resulting from temperature changes; this type of construction occupies nearly as much space as reinforced concrete. Also, the possible lower damping of individual elements of a naked steel structure might make it less satisfactory for supporting a machine which may be subjected to some unbalance, and which may be in resonance with the foundation or with one of its elements.

The concrete foundation is elastic in its application and, under normal conditions, can be constructed in less time than the steel foundation. The cost of a foundation that will assure successful operation is a very small percentage of the cost of the complete installation, and it is impossible to estimate the expense that results from failure of a machine due to an inadequate foundation.

It was formerly believed that steel structures were more readily adaptable to changes in station design; but many installations using reinforced concrete have been made in recent years with machines and accessories—such as condensers—that were much increased beyond the size contemplated when the original station layout was made. For these and other reasons it is recommended that the type of foundation chosen be reinforced concrete.

In the design of a station it is desirable to isolate turbine-generator foundations from the building structure. If the foundation of a rough-running machine is attached to the floor or walls of the station, there is a possibility that the vibration of the machine will be transmitted to other machines. If necessary, however, floors abutting the foundation superstructure may be supported thereon, all connections being made without any moment capacity at the ends. Light cantilever construction of any kind should be avoided.

FOUNDATION DESIGN LOADS

In designing machine foundations, it is usual to provide for all the loads to which the structure will be subjected. The beams, girders, columns, and bracing should be so designed that they will be adequate for the maximum combination of loading herein suggested.

The conventional loadings usually provided for are listed below, and the location of these loads is indicated in Fig. 1 by arrows having the same numbers as the following paragraphs:

1. ALL VERTICAL LOADS due to the weight of the machine, auxiliary equipment, piping, valves, etc. Machine loads should be increased not less than 25 per cent for four-pole machines and 50 per cent for two-pole machines.
2. THE WEIGHT OF THE CONDENSER on the turbine exhaust nozzle. The load on the turbine exhaust nozzle from the condenser must be concentric. The usual practice is to use net condenser loading.
3. THE WEIGHT OF AIR-COOLING OR HYDROGEN-COOLING EQUIPMENT for the generator, including the housing, if any.
4. TORQUE LOAD.

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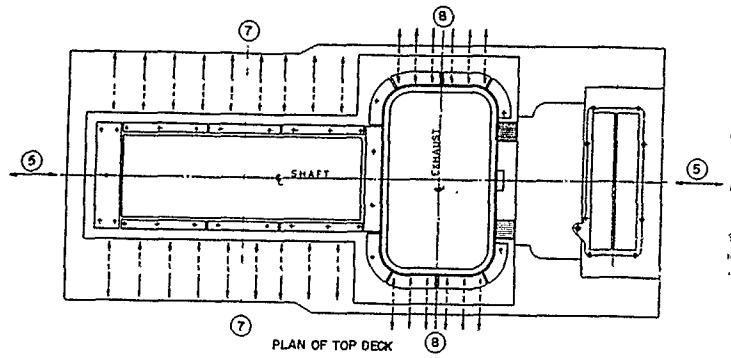


FOUNDATION DESIGN LOADS

THE DESIGN OF TURBINE-GENERATOR FOUNDATIONS SHOULD PROVIDE FOR THE FOLLOWING CONVENTIONAL LOADINGS. UNUSUAL ARRANGEMENTS MAY REQUIRE THAT ADDITIONAL LOADING BE CONSIDERED.

1- ALL VERTICAL LOADS DUE TO WEIGHT OF MACHINE (SEE MACHINE OUTLINE DRAWING), AUXILIARY EQUIPMENT PIPING, VALVES, ETC. MACHINE LOADS SHOULD BE INCREASED NOT LESS THAN 25 & 50% FOR 1800 & 3600 R.P.M. MACHINES, RESPECTIVELY.

2 THE CONDENSER LOAD (OPERATING WEIGHT) ON TURBINE EXHAUST NOZZLE IF CONDENSER IS SPRING SUPPORTED (SEE MACHINE OUTLINE DRAWING), OR VACUUM LOADED IF EXPANSION JOINT IS USED BETWEEN THE TURBINE EXHAUST NOZZLE & THE CONDENSER. THE LOAD ON TURBINE EXHAUST NOZZLE FROM CONDENSER MUST BE CONCENTRIC. THE USUAL PRACTICE IS TO USE NET CONDENSER LOADING

3- THE WEIGHT OF AIR OR HYDROGEN COOLING EQUIPMENT INCLUDING HOUSING IF ANY

4 TORQUE LOAD

5 A LONGITUDINAL FORCE EQUAL TO 50 & 100 % OF THE ROTATING WEIGHTS FOR 1800 & 3600 R.P.M. MACHINES, RESPECTIVELY, APPLIED AT THE SHAFT CENTER LINE

6- TRANSVERSE FORCES AT EACH BENT, EQUAL TO 50 & 100 % OF THE ROTATING WEIGHTS FOR 1800 & 3600 R.P.M. MACHINES, RESPECTIVELY, APPLIED AT THE SHAFT CENTER LINE

7- THE HORIZONTAL FORCES INDICATED BY ARROWS WITH AN ASSUMED MAGNITUDE EQUAL TO THE STATOR LOADING GIVEN ON THE MACHINE OUTLINE DRAWING

8- THE HORIZONTAL FORCES INDICATED BY ARROWS WITH AN ASSUMED MAGNITUDE EQUAL TO THE TURBINE EXHAUST LOADING GIVEN ON THE MACHINE OUTLINE DRAWING. SINCE THE ABOVE GROUPS OF FORCES (7 & 8) ARE ASSUMED EQUAL & OPPOSITE, THEY SHOULD NOT BE CONSIDERED AS EFFECTING THE OVERTURNING TENDENCY OF THE FOUNDATION

9 STRESSES DUE TO TEMPERATURE VARIATION

10- PIPE THRUSTS, ATMOSPHERIC RELIEF VALVE, WEIGHT OF PIPING & FITTINGS

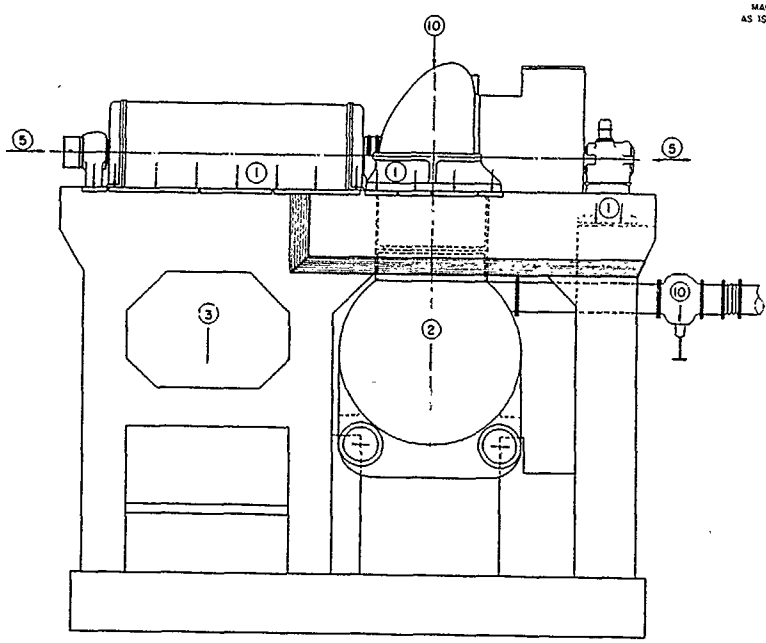
11- FOUNDATION DEAD LOAD

DESIGN LOADING IS FURTHER DISCUSSED IN THE TEXT

FOUNDATION OUTLINE SHOWN IS A REINFORCED CONCRETE STRUCTURE, BUT THE LOADING INDICATED APPLIES OF COURSE TO ANY TYPE OF FOUNDATION

DEFLECTIONS

RESULTANT MAXIMUM COLUMN SHORTENING AND BEAM & GIRDER DEFLECTION UNDER MOST UNFAVORABLE LOADING CONDITIONS SHOULD NOT EXCEED 20 MILS FOR 3000 AND 3600 R.P.M. MACHINES. BEAMS, GIRDERS AND COLUMNS FOR SLOWER SPEED MACHINES SHOULD BE AS STIFF AS IS CONSISTANT TO AVOID ANY RESONANT TENDENCIES (SEE SECTION ON DEFLECTION LIMITS)



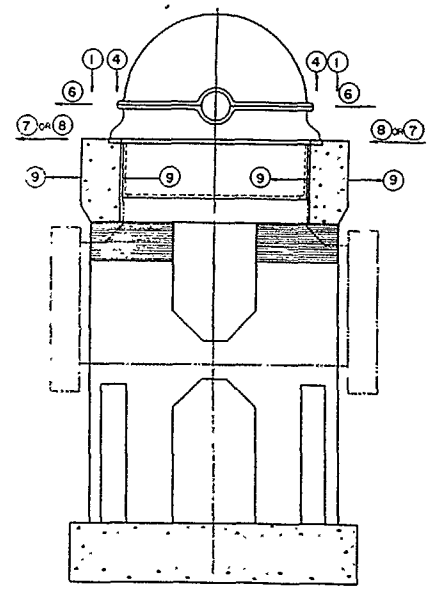


Fig. 1. Foundation Loading Diagram

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5. A LONGITUDINAL FORCE equal to not less than 50 per cent of the rotating weights for four-pole machines and 100 per cent for two-pole machines, applied at the shaft centerline.

6. TRANSVERSE FORCES at each bent equal to not less than 50 per cent [redacted] of the rotating weights for four-pole machines and 100 per cent for two-pole machines, applied at the shaft centerline.

7. THE HORIZONTAL FORCES indicated by arrows, with an assumed magnitude equal to the generator-stator loading given on the machine outline drawing.

8. THE HORIZONTAL FORCES indicated by arrows, with an assumed magnitude equal to the turbine exhaust-feet loading given on the machine outline drawing. Since the above group of forces (7 and 8) are assumed equal and opposite, they will not affect the overturning tendency of the foundation.

9. STRESSES DUE TO TEMPERATURE VARIATION.

10. PIPE THRUSTS, ATMOSPHERIC RELIEF VALVE, WEIGHT OF PIPING AND FITTINGS.

11. FOUNDATION DEAD LOAD.

The foundation outline shown in Fig. 1 is that of a reinforced-concrete structure, but the loading indicated applies to any type of construction.

The resultant maximum column shortening and beam and girder deflection, under the most unfavorable loading combination, should not exceed 20 mils in the case of two-pole machines. For lower-speed machines, the foundation should be as stiff as is consistent with the avoidance of any tendency toward resonance. See DEFLECTION LIMITS, page 8.

Each of the above 11 loadings are discussed in the following correspondingly numbered paragraphs:

1. Machine Weight and Accessories

The weight of the machine and its assumed distribution are shown on the machine outline drawing. The actual distribution and magnitude of this load may vary from the figures given. The usual practice is to increase this loading by some arbitrary percentage. To allow for the variation of load, it is customary to increase the machine weights by 25 per cent for four-pole machines and 50 per cent for two-pole machines. Accessory weights, such as weight of condenser, oil coolers, generator air coolers, etc, are usually obtained from the manufacturers of such equipment, or allowance is made from previous experience with equipment of similar size.

2. Condenser Load

Provision in foundation design should be made for all loads from accessory apparatus, particularly the steam condenser. The condenser arrangement, if spring-supported, should be such as to avoid unsymmetrical loading on the turbine-exhaust nozzle. Many condenser arrangements are developed without regard to the manner of loading the turbine exhaust flange; unsymmetrical condenser arrangement will subject the turbine to objectionable distortion from such loading. The allowable suspended load from the turbine exhaust nozzle is based on the assumption that this load will be concentric, and that none of it is due to torsion.

As early as possible in the development of the turbine-generator arrangement, the proposed condenser arrangement, spring calculations, and condenser-water piping should be submitted to the General Electric Company for examination and comment.

3. Weight of Generator-cooling Equipment

Provision should be made for the working-condition weight of the generator air-cooler system.

If hydrogen-cooling equipment is used, the cooler weights are included in the generator-stator weights. Auxiliary apparatus, such as detraining tank, etc, is not included in the cooler weight, and provision should be made for such equipment if it is placed on the foundation.

4. Torque Load

The maximum torque loading will vary. In the absence of definite data, it is recommended that 500 per cent of the normal torque be used.

Torque, in foot-pounds, may be computed from the formula $T = \frac{7040 \times kw}{Rpm}$.

5-6. Horizontal Loads

In order to provide reasonably satisfactory bracing of the foundation, both transverse and longitudinal, it is usually assumed that the loads producing stresses in the structure are not less than 50 per cent of the rotating weights of four-pole machines and 100 per cent for two-pole machines. It is also assumed that these loads are applied to the shaft centerline and that they act in a horizontal plane. These forces need not be assumed as acting simultaneously.

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For diagonal bracing of steel foundations, effort should be made to induce a substantial initial stress.

7-8. Horizontal Forces

The generator-stator and turbine exhaust girders should have a generous degree of transverse stiffness.

In order to provide these girders with sufficient transverse stiffness, it is recommended that they be designed to take a horizontal load, applied to the top flange of the girders, equal in magnitude to the generator-stator loading or turbine exhaust-feet loading given in the machine outline drawing.

Since these forces are assumed to be equal and opposite, they should not affect the overturning tendency of the foundation.

The horizontal forces are indicated by full and dotted arrows, in Fig. 1, and are assumed as acting in either direction.

The horizontal stiffness of the generator-stator and turbine exhaust girders should be comparable with their vertical stiffness. Resonance should be avoided.

9. Stresses Due to Temperature Changes

Increase or decrease of temperature involves a change in length, inducing stresses. Effort should be made to provide for these distortions. These stresses are indeterminable, and therefore reinforcement for this purpose should be based on practice followed in structures that have proved to be satisfactory.

All beams or girders subjected to temperature changes should be provided with sufficient steel so that cracking of the concrete or the concrete casing of such members will not impair their usefulness. This steel reinforcement is placed in vertical planes adjacent to the outside and inside faces of these beams and girders. The illustrations in this booklet show reinforcement placed for this purpose.

10. Loading from Pipe Thrusts

Provision should be made for loads from pipe, valves, and pipe thrusts, and loads resulting from pressures or vacuums in pipe lines due to the use of expansion joints.

11. Foundation Dead Load

Complete provision, of course, should be made in the foundation design for the weight of the foundation, or dead loads.

DEFLECTION LIMITS

The physical properties of completed structures are known to vary so widely that it is useless to try to make too precise calculations of deflections or natural periods of vibrations. The foundation structure framing is usually so involved that calculation of the natural period of the various members or of the structure as a whole is indeterminate.

The foundation should be sufficiently stiff so that machine erection may be expeditiously and satisfactorily performed and that machine alignment may be permanently held. Also, none of the foundation elements should be resonant, nor should the foundation as a whole be resonant.

Despite the impossibility of making any exact calculation of over-all resonance, it is certain that supports for high-speed machinery should not be resonant. In the absence of any estimate of natural frequency, the stiffer the structure is the better it will be. However, a degree of stiffness that would just correspond to the operating speed should be avoided, and this can be done without failing to comply with the other necessary requirements of good design. To guard against resonance, it is suggested that the deflection of the main columns plus that of the girders, due to the total of rigidly connected gravity loads, should avoid the values of deflection corresponding to resonance as given in the following table for simple elastically supported weights:

Speed	Resonant Deflections
1200 rpm	25 mils
1500 rpm	15 mils
1800 rpm	11 mils
3000 rpm	4 mils
3600 rpm	2.8 mils

In computing such resonant deflections, all actual rigidly connected gravity loads should be taken into account, including the foundation table, the condenser total weight when in operating condition, the piping, and other accessories.

On the other hand, the 25 per cent or 50 per cent added to the machine loads for conservative design, and also transitory torque loadings, must be disregarded in computing resonance. Actual weights only should be used.

The share of the condenser weight carried on soft springs (which decreases the actual loads on the columns and girders) does not decrease the resonant deflection, since the whole weight moves up and down on the main support during vibration.

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Therefore, the entire rigidly connected weight must be computed.

From the experience of the Company it has been determined that when a well designed structure having a stiffness corresponding with the above described requirements is constructed with good materials and proper workmanship, a successful structure should result.

STEEL FOUNDATIONS

The framing elements of the deck of a steel foundation should be such that a direct supporting surface is provided for all bearing surfaces of the machine.

The deck elements should consist of girders parallel and normal to the machine-shaft center-line.

The outside or exhaust girders should run the full length of the foundation deck. If these girders terminate at the middle bearing, the result is weak construction, both transversely and vertically.

As many columns should be used as the equipment requirements will allow.

Cantilevers, particularly those of light-bracket construction, should be avoided. If such construction is unavoidable, the cantilevers should be made practically as stiff as the main deck girders. One acceptable method of providing a walkway around the machine is shown in Fig. 9.

Bracing should be provided in transverse and longitudinal bents to the extent necessary to prevent appreciable distortion of the foundation superstructure, based on the assumed machine-unbalance loading.

Stiff bracing members should be used, consisting preferably of such cross sections that equal, or approximately equal, stiffness is obtained about both axes. Two channels latticed together and provided with batten plates at the points of lattice interruption make excellent bracing sections.

Symmetrical connections should be provided for all important members.

Generous use of symmetrically placed stiffeners should be made, particularly at the points of concentrated loading. Stiffeners should be substantial, and positive bearing should be provided at their ends. They should be fitted by grinding, or contact should be provided by welding.

In general, all member make-up and end connections should be such that excessive secondary stresses are avoided.

Steel foundations should be completely assembled in the structural fabricator's factory. Necessary corrections can then be made in order to provide a structure that will be in repose when erected on its own foundations.

All holes for field joints should be sub-punched and reamed to full size while the foundation is temporarily assembled at the fabricator's shop.

After the shop assembly has been completed, each member should be given match marks, and these match marks should be placed on the erection diagram for the use of the field erector.

When faulty workmanship must be corrected during actual installation, the results, which usually include delay and extra expense, are not always satisfactory.

Steel foundations should be erected with column bases supported on shims. After all riveting and/or welding has been completed, the space between the column baseplates and the sub-foundations should be carefully grouted. No further loading of the foundation should take place until this grout has reached sufficient strength.

To facilitate obtaining a satisfactory grout job, column baseplates or other baseplates should be provided with generous-sized holes to allow entrapped air to escape.

Positive means should be employed to obtain good bearing surfaces where one beam or girder bears on another or on the columns. Bent or distorted flange angles or rough surfaces prevent the obtaining of a satisfactory bearing.

Machined bearing surfaces will aid in eliminating some of the objections due to imperfections of girder and other member make-up.

Elimination of vibration is very essential, and spring action—such as results from faulty bearing surfaces—should be avoided.

It is recommended that the selection of materials, details, and method of fabrication of steel foundations be in accordance with the requirements of the American Society of Civil Engineers' "Specifications for Bridge Design and Construction," or the bridge specification of some one of the first-class railroad companies. If conventional steel-building design, fabrication, and erection practice are followed, unsatisfactory work may result.

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For design purposes, the rivet values used should not be greater than 50 per cent of the usual values—preferably they should be less.

The fabrication and erection of steel foundations should be entrusted only to firms that have the equipment and the personnel necessary to produce heavy work satisfactorily.

Provision should be made for a layer of concrete not less than six inches thick, suitably reinforced above the tops of all deck framing steel and well tied thereto as a foundation for the baseplate grout.

Steel foundation superstructures should not be tied to any part of the station structure. The superstructure should be sufficiently stiff, in itself, so that no reliance for stability need be placed on the station floor or building framing.

Walkways extending from foundation superstructures to the station floor should be mounted on resilient material, and means should be provided against introducing stiffness in the end supports.

Provision should be made, in the form of substantial gusset plates, for negative moments where discontinuity exists. No reliance should be placed on the rivets or welds of the joints, nor on the end connections or other connections of the kind, to take moment.

An ample number of holes of the proper size should be provided in the webs of girders, beams, and columns to allow tying together the reinforcing of the superstructure concrete encasement.

REINFORCED-CONCRETE FOUNDATIONS

All foundation elements—that is, beams, girders, columns, etc—should be designed so that the unit stresses specified below will not be exceeded for the most unfavorable combinations of loading suggested elsewhere in this book. See DEFLECTION LIMITS, page 8. All loads should be assumed to be acting simultaneously except as otherwise specified.

UNIT STRESSES

Concrete, compression.....	350 lb per sq in.
Concrete, bending.....	400 lb per sq in.
Steel, tension.....	10,000 lb per sq in.
Steel, compression (E_s/E_c = 10).....	4000 lb per sq in.

No reliance should be placed on concrete in shear. Suitable-sized closed stirrups should be provided.

Proper provision should be made for negative moments wherever they develop. The use of bent-up bars to take this tension should be avoided. Straight bars in both flanges are preferable, since it is not possible to compute accurately the point of contraflexure.

The ultimate strength of concrete in compression should not be less than 3000 pounds per square inch, when 28 days old.

SUB-FOUNDATION

A large percentage of machine superstructures are founded on a sub-foundation consisting of a reinforced-concrete slab or mat. The function of this mat is to distribute the foundation loading over a larger area than would be obtained with individual column footings. It also allows greater pile spacing than individual footings, with higher allowable individual pile loading. The mat can also be used to restrain the lower ends of the columns.

The sub-foundation should be of a substantial thickness, preferably reinforced with two layers of bars in each flange of the slab. Bending-up of the bars from one flange to the other is not advisable, since the stress distribution may not be known accurately enough to provide for all tensions. Structural steel bents or horses should be used to locate accurately the reinforcement and prevent its displacement when concrete is being deposited.

Provision should also be made in the sub-foundation for the proper embedment of column dowels or column anchor bolts. Depressions or recesses should be provided in the upper surface of the mat for keying the columns.

The area of the mat should be such that safe soil-bearing capacity is not exceeded to the point of allowing excessive settlement to take place. Settlement, particularly unequal settlement, obviously must be avoided.

Soil-bearing capacity and attendant settlement under the loading proposed on the soil should be determined accurately.

If a yielding soil is encountered, it may be necessary to supplement the bearing capacity of the soil by the use of piles or caissons.

When computing soil loading, the eccentricity of the foundation, machine, and machine acces-

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sories must be considered if the center of gravity of this loading does not coincide with the center of gravity of the mat area. The total maximum load on the soil will be the sum of the vertical loads plus the loading produced by the moment of all the vertical forces into their eccentricity.

Complete coincidence of the two centers of gravity would be desirable; but, because of torque and overturning effect, full coincidence is unobtainable.

Foundation construction is frequently required in existing power stations, and this work is often done under difficulties. Foundation structures of greater size than those originally contemplated are sometimes necessary, requiring working close to existing foundations. Under these conditions it is particularly necessary to prevent "loss of ground," or the flowing out of soil from underneath existing machine and building foundations. Judicious use of sheet-steel piling, well braced, may prevent the "loss of ground" or boiling.

Large-diameter open caissons or wells have been used for soil control and for providing support for the foundation superstructure. When large-diameter caissons or wells are used, unequal deflections due to variations in span lengths of superstructure framing elements must be guarded against.

The mat is the first part of the foundation poured. It will be used as a working floor and also for the foundation of the superstructure forms. Superstructure-form construction will be facilitated if the mat is made about two feet wider and longer than the over-all dimensions of the superstructure.

Mat or sub-foundation concrete should not be deposited in water. Nor should it be deposited on soft or disturbed ground. If soft ground is encountered, the excavation may be made about six inches deeper than the depth called for by the depth of the mat, and this space filled with coarse gravel or crushed stone.

POURING CONCRETE

Concrete, when being deposited, should not be dropped through any distance that might allow segregation to take place. An excellent device to use in the placing of concrete in forms which contain obstructions such as reinforcement, anchor bolts, and form projections, is the tremie. A tremie can be made of comparatively lightweight metal, eight to ten inches in diameter, and in short lengths fastened together with chains or other means to allow convenient and rapid disassembly as the forms are filled. The tremie should be provided with a suitably sized hopper at the top. As the forms are filled, the bottom sections of the tremie are removed.

In order to eliminate void spots in the bottoms of columns, girders, beams, etc, due to segregation, mortar—that is, a mixture of sand and cement only—should first be placed in these forms. A depth of about six inches for columns and three inches for beams and girders will probably be satisfactory. A similar application of mortar should be made on top of all sections when pouring is resumed after a sufficient lapse of time to allow shrinkage to take place. All laitance should be removed before pouring is resumed.

Concrete surfaces intended to support machine soleplates or baseplates should have high strength. Better bearing surfaces will be obtained if the concrete at these locations is poured high and, after hardening, is chipped down to the desired grade. The magnitude of high pouring will depend on the amount of laitance formed; three inches will probably prove ample.

All forms should be thoroughly cleaned and well wet down before any concrete or mortar is deposited.

The strength and durability of concrete depend to a large extent on the care taken to cure it after the pouring operations have been completed. It should be remembered that freezing temperatures should be avoided, and that the concrete structure should be kept wet down for a period of not less than ten days.

ANCHOR-BOLT TEMPLATES

For some time it has been the practice of General Electric to discourage the use of machine-anchor-bolt sleeves in reinforced-concrete structures. Because of the limited amount of space available in some heavily loaded beams and girders where cracking of the concrete should be avoided, the tendency to crack will be materially reduced if pipe sleeves are omitted.

In order to hold the anchor bolts accurately to line and grade, an anchor-bolt template made of structural shapes well braced with diagonal members is recommended. Two such templates are shown in this publication, Fig. 18 being for a 7500-kw turbine and Fig. 18a for a 110,000-kw turbine.

The framing of the template is completely fabricated except for the anchor-bolt holes. The

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templates are completely assembled, the anchor-bolt holes are located, the members are match-marked, and the anchor-bolt holes are then drilled. Anchor-bolt holes are usually provided with a clearance not to exceed the diameter of the anchor bolt by $\frac{1}{16}$ in. The lower ends of the anchor bolts are usually secured with wire to the structure reinforcement to prevent movement.

POURING SCHEDULE

The pouring of reinforced-concrete structures must be interrupted where struts, beams, or girders intersect columns or walls, in order to allow the concrete to consolidate and shrink. If these precautions are not taken, the walls or columns will take their shrinkage; but the shrinkage of the structure above the undercut will be restrained from following the wall or column shrinkage by the forms or other obstruction. This would result in leaving a sizable space between the column or wall tops and the bottom of struts, beams, etc.

Fig. 14 illustrates methods followed in pouring reinforced-concrete machine foundations to prevent shrinkage cracks from developing.

The general recommendations are that concrete be poured in such a way as to produce, as far as practicable, a monolithic structure. What is desired is a concrete mass thoroughly bonded together—a result which would be obtained by an uninterrupted or continuous pouring process. However, if this method of pouring were followed, it would result in shrinkage of such magnitude that the structure would probably be useless.

Many satisfactory structures have been obtained by a compromise between the ideal and the practical method.

It is well known that a large percentage of the total shrinkages in any given concrete pour is obtained in a few hours after pouring, and that this shrinkage continues at a lower rate for some time thereafter. The total elapsed time for practically full shrinkage to take place is a function of the temperature, the richness of the mix, the amount of water used, the volume of concrete, and the rate of pouring.

The method generally followed is to fill one column after another to the limits indicated by pour No. 1 which, in Fig. 17, is the underside of a strut. Laitance is removed and provision made for keying the abutting sections together and placing mortar. After a suitable lapse of time, pouring is resumed up to the limits of No. 2 pour. This pour is allowed its time for shrinkage, laitance removal, etc, and another pour is then made, completing the structure.

The pouring schedule shown by Fig. 17 is, of course, typical. Each structure is a problem requiring individual consideration.

The exact time to be allowed for shrinkage depends on many factors, and should be determined locally.

FORMS FOR CONCRETE

Since the forms for machine-foundation concrete are loaded substantially more than forms used for light reinforced-concrete construction, the design, selection of materials, and workmanship should be given careful consideration. Column and beam forms should be designed on the basis of hydrostatic loading, the head depending on the rate at which the concrete is poured.

Forms for concrete should be constructed in a very substantial manner, since light form work is unsatisfactory and its use will delay and increase the cost of the work.

Forms should be constructed to exact dimensions and in such a manner that dismantling may be expeditiously done without damaging the concrete bodies, edges, or surfaces.

They should be tight in order to prevent the leakage of mortar, and should be well braced if the structure line, shape, and grades are to be controlled. The lack of form bracing, or insufficient form bracing, has caused much delay and expense.

The lumber for form construction should be dressed. Tongue-and-groove material should be used for flat surfaces, and the material should be of a kind that would be satisfactory for structural purposes. Care should be exercised to select lumber free from knots, warp, and twists, and free from characteristics which would tend to reduce the strength of the material. No lumber of a nominal thickness less than two inches should be used.

All intersections of plane surfaces should be chamfered. The size of the chamfer should be not less than one inch. The chamfer may be deeper for heavier members.

Nails should not be used for transfer of stresses. Steel rods with washers should be used in place of steel-wire ties. Joints transmitting stress may be made with bolts or toothed-ring connectors.

Forms should be so constructed that they will allow the removal of beam and girder sides, but will still allow the support of the underside of the beams and girders to remain in place to support these elements until sufficient time has elapsed

USHO 002710

to make it safe to remove the supports. Such an arrangement is desirable, since it is advisable to keep the concrete saturated with water for at least ten days after the concrete has sufficiently hardened so that no danger will result to the concrete from the removal of the forms or the application of the water.

Forms or supports should remain in place for a sufficient length of time to prevent sagging or collapse of the structure. The length of time the supports should remain in place will depend upon the temperature and upon the size of the members. Under no circumstances should a reinforced-concrete foundation be loaded in less than 28 days after the last of the concrete has been placed. A longer period may be required if the temperature is below 60 F.

Generous-sized fillets should be used. Sharp or angular intersections for such construction, unless softened, may produce planes of weakness.

The form construction, as a whole, should be amply braced against unyielding surfaces to hold the entire structure to proper alignment. It is not only advisable to brace the elements of the foundation, but it is very essential that the structure as a whole be braced against displacement.

For most installations the surface obtained by the use of dressed lumber is usually satisfactory. If better surfaces are desired, the inside of the forms may be lined with metal or some type of composition board. In some instances the inside of concrete forms has been plastered, and the plaster treated to prevent the adherence of the foundation concrete.

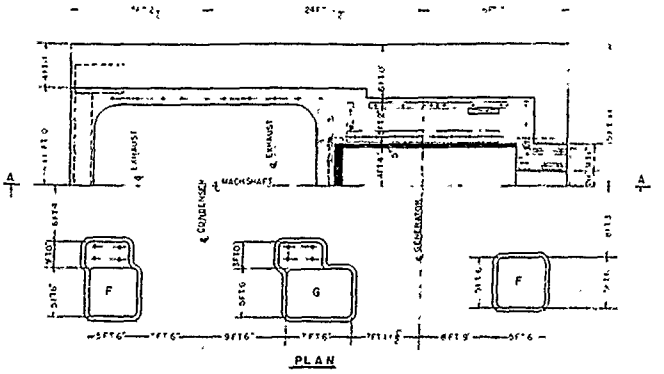
Provision should be made in the lower end of column forms to allow the removal of debris immediately preceding the placing of the concrete. Other openings at higher elevations, depending upon the height of the structure, should be provided to allow the placing of the concrete and to eliminate the necessity of dropping the concrete through any greater distance than is absolutely necessary.

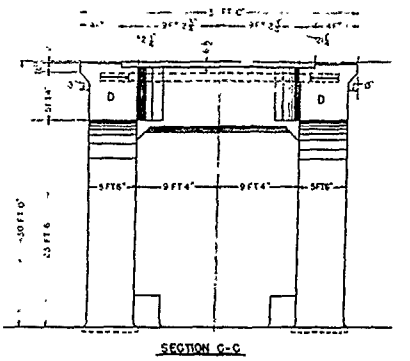
The forms should be tight to prevent the loss of the fine aggregate or mortar which, it is needless to point out, will make honeycomb spots in the surface of the structure when the forms are removed.

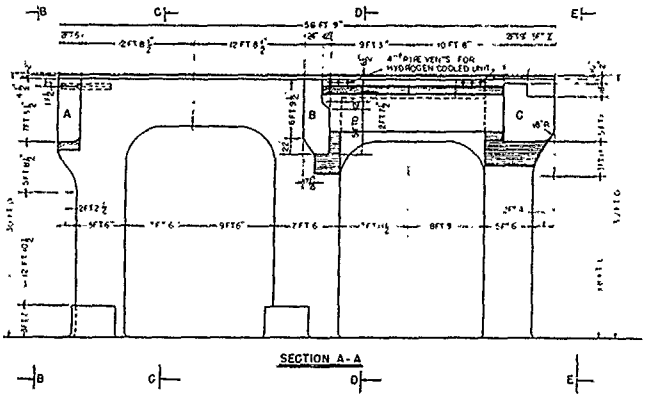
It is recommended that unit stresses for the form lumber be limited to those used in first-class engineering practice, and not increased above these limits, as is ordinarily done in form construction because the form is only a temporary structure. The use of too-high unit stresses has resulted in the sagging of beams and girders and the bulging of column sides.

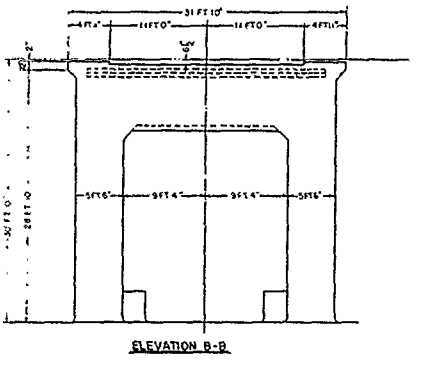
It has been the custom for some time for many engineering-contracting organizations to design the concrete form work completely, and to determine the type and details of all connections and the type and kind of bracing; this system is highly recommended, since none of these matters are then left for the attention of the field construction force.

USHO 002711

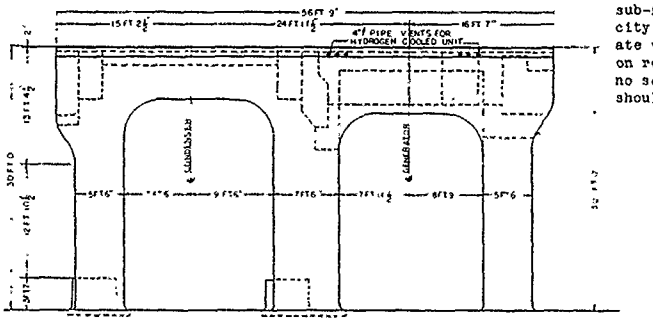


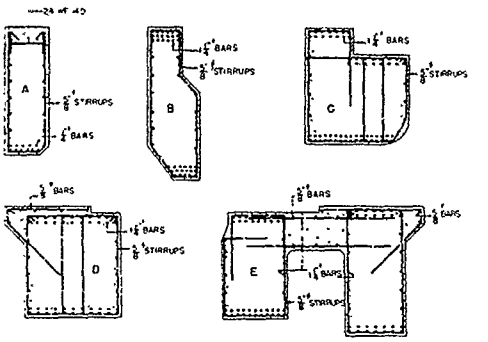


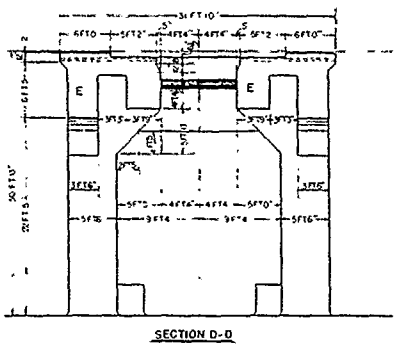


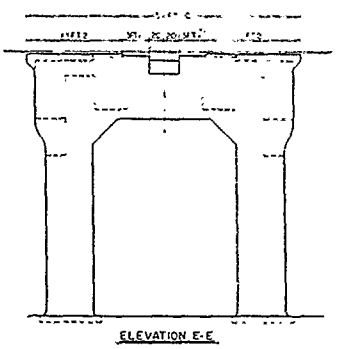


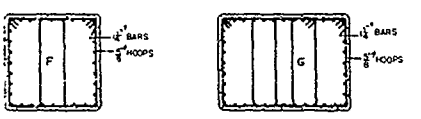
SUB-FOUNDATION: Depth, size, reinforcement, and other details of sub-foundation should be designed to conform to the bearing capacity of the soil and to the structure arrangement in the immediate vicinity of the foundation. If the structure is not founded on rock, the soil pressures must be such as to insure practically no settlement. If necessary, piles, caissons, and other means should be used to prevent such settlement.











TYPICAL REINFORCING DETAILS

Fig. 2. Typical Foundation for 110,000-kw, 1800-rpm, Condensing, Steeple-compound Turbine-generator Set

(Continued in Fig. 2a)

USHO 002712

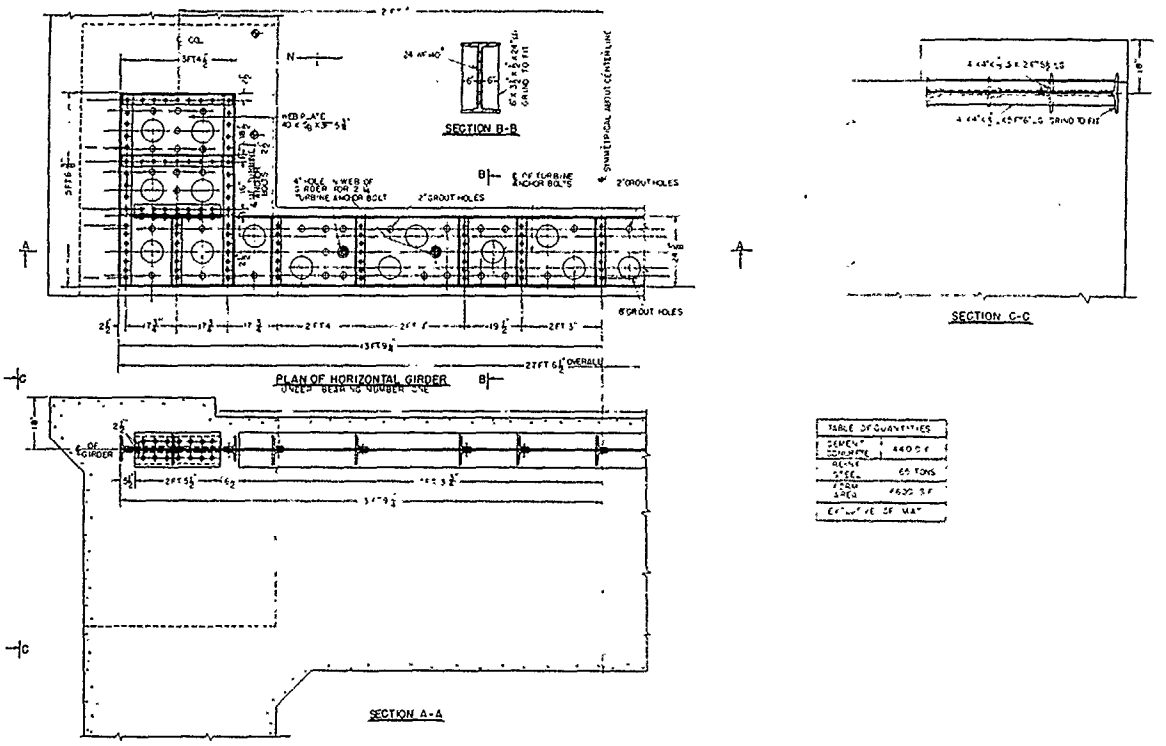
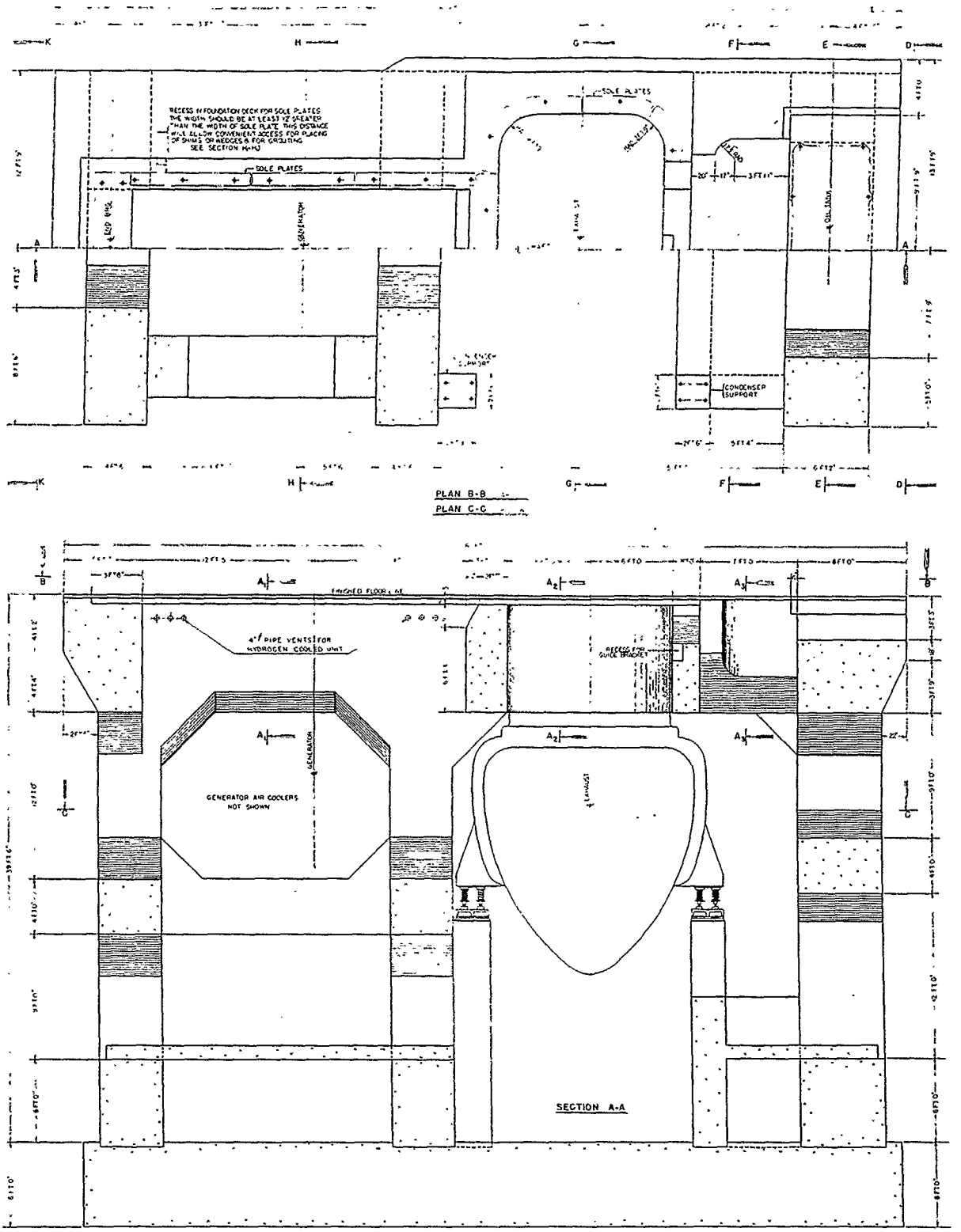


Fig. 2a. Continuation of Fig. 2. Typical Foundation for 110,000-kw, 1800-rpm, Condensing, Steeple-compound Turbine-generator Set

USHO 002713



SUB-FOUNDATION: Depth, size, reinforcement, and other details of sub-foundation should be designed to conform to the bearing capacity of the soil and to the structure arrangement in the immediate vicinity of the foundation. If the structure is not founded on rock, the soil pressures must be such as to insure practically no settlement. If necessary, piles, caissons, and other means should be used to prevent such settlement.

Fig. 3. Typical Foundation for 80,000-kw, 1800-rpm, Condensing Turbine-generator Set

(Continued in Fig. 3a and 3b)

USHO 002714

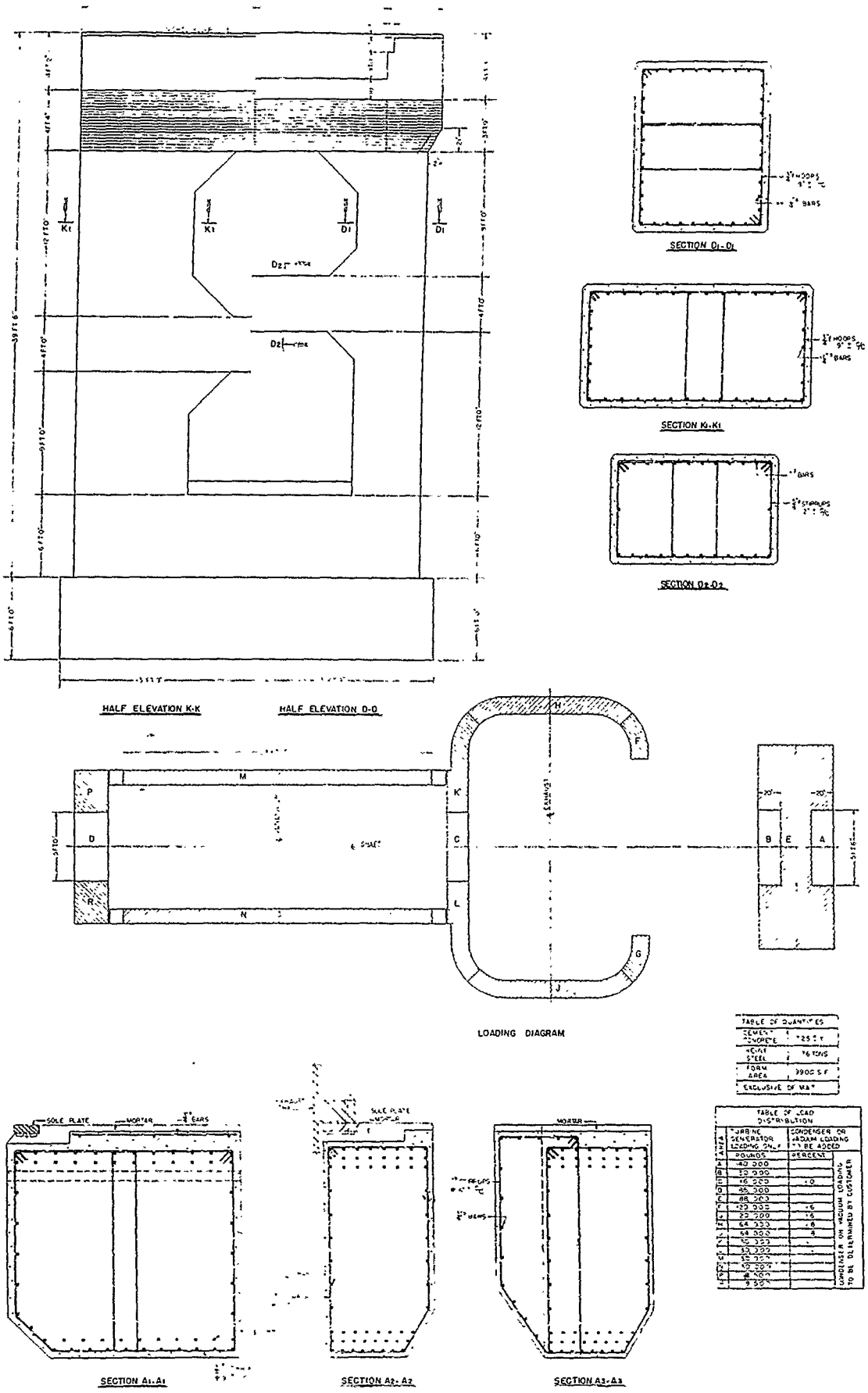
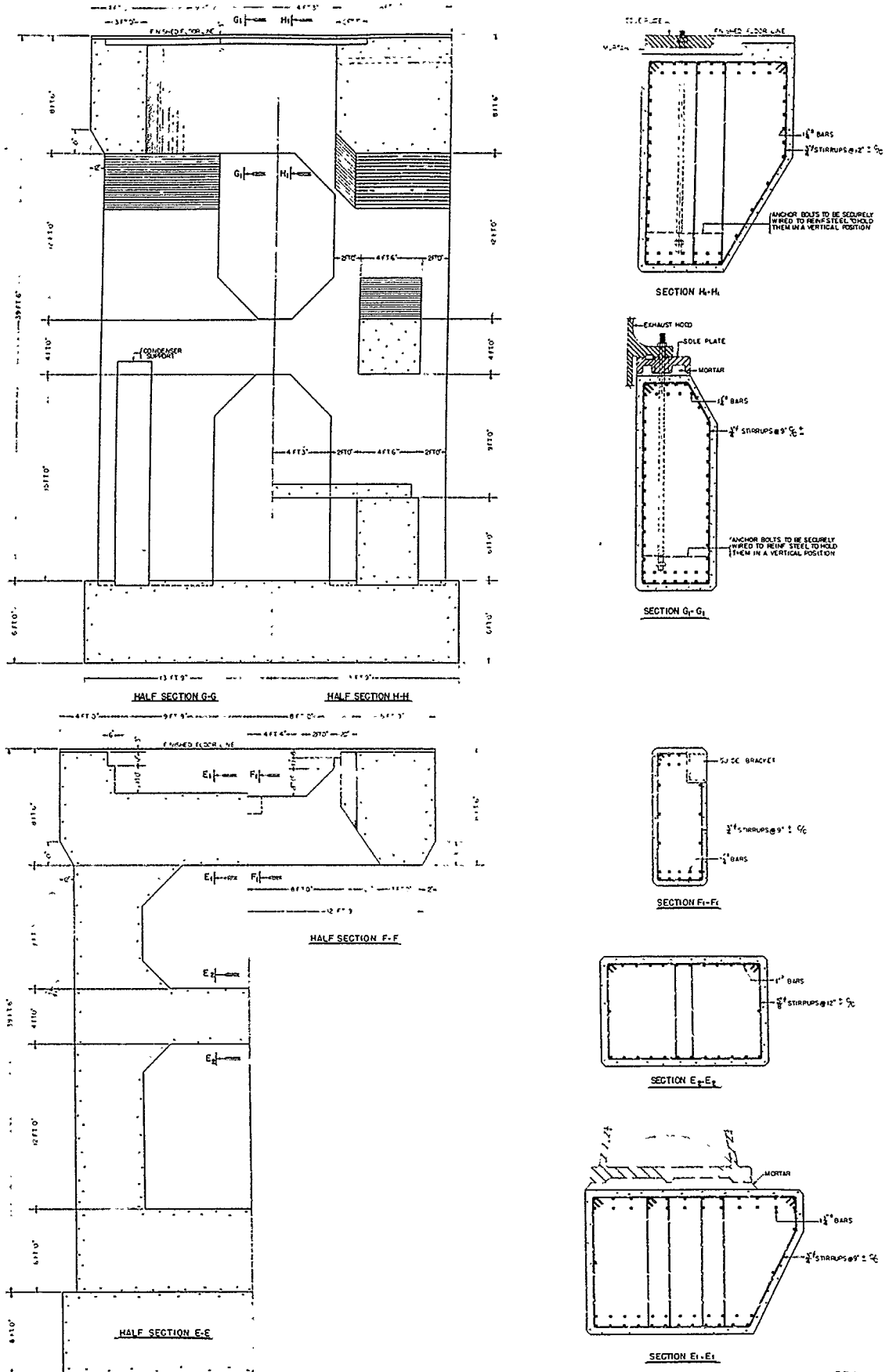


Fig. 3a. Continuation of Fig. 3. Typical Foundation for 80,000-kw, 1800-rpm, Condensing Turbine-generator Set

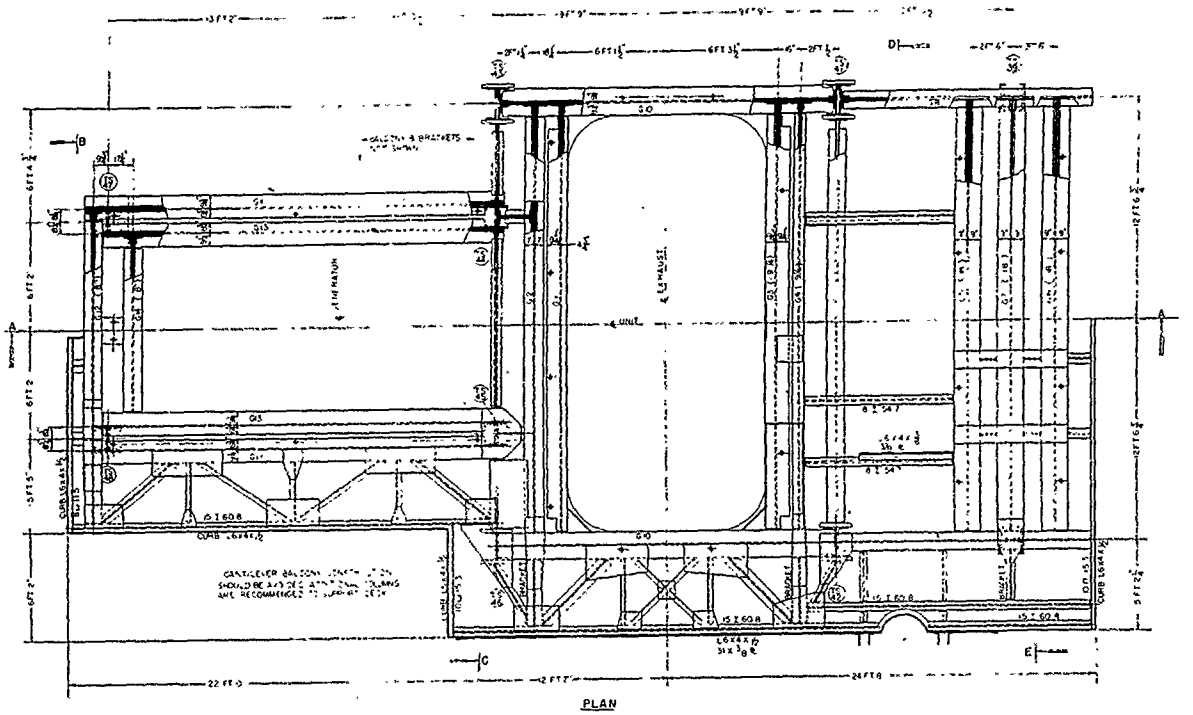
(Continued in Fig. 3b)

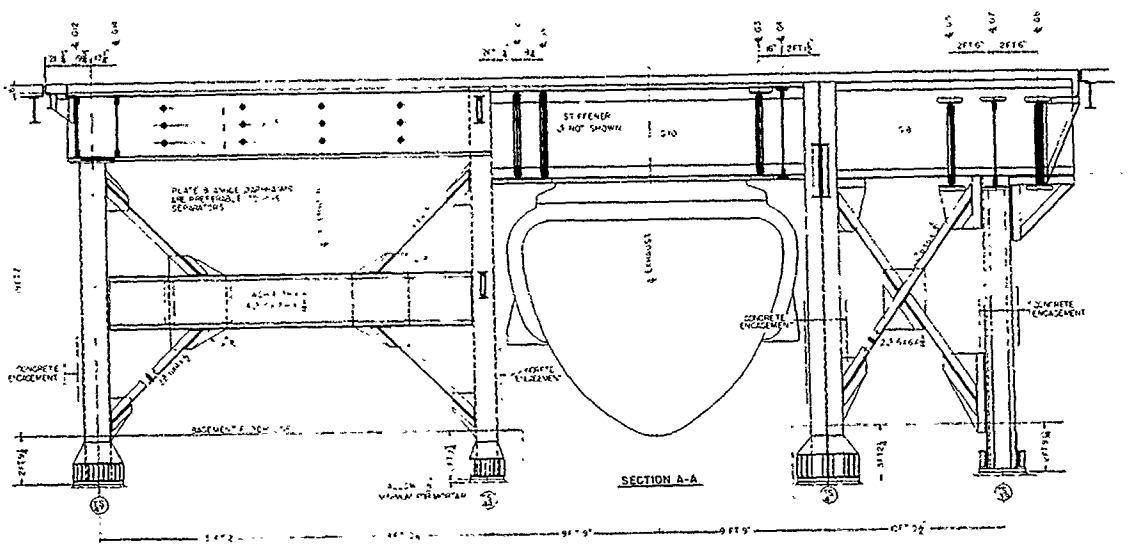
USHO 002715



USHO 002716

Fig. 3b. Continuation of Fig. 3. Typical Foundation for 80,000-kw, 1800-rpm, Condensing Turbine-generator Set



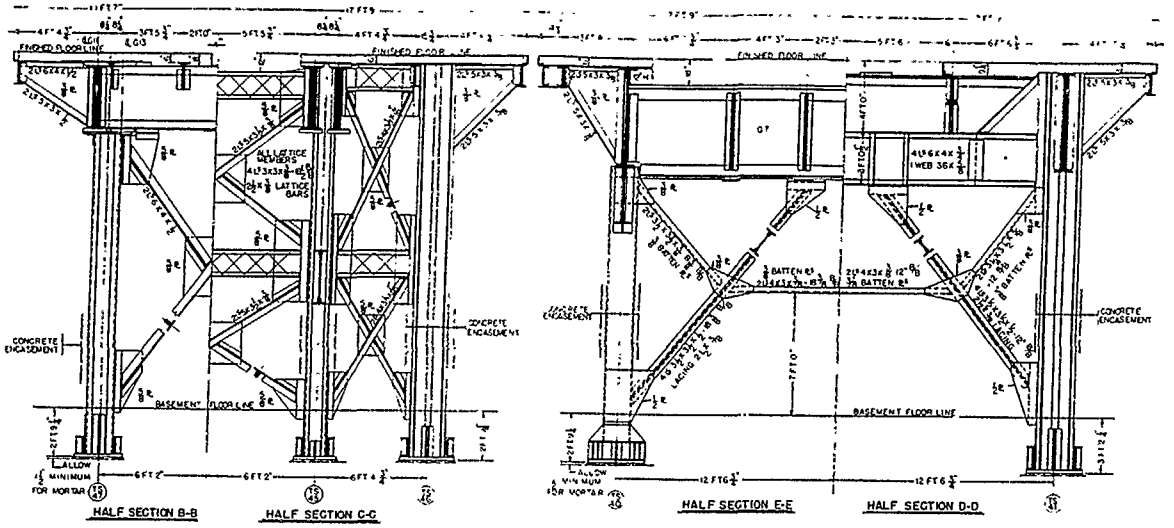


SUB-FOUNDATION: Depth, size, reinforcement, and other details of sub-foundation should be designed to conform to the bearing capacity of the soil and to the structure arrangement in the immediate vicinity of the foundation. If the structure is not founded on rock, the soil pressures must be such as to insure practically no settlement. If necessary, piles, caissons, or other means should be used to prevent such settlement.

Fig. 4. Typical Foundation for 75,000-kw, 1800-rpm, Condensing Turbine-generator Set

(Continued in Fig. 4a and 4b)

USHO 002717



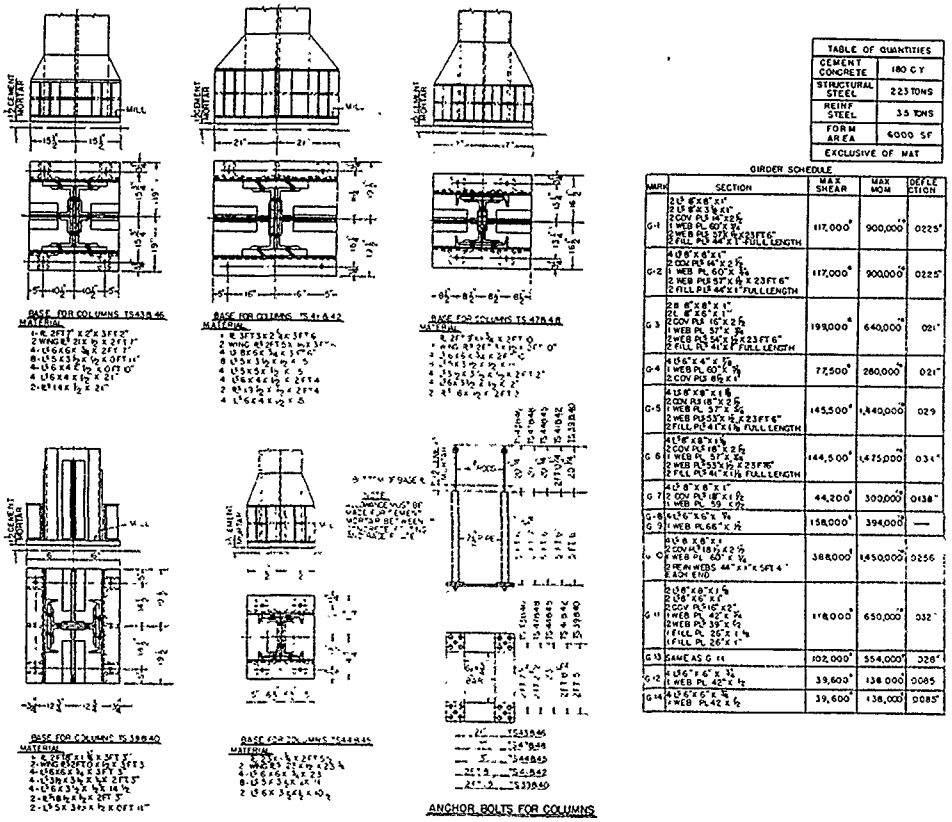


Fig. 4a. Continuation of Fig. 4. Typical Foundation for 75,000-kw, 1800-rpm Condensing Turbine-generator Set

(Continued in Fig. 4b)

USHO 002718

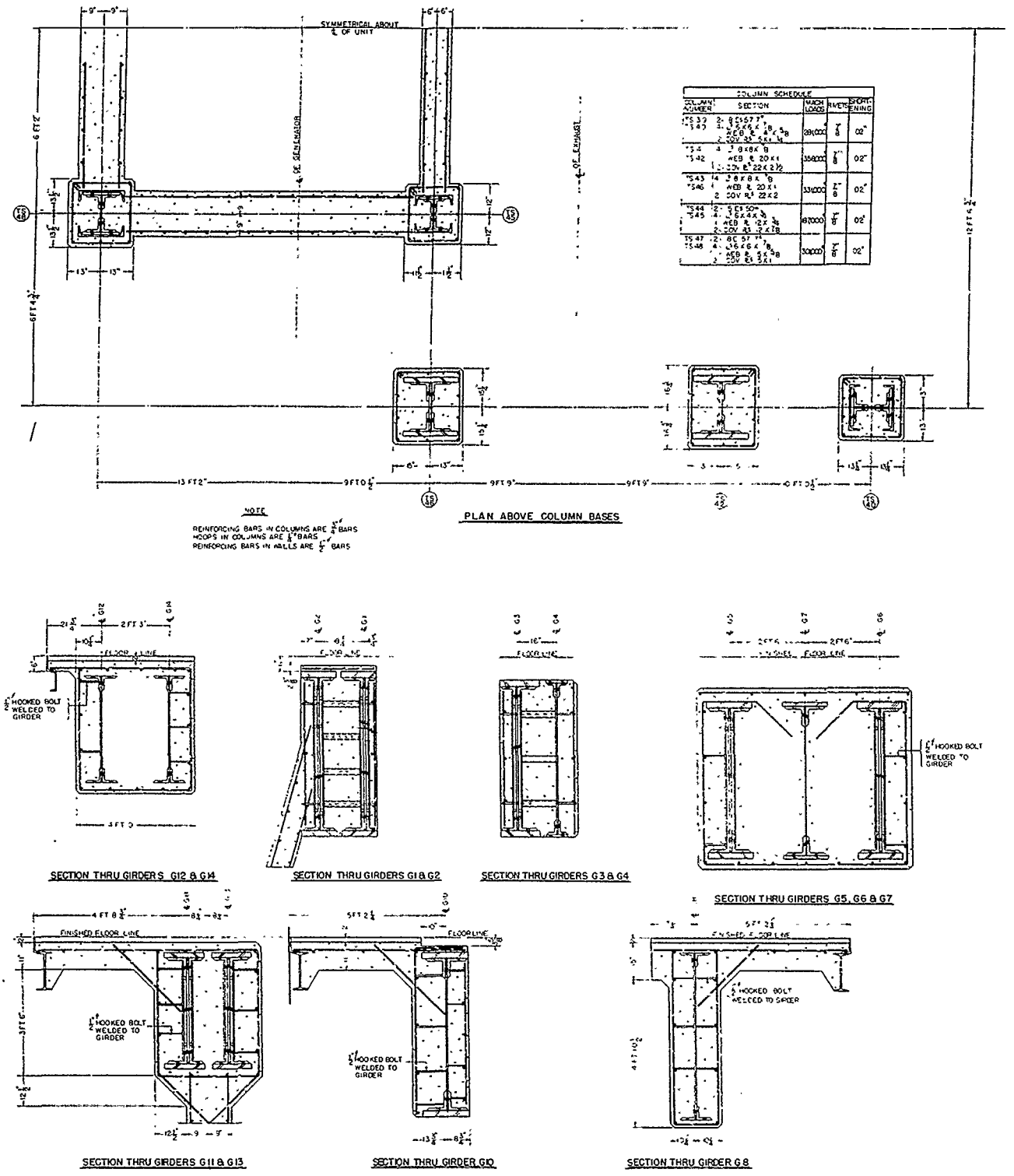
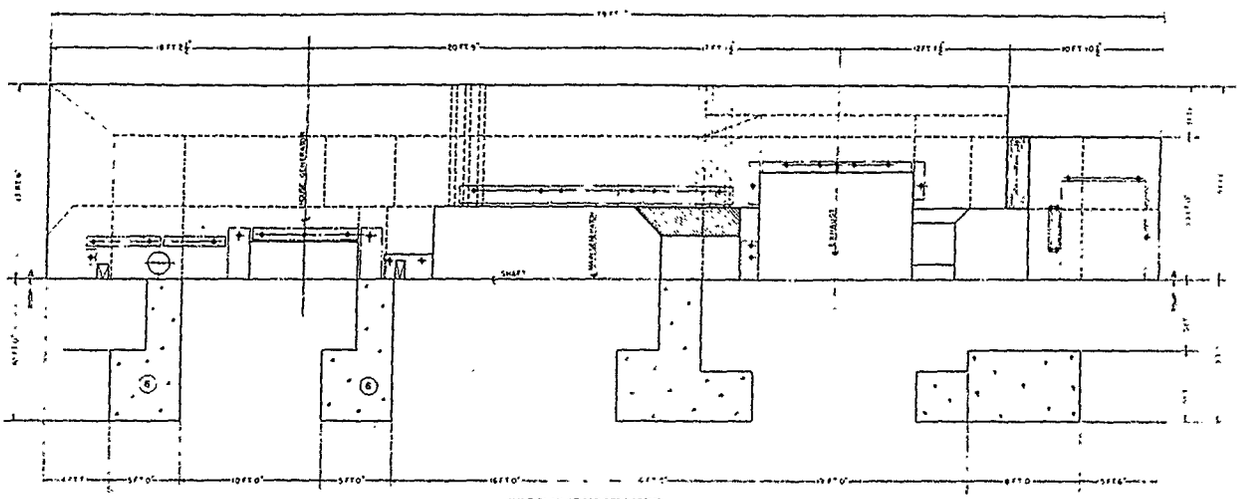


Fig. 4b. Continuation of Fig. 4. Typical Foundation for 75,000-kw, 1800-rpm Condensing Turbine-generator Set

USHO 002719



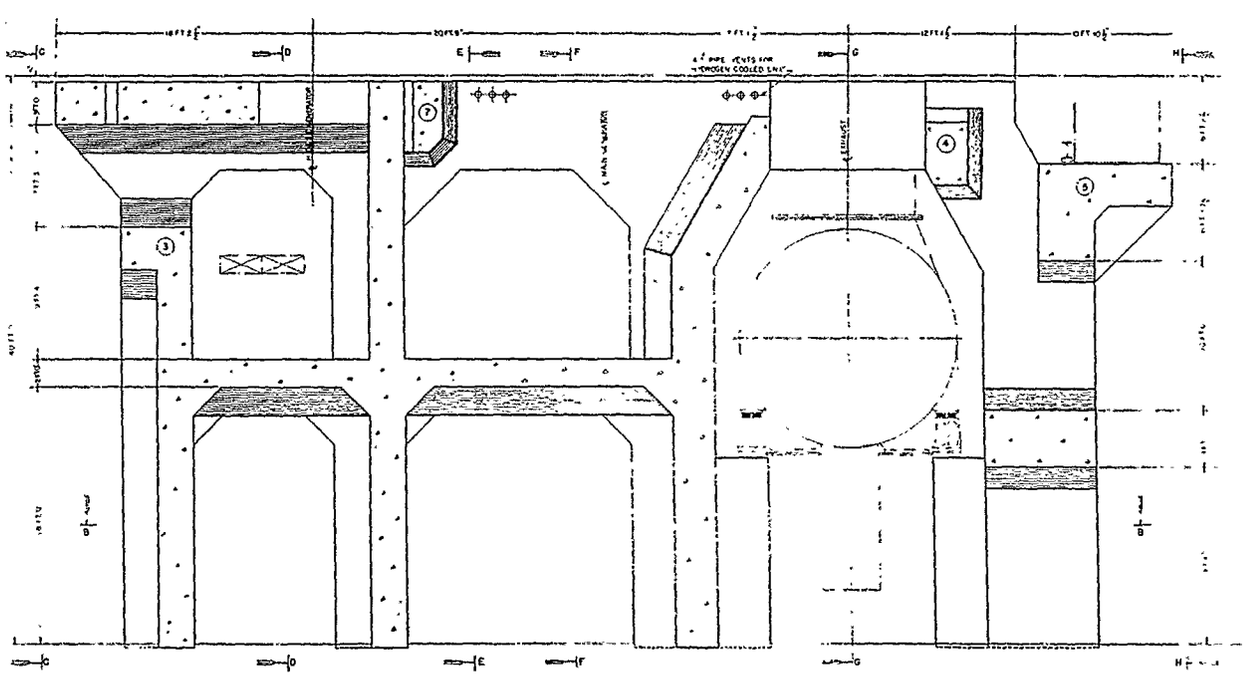


Fig. 5. Typical Foundation for 50,000-kw, 3000-rpm, Condensing Turbine-generator Set

(Continued in Fig. 5a)

USHO 002720

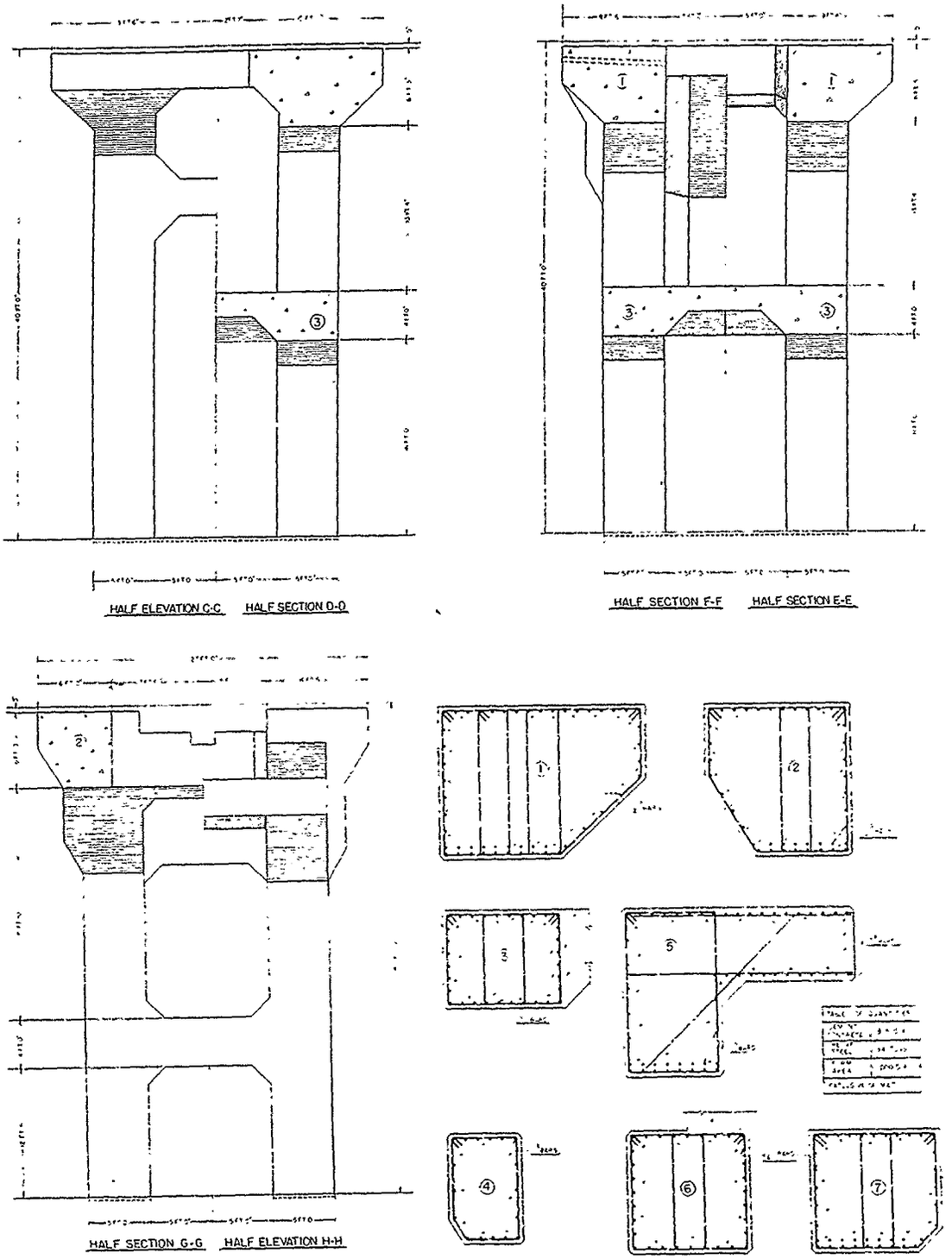
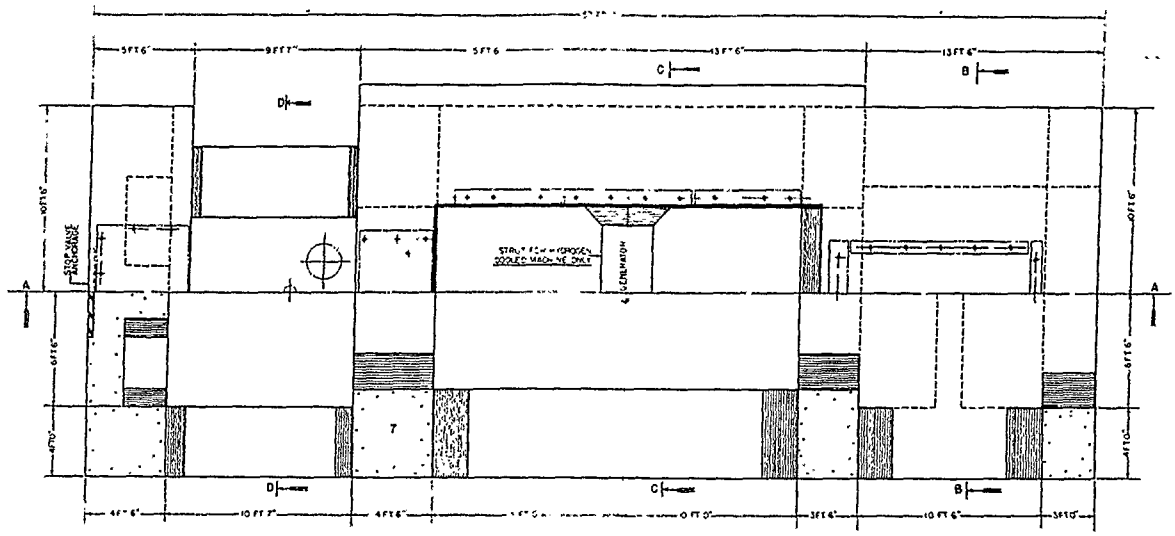
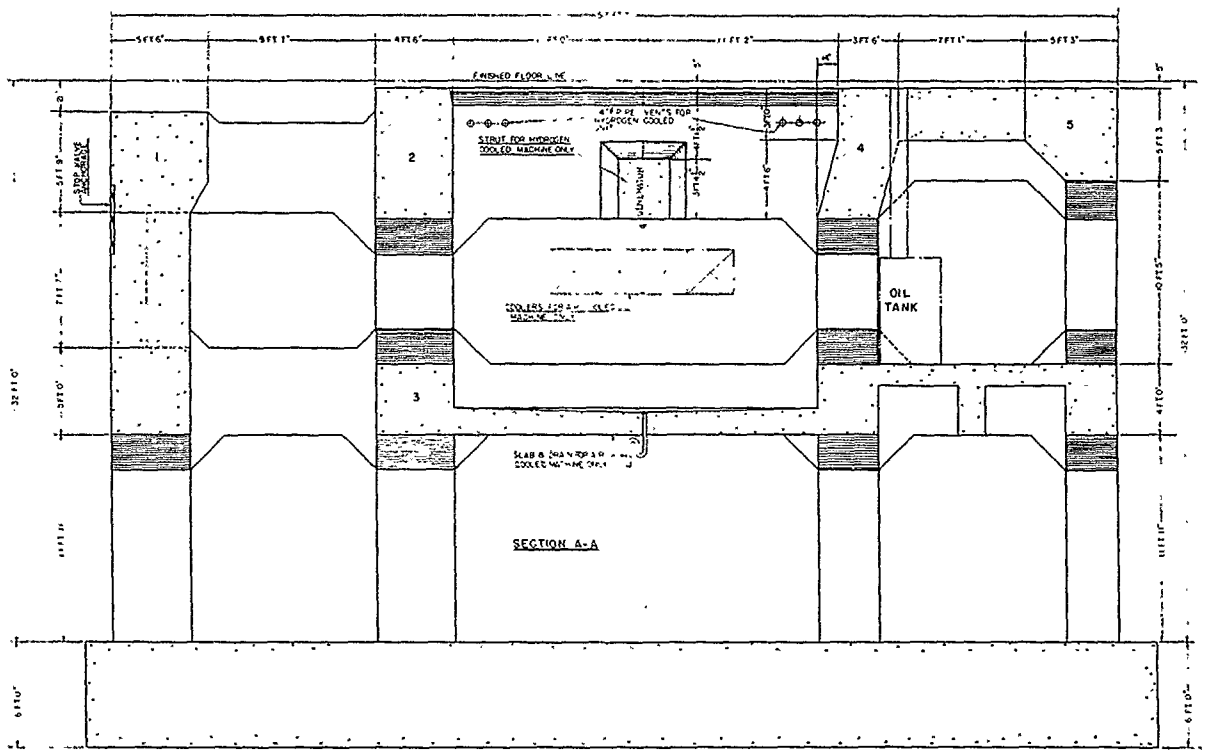


Fig. 5a. Continuation of Fig. 5. Typical Foundation for 50,000-kw, 3000-rpm, Condensing Turbine-generator Set

USHO 002721





SUB-FOUNDATION: Depth, size, reinforcement, and other details of sub-foundation should be designed to conform to the bearing capacity of the soil and to the structure arrangement in the immediate vicinity of the foundation. If the structure is not founded on rock, the soil pressures must be such as to insure practically no settlement. If necessary, piles, caissons, and other means should be used to prevent such settlement.

Fig. 6. Typical Foundation for 50,000-kw, 3600-rpm, Non-condensing Turbine-generator Set

(Continued in Fig. 6a)

USHO 002722

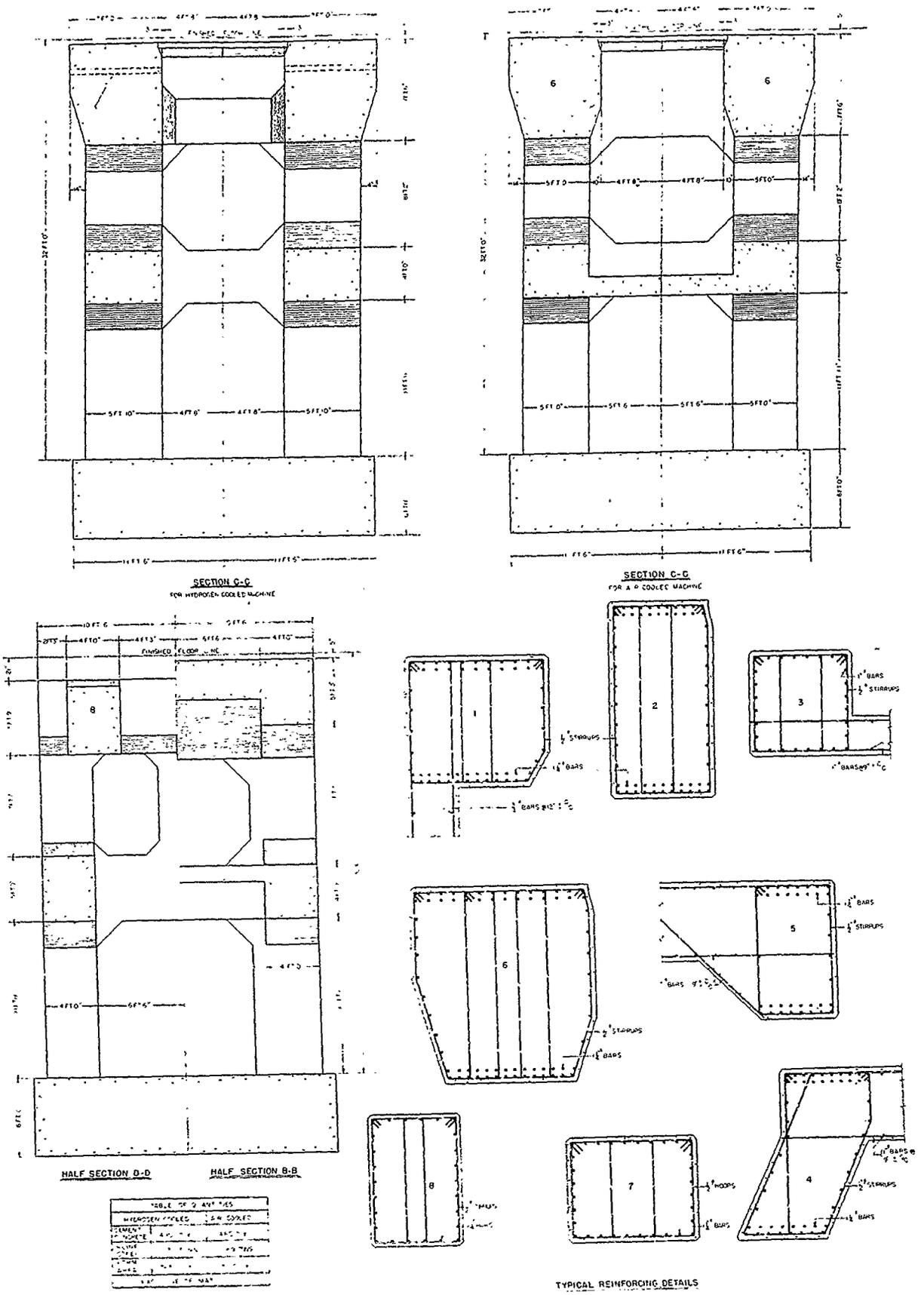
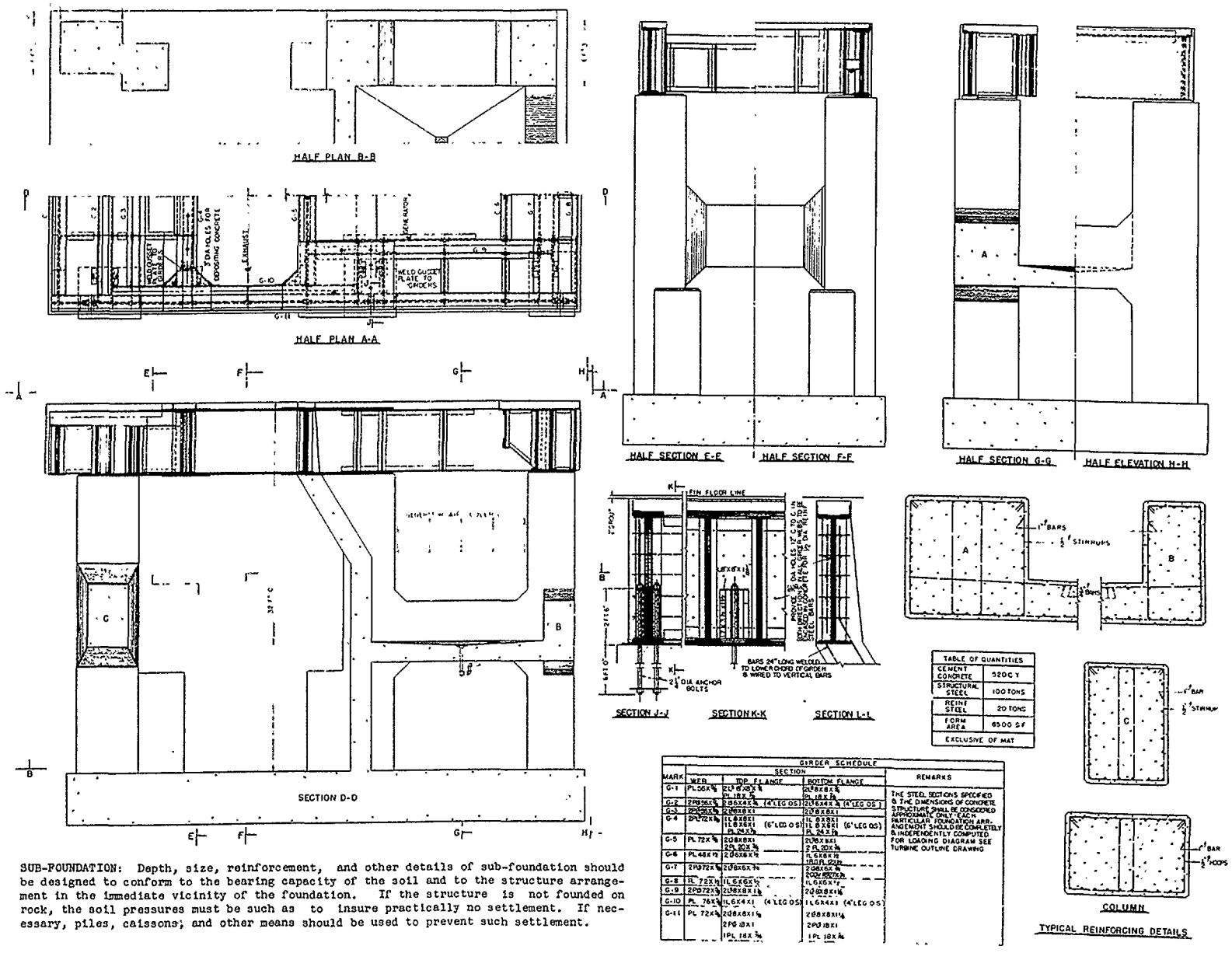


Fig. 6a. Continuation of Fig. 6. Typical Foundation for 50,000-kw, 3600-rpm, Non-condesning Turbine-generator Set

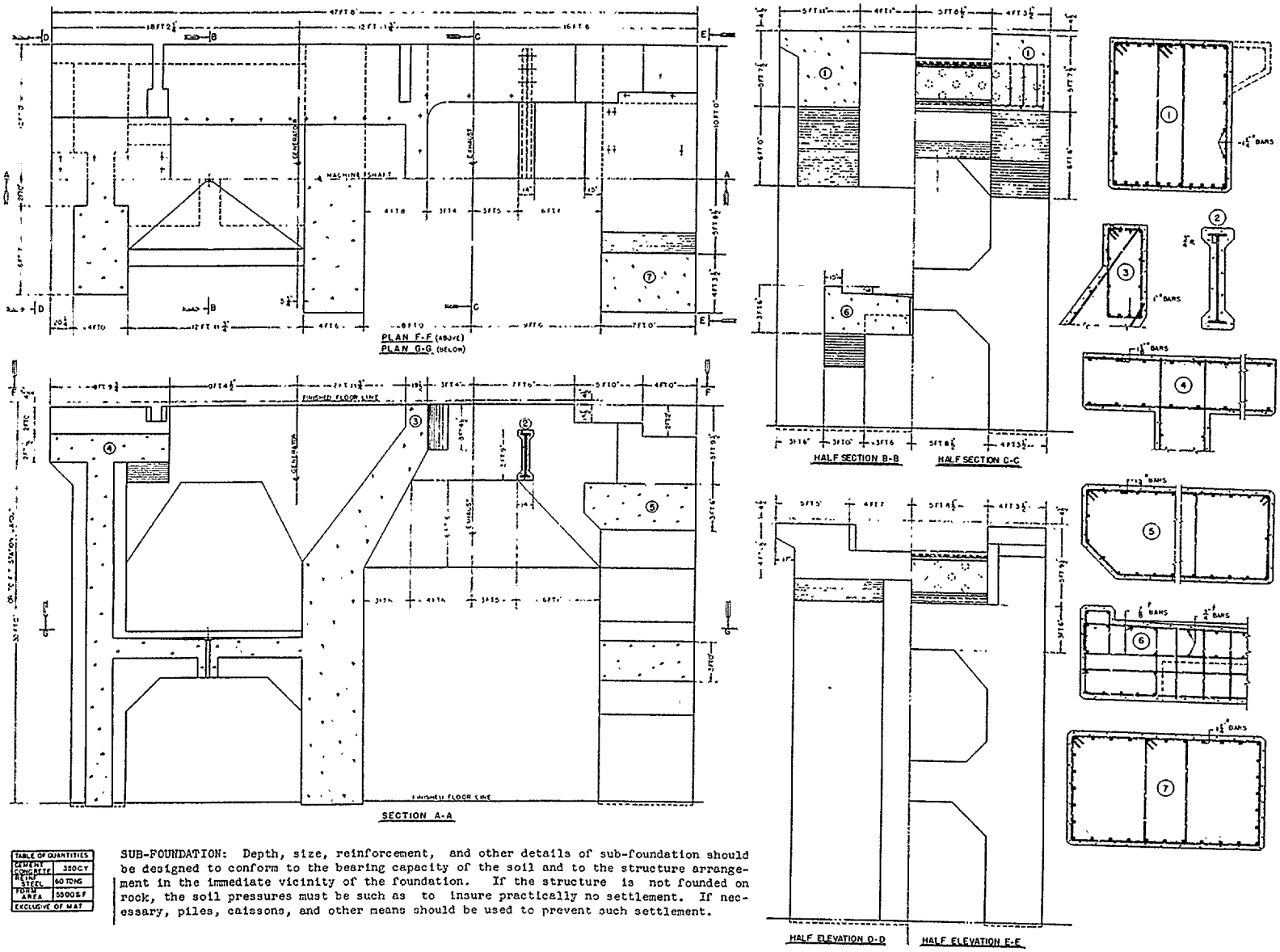
USHO 002723



SUB-FOUNDATION: Depth, size, reinforcement, and other details of sub-foundation should be designed to conform to the bearing capacity of the soil and to the structure arrangement in the immediate vicinity of the foundation. If the structure is not founded on rock, the soil pressures must be such as to insure practically no settlement. If necessary, piles, caissons; and other means should be used to prevent such settlement.

Fig. 7. Typical Composite Foundation for 35,000-kw 1800-rpm, Condesning Turbine-generator Set

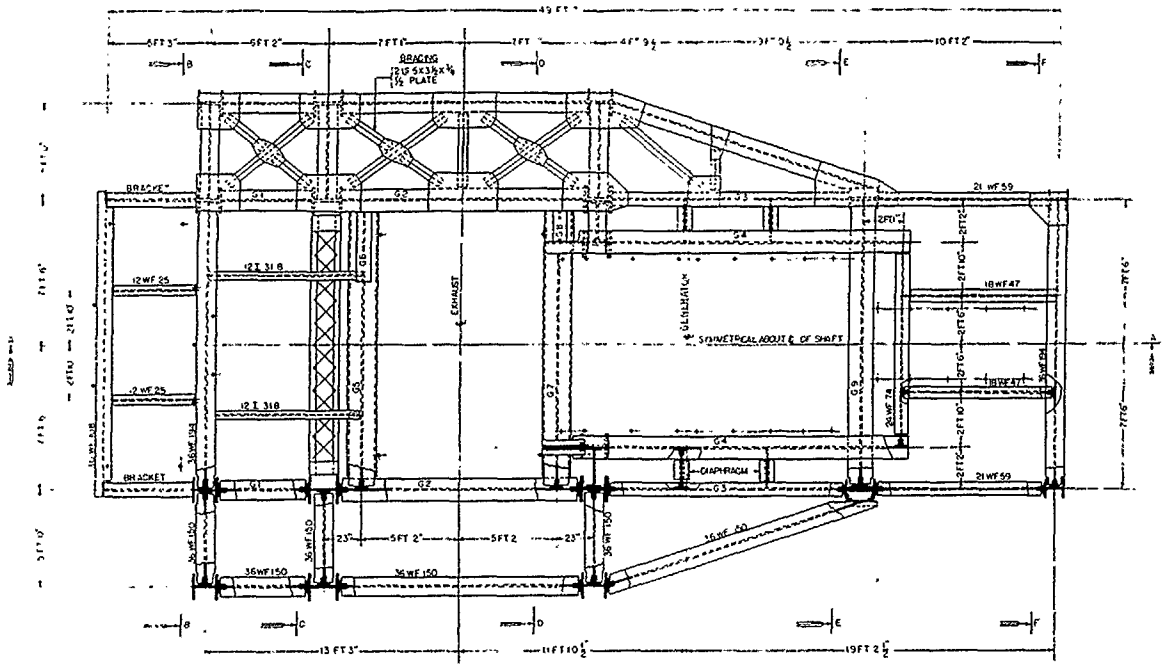
USHO 002724



SUB-FOUNDATION: Depth, size, reinforcement, and other details of sub-foundation should be designed to conform to the bearing capacity of the soil and to the structure arrangement in the immediate vicinity of the foundation. If the structure is not founded on rock, the soil pressures must be such as to insure practically no settlement. If necessary, piles, caissons, and other means should be used to prevent such settlement.

Fig. 8. Typical Foundation for 25,000-kw, 3600-rpm, Condensing Turbine-generator Set

USHO 002725



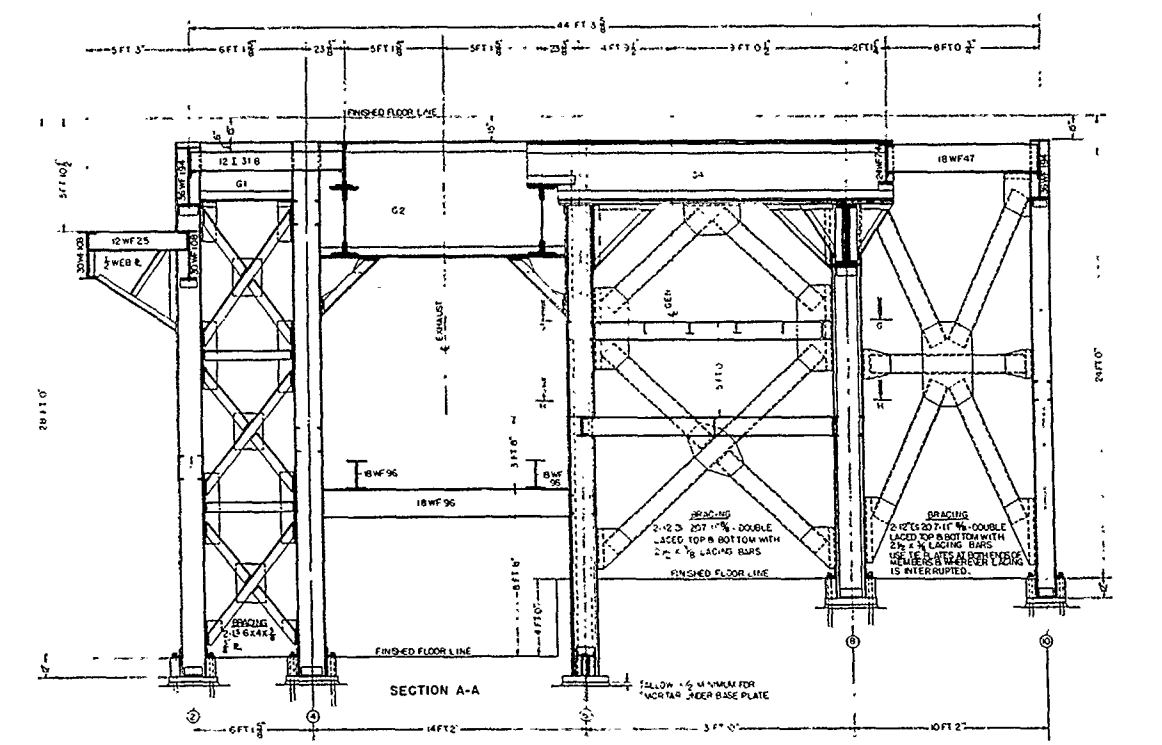
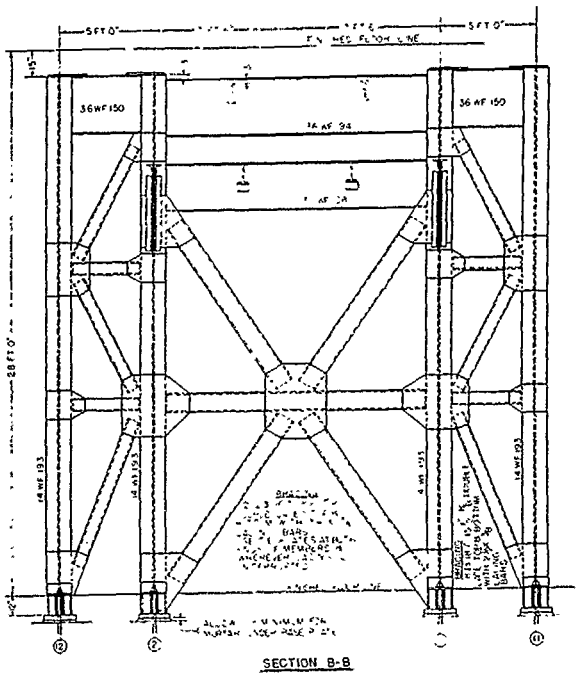
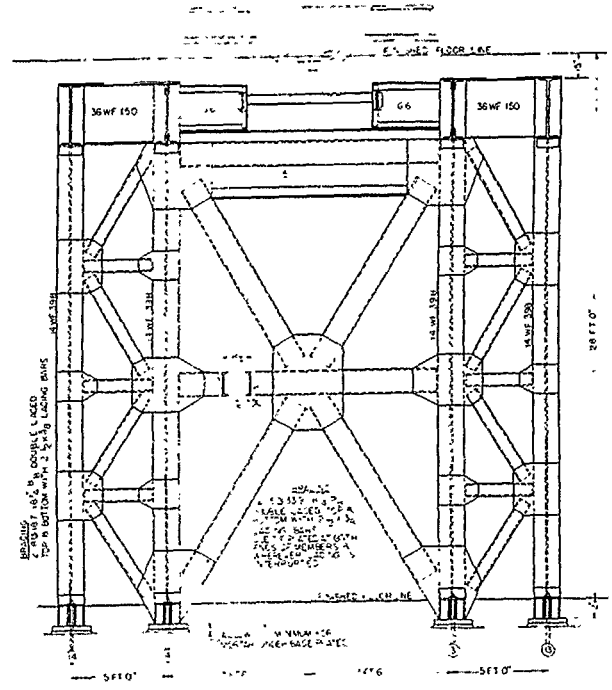


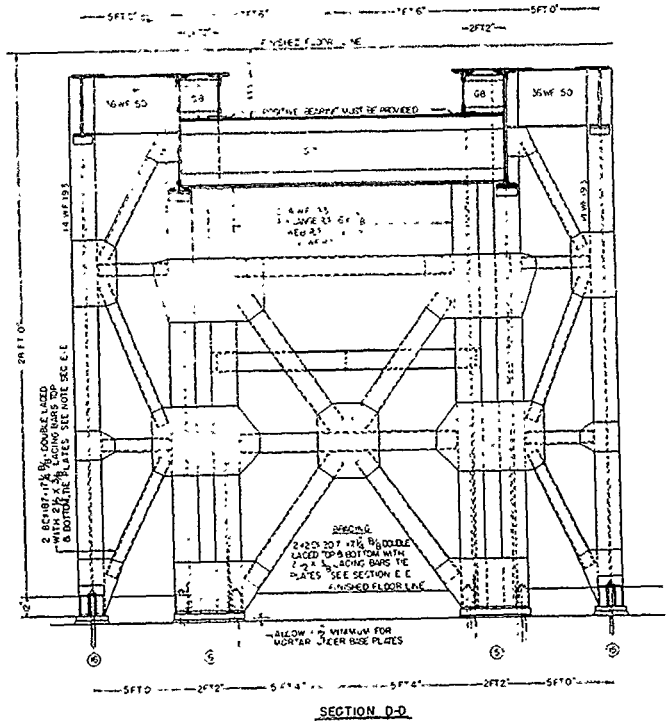
Fig. 9. Typical Foundation for 20,000-kw, 3600-rpm, Condensing Turbine-generator Set

(Continued in Fig. 9a, 9b, and 9c)

USHO 002726







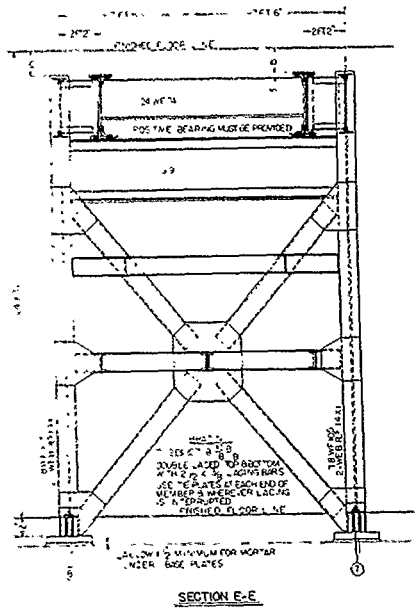


Fig. 9a. Continuation of Fig. 9. Typical Foundation for 20,000-kw, 3600-rpm, Condensing Turbine-generator Set

(Continued in Fig. 9b and 9c)

USHO 002727

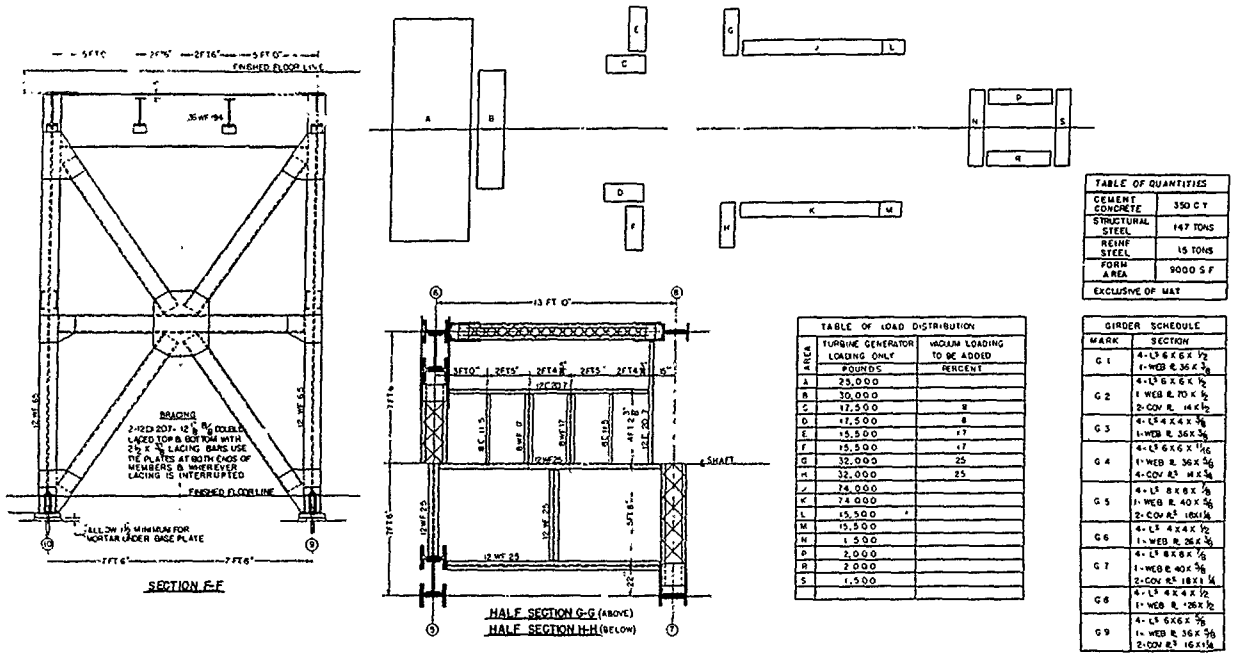
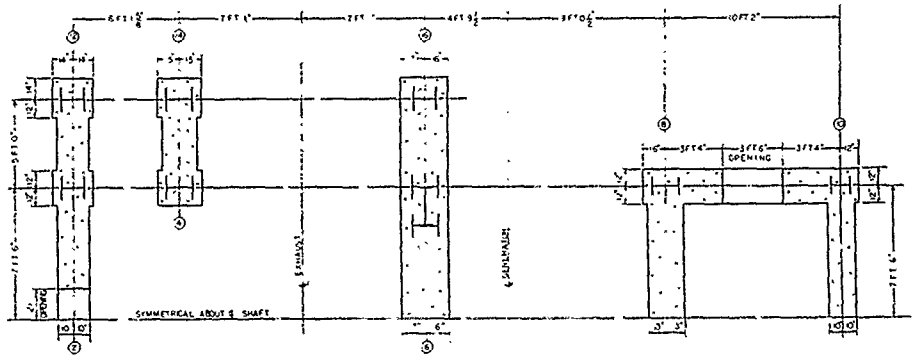


TABLE OF QUANTITIES	
CEMENT CONCRETE	350 C Y
STRUCTURAL STEEL	147 TONS
REINF STEEL	15 TONS
FORM AREA	9000 S F
EXCLUSIVE OF MAT	

TABLE OF LOAD DISTRIBUTION		
AREA	TURBINE GENERATOR LOADING ONLY POUNDS	VACUUM LOADING TO BE ADDED PERCENT
A	25,000	
B	30,000	
C	17,500	8
D	17,500	8
E	15,500	17
F	15,500	17
G	32,000	25
H	32,000	25
J	74,000	
K	74,000	
L	15,500	
M	15,500	
N	1,500	
P	2,000	
R	2,000	
S	1,500	

GIRDER SCHEDULE	
MARK	SECTION
G 1	4-L^3 6 X 6 X 1/2 1-WEB R. 36 X 3/8
G 2	4-L^3 6 X 6 X 1/2 1 WEB R. 70 X 1/2 2-COV R. 14 X 1/2
G 3	4-L^3 4 X 4 X 3/8 1-WEB R. 36 X 3/8
G 4	4-L^3 6 X 6 X 11/16 1-WEB R. 36 X 5/8 4-COV R^3 14 X 3/8
G 5	4-L^3 8 X 8 X 7/8 1-WEB R. 40 X 5/8 2-COV R^3 18X1/4
G 6	4-L^3 4 X 4 X 1/2 1-WEB R. 26 X 3/8
G 7	4-L^3 8 X 8 X 7/8 1-WEB R. 40 X 5/8 2-COV R^3 18 X 1/4
G 8	4-L^3 4 X 4 X 1/2 1-WEB R. 28 X 1/2
G 9	4-L^3 6X6X 5/8 1-WEB R. 36 X 5/8 2-COV R^3 16X1/4



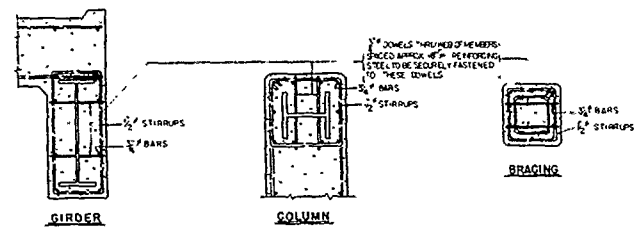


Fig. 9b. Continuation of Fig. 9. Typical Foundation for 20,000-kw, 3600-rpm, Condensing Turbine-generator Set

(Continued in Fig. 9c)

USHO 002728

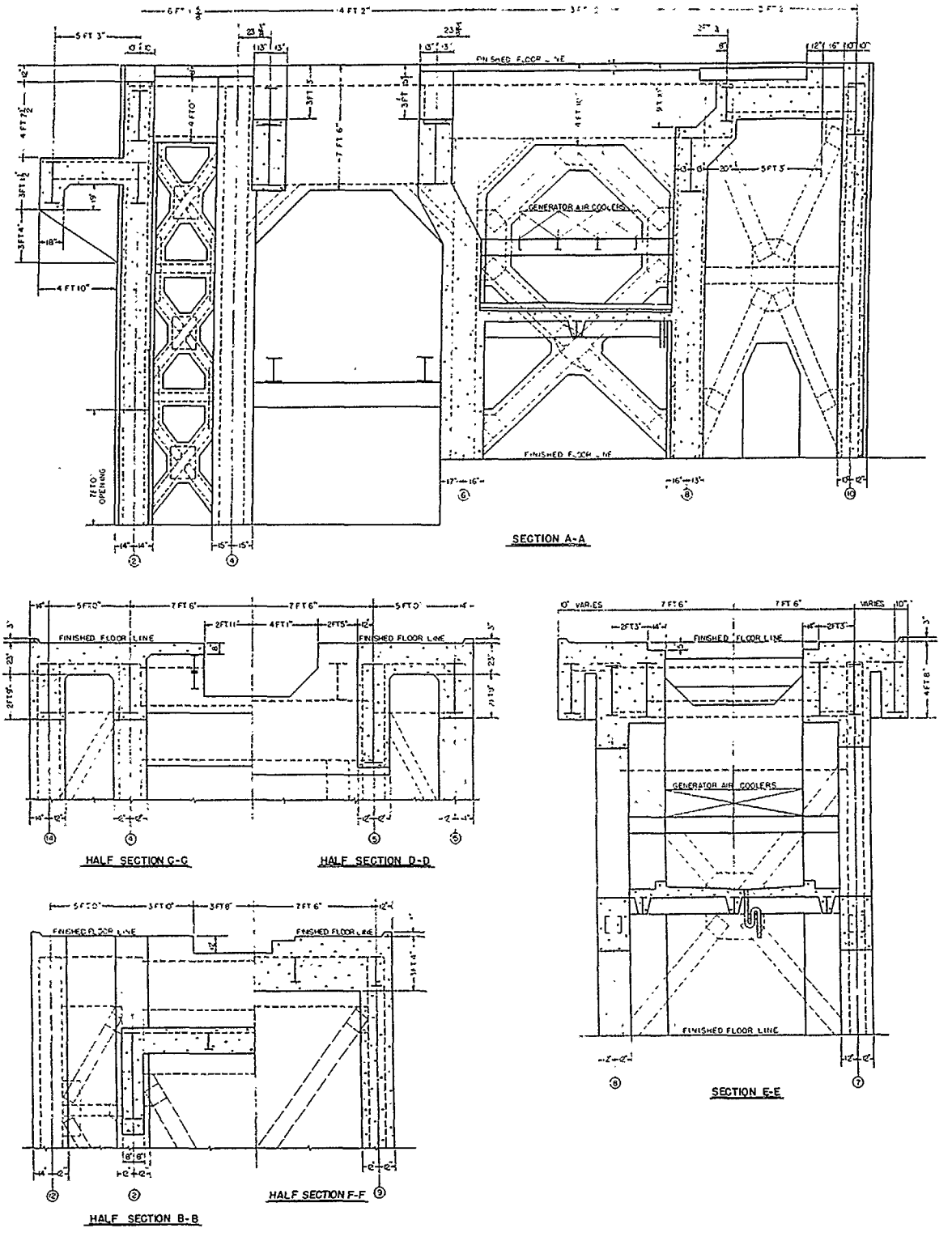


Fig. 9c. Continuation of Fig. 9. Typical Foundation for 20,000-kw, 3600-rpm, Condensing Turbine-generator Set

USHO 002729

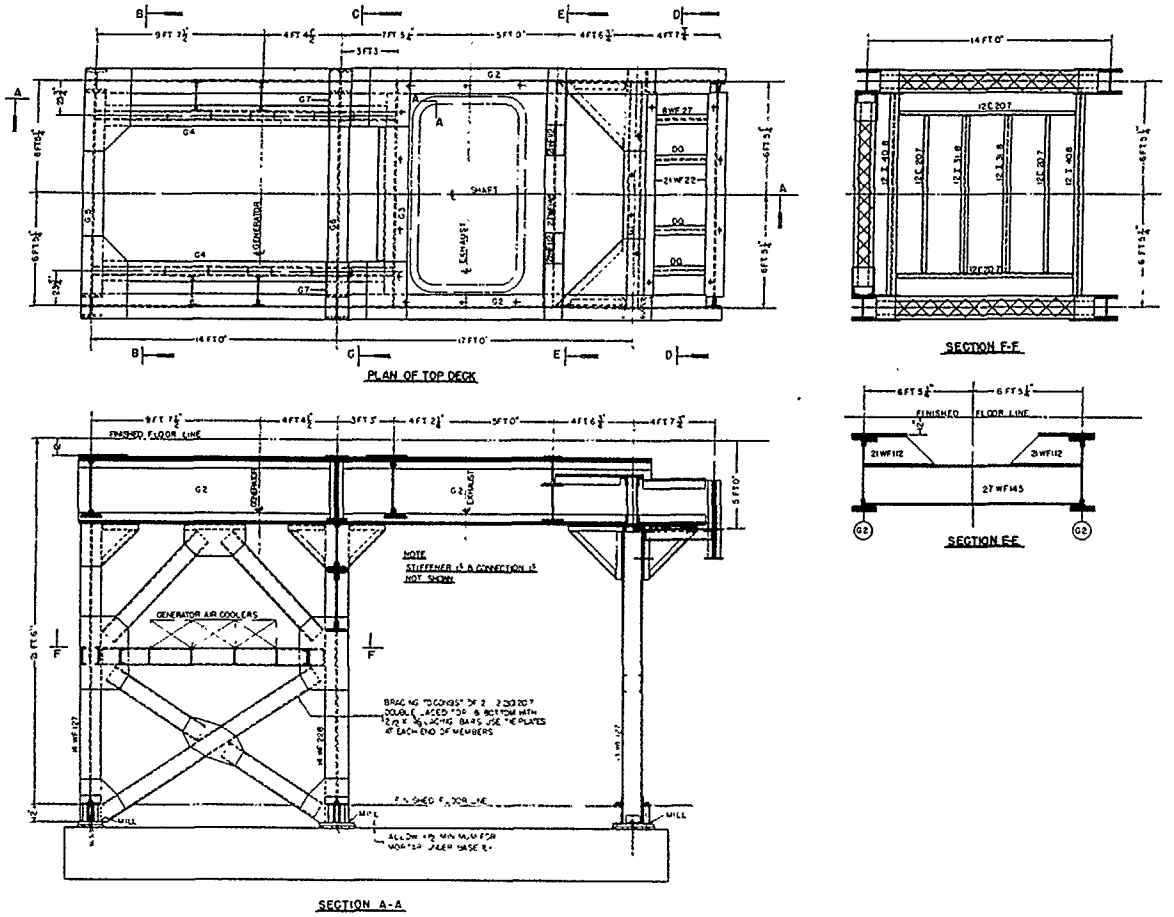


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Fig. 10. Typical Foundation for 15,000-kw, 3600-rpm, Condensing Turbine-generator Set

(Continued in Fig. 10a)

USHO 002730

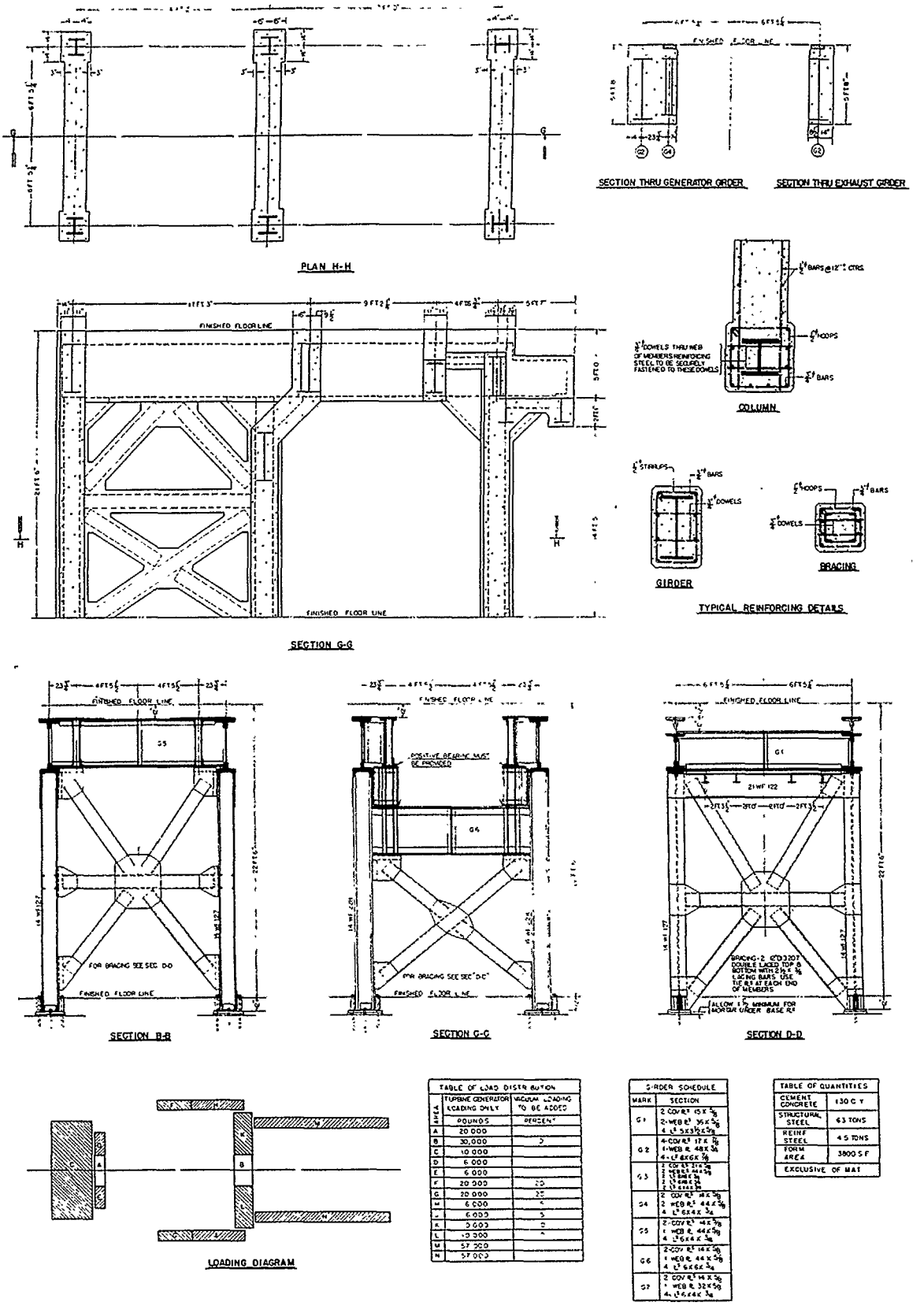

TABLE OF LOAD DISTRIBUTION		
AREA	TURBINE GENERATOR LOADING ONLY	VACUUM LOADING TO BE ADDED
	POUNDS	PERCENT
A	20 000	
B	30,000	5
C	10 000	
D	6 000	
E	6 000	
F	20 000	25
G	20 000	25
H	6 000	"
I	6 000	5
K	3 000	0
L	13 000	"
M	57 500	
N	57 000	

G-RDER SCHEDULE	
MARK	SECTION
G1	2 COV PL 15 X 5/8 2-WEB PL 35 X 5/8 4 L 6 X 4 X 5/8
G2	4-COV PL 17 X 5/8 4-WEB PL 48 X 3/8 4-L 6 X 6 X 5/8
G3	2 COV PL 21 X 5/8 2 WEB PL 44 X 5/8 2 L 6 X 4 X 5/8
G4	2 COV PL 14 X 5/8 2 WEB PL 44 X 5/8 4 L 6 X 4 X 5/8
G5	2-COV PL 14 X 5/8 1 WEB PL 44 X 5/8 4 L 6 X 4 X 5/8
G6	2-COV PL 14 X 5/8 1 WEB PL 44 X 5/8 4 L 6 X 6 X 5/8
G7	2 COV PL 14 X 5/8 1 WEB PL 32 X 5/8 4 L 6 X 4 X 5/8

TABLE OF QUANTITIES	
CEMENT CONCRETE	130 C Y
STRUCTURAL STEEL	63 TONS
REINF STEEL	4.5 TONS
FORM AREA	3800 S F
EXCLUSIVE OF MAT	

Fig. 10a. Continuation of Fig. 10. Typical Foundation for 15,000-kw, 3600-rpm, Condensing Turbine-generator Set

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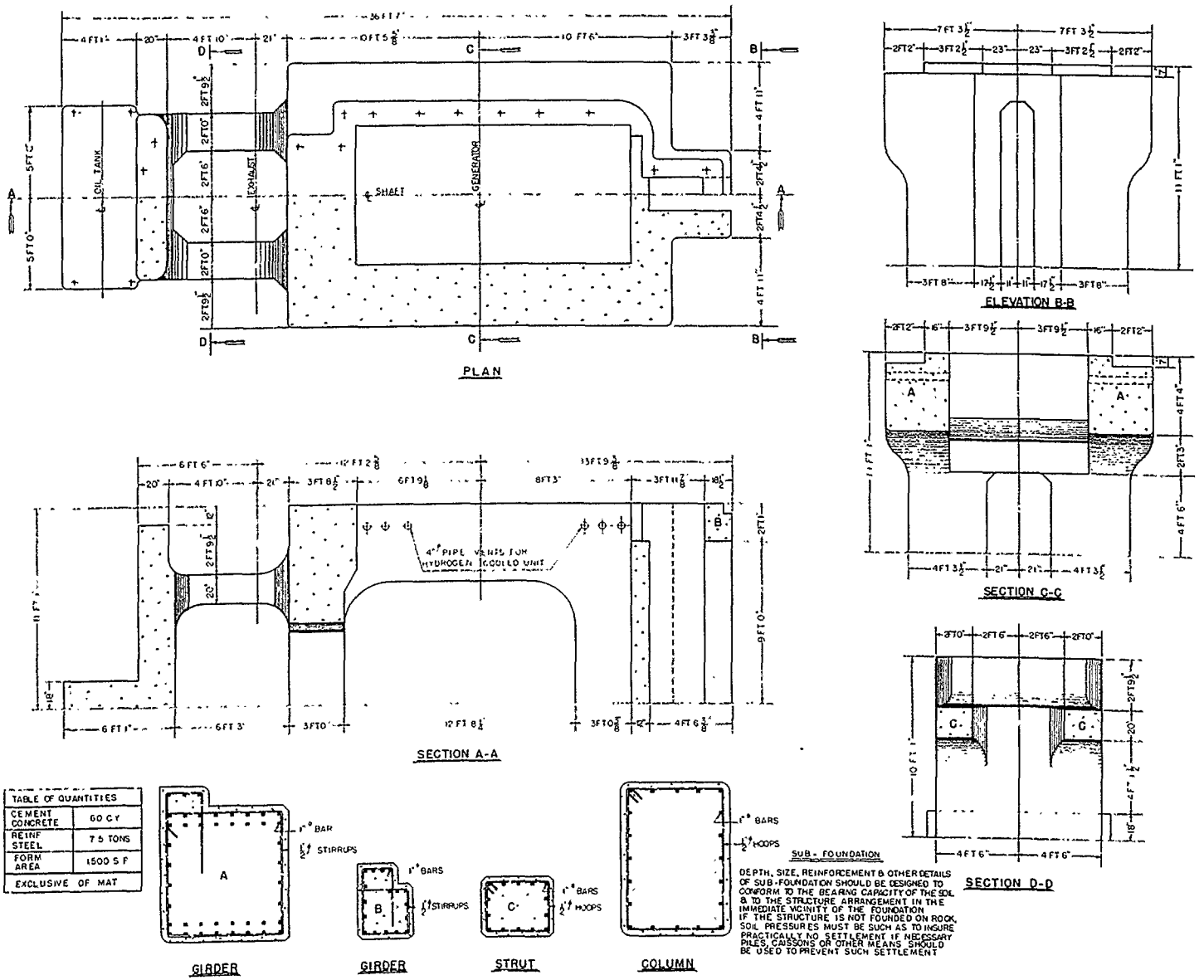

Fig. 11. Typical Foundation for 15,000-kw, 3600-rpm, Non-condensing Turbine-generator Set

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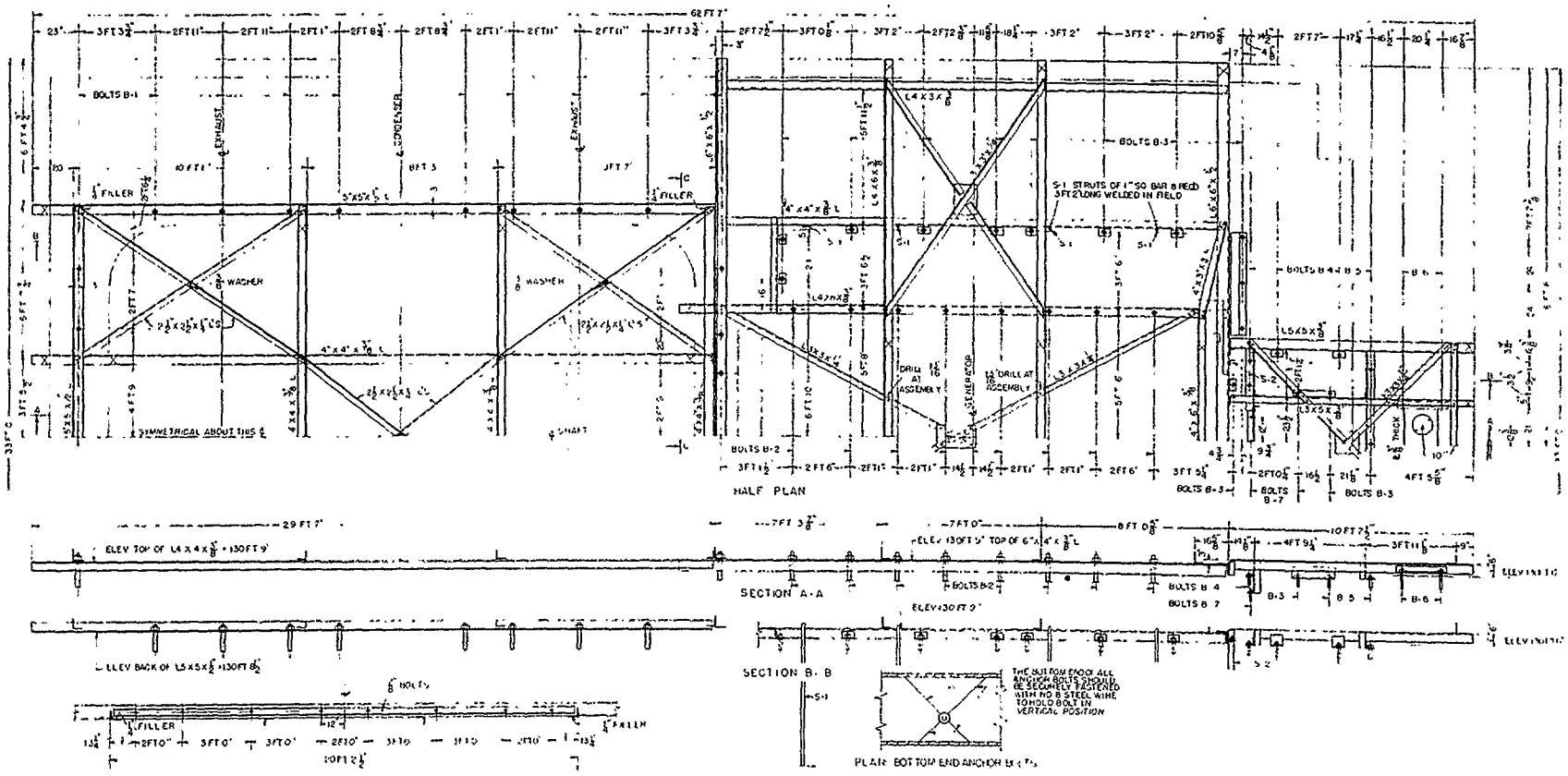


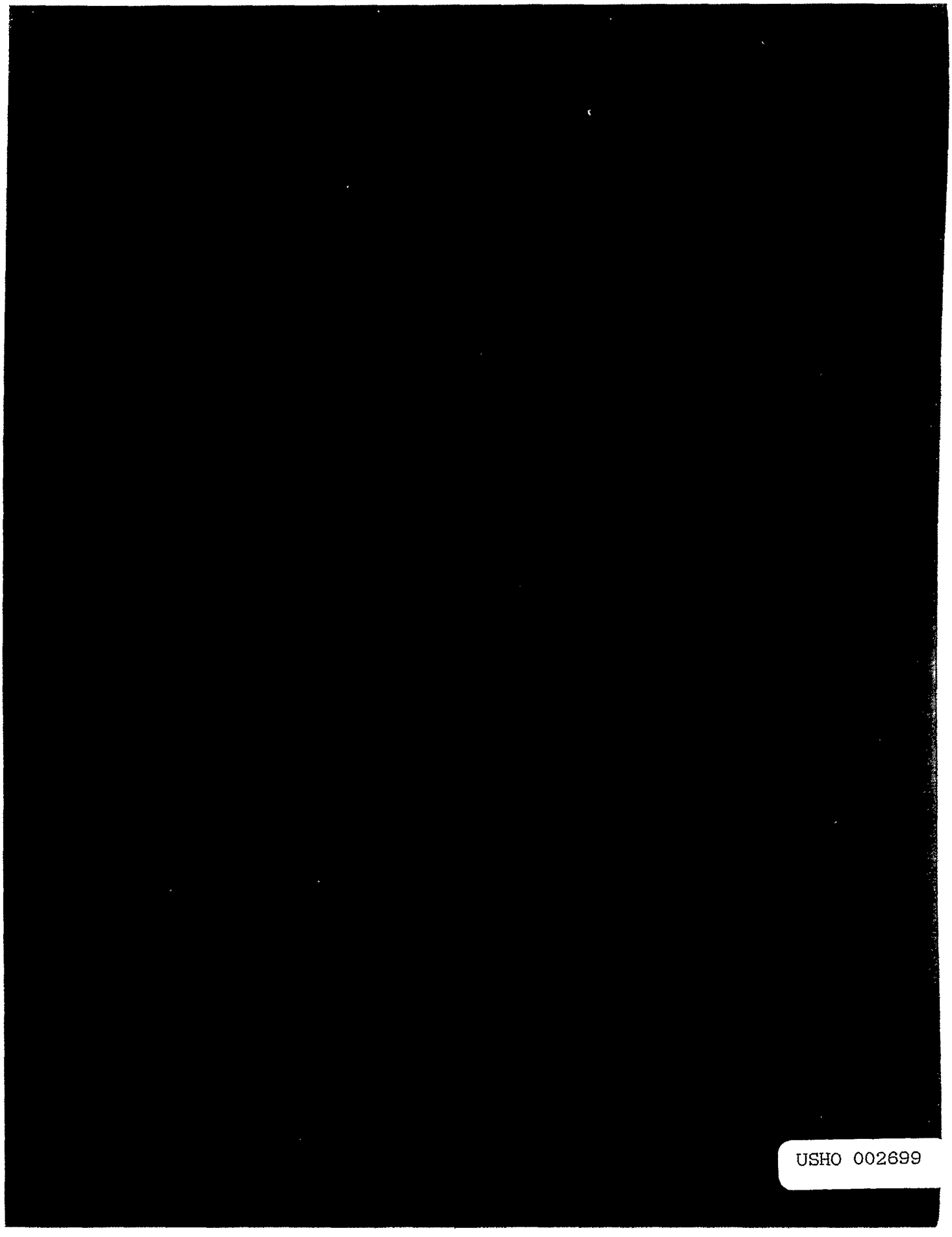
MARK	NO REQD	DIA	LENGTH	ELEV TOP OF BOLT	DIA OF DRILLED HOLE IN TEMPLATE	WASHER PLATES NO REQD	SIZE	DIA OF HOLE	PIPE SPEED		EQUIPMENT ANCHORED
B-1	26	2 1/4	6 FT 3"	131 FT 1 1/4	2 5/16	26	8x5x8	2 1/2			TURBINE
B-2	16	2 1/4	6 FT 3"	131 FT 0 3/4	2 5/16	16	8x5x8	2 1/2			GENERATOR
B-3	28	1 1/2	2 FT 3"	130 FT 5 3/4	1 9/16	28	4x4x3/4	1 3/4			GENERATOR HOUSING & EXCITER
B-4	8	1 1/2	2 FT 3"	130 FT 5 1/2	1 9/16	8	4x4x3/4	1 3/4			EXCITER HOUSING
B-5	3	3/4	9"	130 FT 5 1/2	13/16	3	6x1/2x6	1"	—	—	EXCITER HOUSING
B-6	4	3/4	12"	130 FT 8 1/2	13/16	4	6x1/2x6	1"	—	—	OIL PUMP
B-7	3	3/4	18"	129 FT 9"	13/16	3	4x1/2x4	1"	—	—	EXCITER BARRIER
B-8	16	1 1/4	3 FT 6"	SEE 657-37 Y	—	16	6x1 x6	1 1/2	3"	2 FT 9"	CONDENSER
B-9	32	1"	2 FT 0"	"	—	8	8x1/2x12	1 1/4	—	—	PLATFORMS
B-10	8	1"	2 FT 0"	"	—	4	4x1/2x10	1 1/4	—	—	PLATFORMS
B-11	12	1"	2 FT 0"	SEE 657-37 T	—	6	4x1/2x10	1 1/4	—	—	PLATFORMS
B-12	4	1"	12"	"	—	4	4x1/2x4	1 1/4	—	—	PIPE HANGER SUPPORT
NEXT BOLTS											

NOTE

All of the NOTES given in Fig. 18 apply here. It should be noted also that the dash-dot lines indicate the outlines of the foundation.

The struts S-1 are of 1-in. square bar 3 ft 2 in. long. They are to be welded to G-4R and G-4L in the field. Struts S-2 are 2 in. x 2 in. x 1/4-in. L, 7 ft 10 in. long, welded to G-6 in the field.

Fig. 18a. Continuation of Fig. 18. Typical Anchor-bolt Templates



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