

CHAPTER IX. Design—SWITCHYARD

A. STRUCTURAL

104. GENERAL. The switchyard is located approximately 850 feet southwest of the right abutment of the dam, and approximately 170 feet higher than the top of the dam. The fill for embankment ranges up to 27 feet in depth and the cut for excavation ranges up to 24 feet in depth.

Since the embankment slopes, as constructed, consisted primarily of fine sand, a 12-inch layer of pit-run gravel was placed on the slopes for protection from wind and water erosion. As an additional protection against water erosion, a curb, gutter, and drain system was later constructed.

105. CONCRETE FOUNDATIONS. All pad and stem type foundations were designed for a gross toe pressure not to exceed 3,000 pounds per square foot and a factor of safety against uplift and overturning of not less than 1.5.

Rock-type foundations were extended a minimum 12 inches into rock to resist shear forces. Anchor bars were designed for a maximum tensile stress of 16,000 pounds per square inch and were embedded to a depth so that the rock shear stress does not exceed 300 pounds per square foot.

106. CONCRETE FOOTINGS FOR APPROACH TOWERS. The footings for towers C1-T2, C2-T2, C3-T2, and C4-T2 were designed as rock-type footings. To resist the shear forces, the footings were extended a minimum of 12 inches into rock. Anchor bars were designed for a maximum tensile stress of 16,000 pounds per square inch and were embedded to a depth so that the rock shear stress does not exceed 300 pounds per square foot.

The footings for rim towers C1-T1, C2-T1, C3-T1, and C4-T1 were designed as rock-type footings. To resist shear forces, the footings were extended a minimum of 24 inches into rock.

Anchor bars were designed for a maximum tensile stress of 16,000 pounds per square inch and were embedded a minimum of 25 feet into rock to attain maximum strength in the bedrock by spanning the bedding planes and stress relief joints which are present near the edge of the canyon rim.

107. CONTROL CABLE TUNNEL. The control cable tunnel extends approximately 1,280 feet from a lower portal near the powerplant to an entry structure

in the switchyard. The control tunnel has concrete walls and a pneumatically applied mortar roof, except for approximately 100 feet at the portal end which has reinforced concrete walls and roof. To relieve any phreatic pressure, the floor of the tunnel was left unpaved.

1. Transformer Circuits and Switchyards

108. LOCATION. The four overhead transformer circuits, three at 345 kilovolts and one at 230 kilovolts, emanate from steel takeoff brackets on the powerplant wall at approximate elevation 3228.5. The three 345-kilovolt circuits pass under the Glen Canyon Bridge and rise to rim towers C1-T1, C2-T1, and C3-T1 (figs. 206, 207, and 208) on the west canyon rim. From these rim towers, the circuits proceed through backup towers C1-T2, C2-T2, and C3-T2 and then to the 345-kilovolt takeoff structure (fig. 209) in the switchyard. The 230-kilovolt circuit also passes under the bridge to rim tower C4-T1 on the east canyon rim, thence across the canyon to tower C4-T2 which accommodates the span to the 230-kilovolt takeoff structure in the switchyard (fig. 210).

The switchyard is located downstream from the dam, near the west canyon rim and south of the State highway and the bridge. This location provides for the most flexible arrangement for the several transmission line approach spans to the 345-, 230-, 69-, and 25-kilovolt yards and to the future 138-kilovolt yard.

109. STEEL STRUCTURES FOR TRANSFORMER CIRCUITS. (a) *Takeoff Brackets.*—A series of eight three-bay takeoff brackets were mounted on the exposed steel column flanges of the powerplant wall columns at a suitable elevation for required electrical clearances and conductor arrangement to the transformers and lightning arresters on the powerplant deck. This essentially provided a continuous run of line attachment beams, with the exception of breaks in continuity as imposed by expansion joints in the powerplant wall. With this takeoff bracket arrangement, sufficient line attachment spacing was realized for lines taking off at maximum 30° horizontal and 37° vertical line angles. The attachment spacing was correlated with phase spacing at the canyon rim towers to meet electrical requirements for midspan circuit spacing and phase separations.

Closely related to the takeoff bracket design was the problem of maintaining safe electrical clearances to

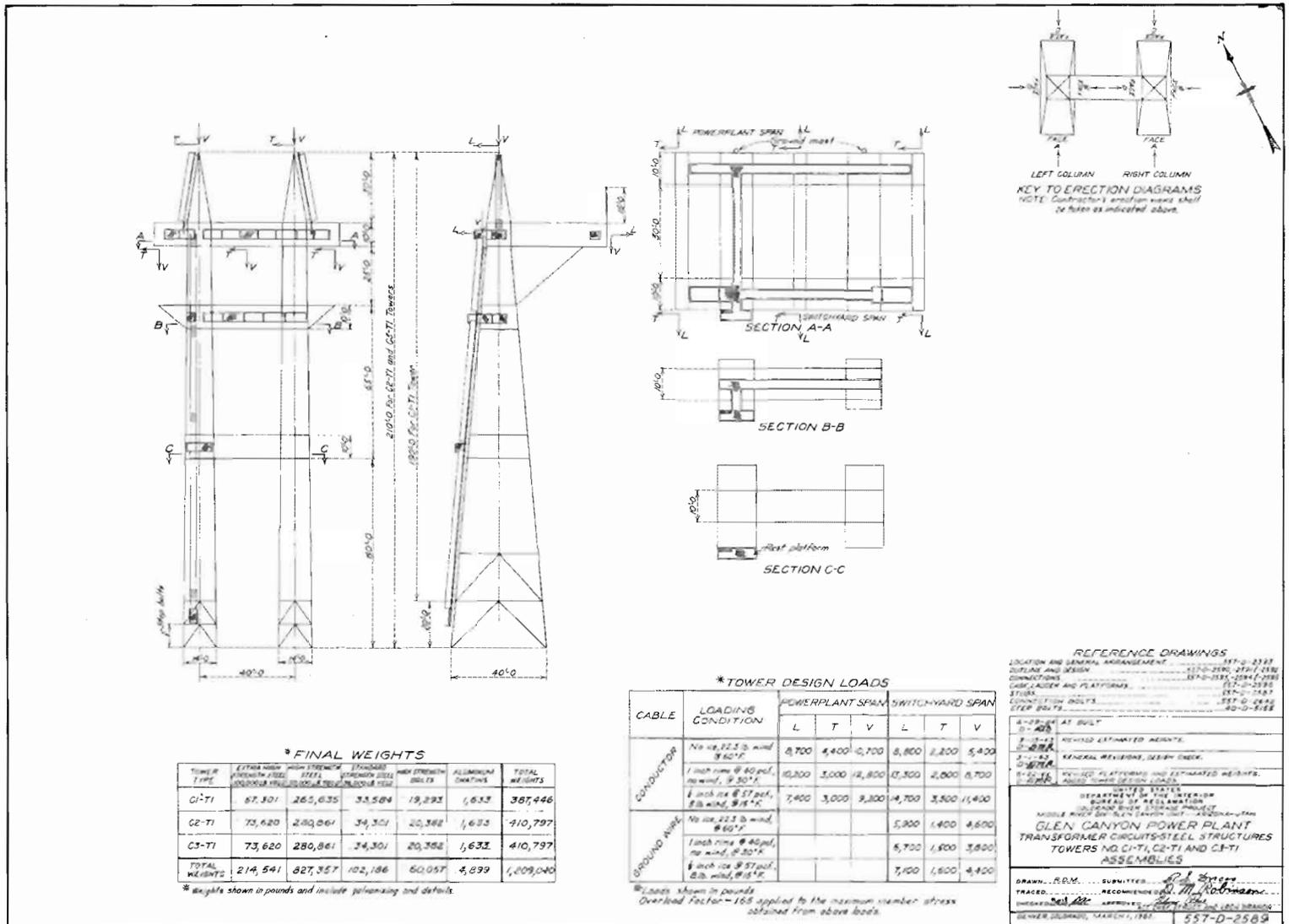


Figure 206.—Transformer circuits steel structures—Assemblies of towers C1-T1, C2-T1, and C3-T1.

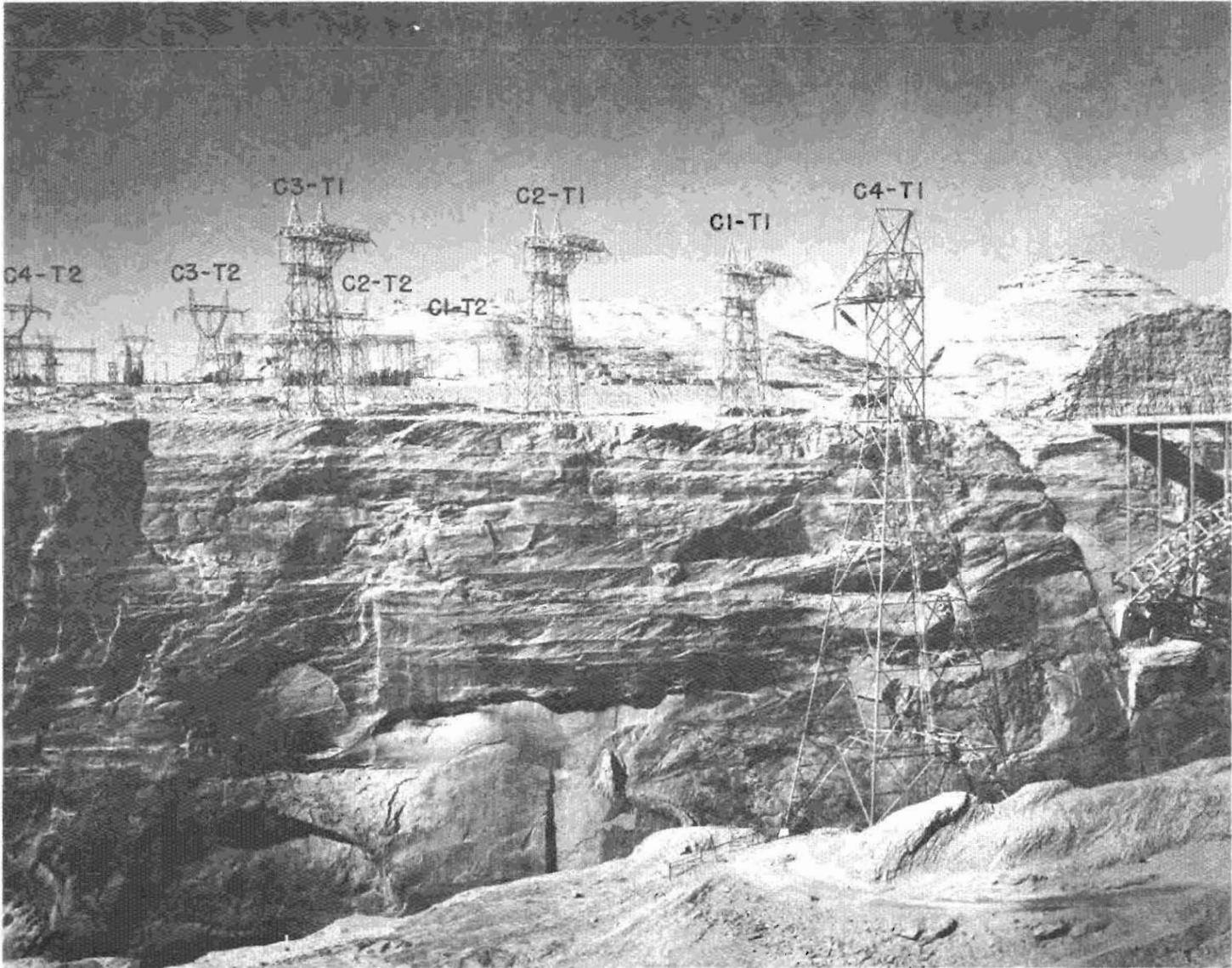


Figure 207.—Telephoto view of transformer circuit steel structures on canyon rim. P557-420-60090NA.

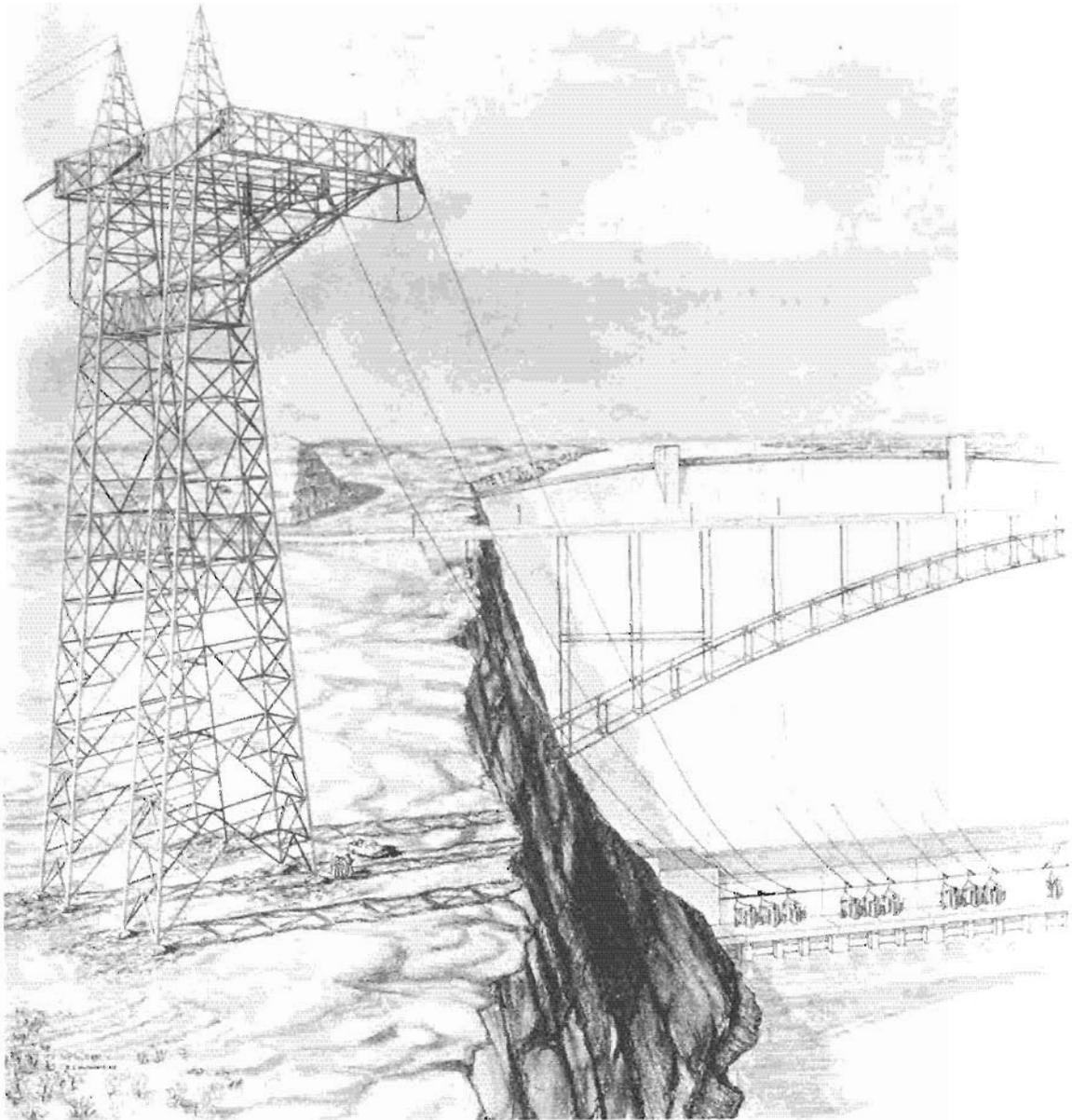


Figure 208.—Artist's conception of 345-kilovolt tower C1-T1 on canyon rim. P557-D-36377.

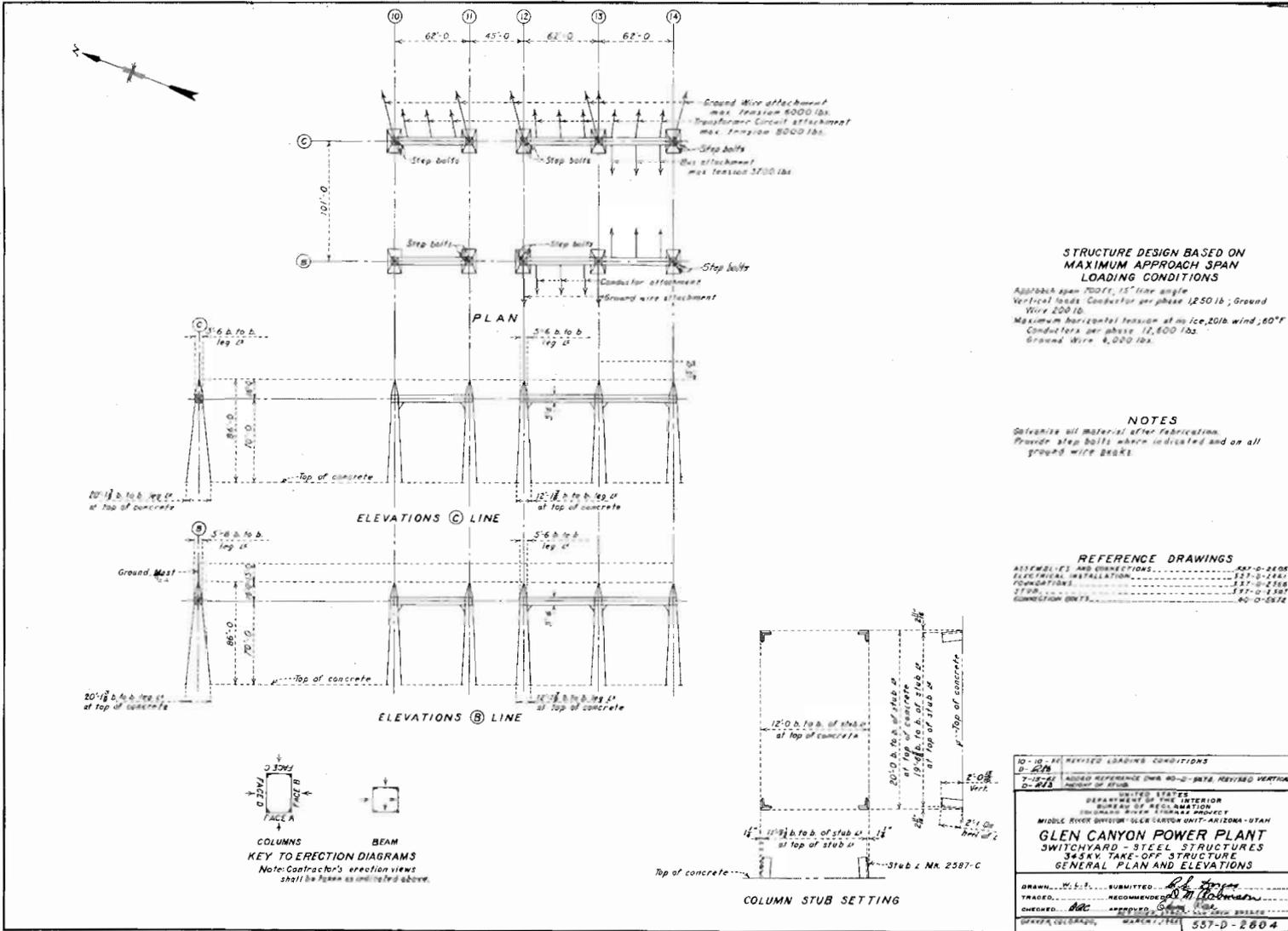


Figure 209.—Switchyard steel structures, 345-kilovolt takeoff structure—General plan and elevations.

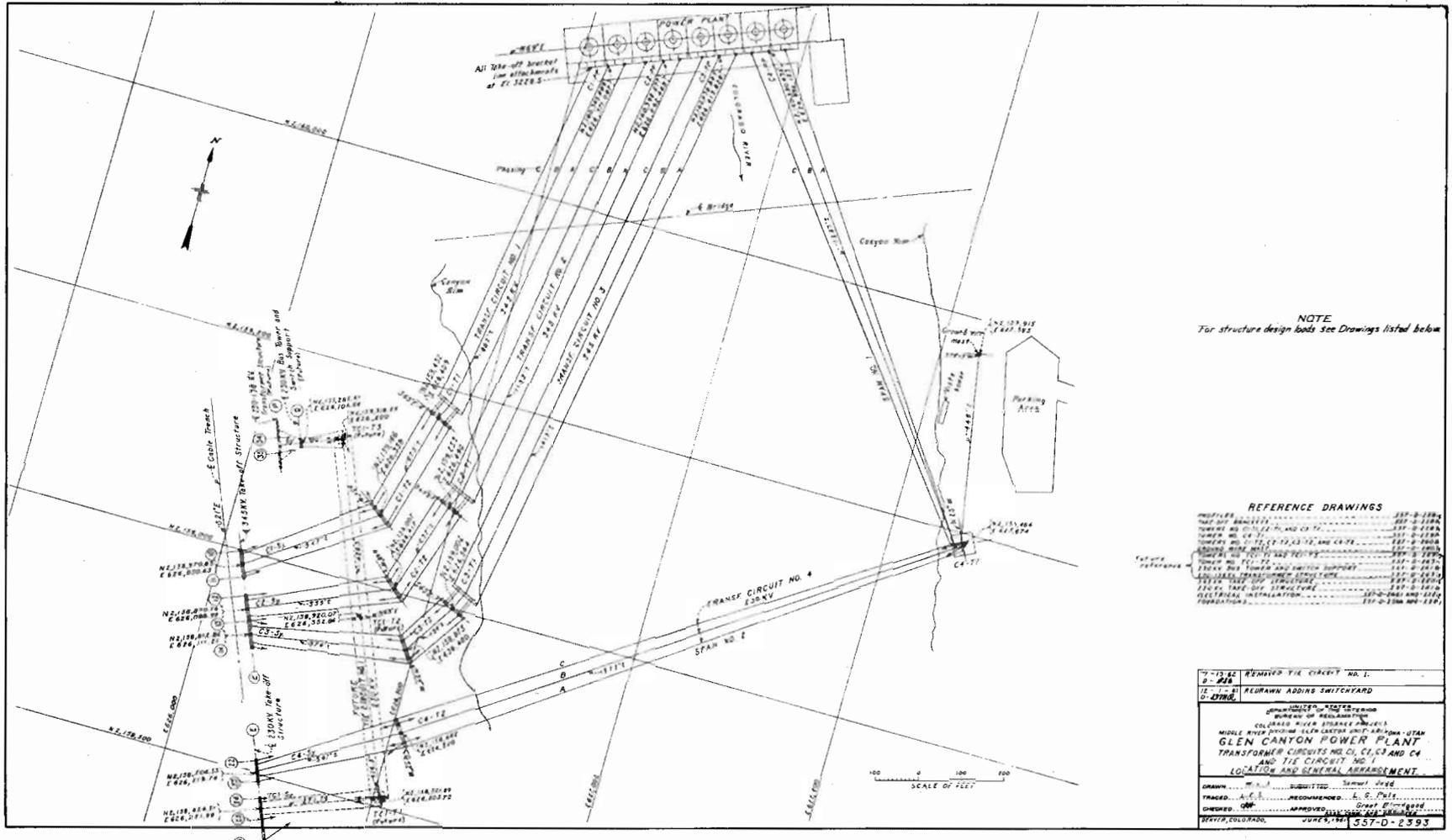


Figure 210.—Transformer circuits No. C1, C2, C3, and C4 and tie circuit No. 1—Location and general arrangement.

the downstream bridge arch, canyon walls, and canyon rims. Using the physical properties of a 2,167,000-circular-mil ACSR (Kiwi) conductor for the three 345-kilovolt circuits and 954,000-circular-mil ACSR (Cardinal) conductor for the one 230-kilovolt circuit, conditions of either sideswing from a 100-m.p.h. wind acting transversely, or the generally accepted elliptical movement in space from possible "galloping" were taken into account. These studies entailed careful positioning of the catenaries of conductors from the takeoff brackets to the rim towers. Also considered in the design was a maximum direct line tension of 16,000 pounds per conductor phase, with 1-inch radial ice at 40 pounds per cubic foot and no wind at 30° F. Because of these conductor problems at midspan, it was necessary to make concurrent designs on the powerplant takeoff brackets and canyon rim towers.

The beams of the takeoff brackets were designed to withstand bending stresses due to the 16,000-pound direct line tensions and torsional stresses induced by the vertical line loads acting in an offset position from centerline of the beam section. Using these line loads, coupled with transverse loads due to a 100-m.p.h. wind, a rigid-frame analysis was executed for designing the beam to bracket arm connections and the bracket arm to powerplant wall column connections.

(b) *345-Kilovolt Rim Towers C1-T1, C2-T1, and C3-T1.*—These towers (figs. 206 and 207) are the first in the United States using the new extra-high-strength structural steel shapes. The towers—two are 210 feet high and one is 190 feet high—incorporate three separate types of steel materials. These are heat-treated alloy steel of extra high strength, minimum yield point of 100,000 pounds per square inch; high-strength low-alloy steels, ASTM A 440, minimum yield point of 50,000 pounds per square inch; and standard-strength carbon steels, ASTM A 36, minimum yield point of 36,000 pounds per square inch. The legs of the two 210-foot towers from the ground to the 145-foot level and the legs of the 190-foot tower to the 125-foot level are of the extra-high-strength steel shapes; the remaining 65 feet of the legs of the structures and the entire web system and chords are the A 440 steel. The cage, ladders, and walkway platform supports are the A 36 steel. The walkway platforms are aluminum, in accordance with Federal Specifications RR-G-661a, type I, for a loading of 50 pounds per square foot.

Each tower supports a 345,000-volt transformer circuit emanating from the 900,000-kilowatt Glen Canyon Powerplant at the toe of the dam. The 3-phase transformer circuits, ranging from 900 to 1,400 feet in horizontal span length, pass under the Glen Canyon

Bridge, a short distance downstream from the dam, and rise 800 feet from the powerplant to the rim towers.

Many unprecedented problems were encountered in the design of these rim towers. Studies were conducted to determine the special structure design characteristics required to overcome the many difficulties presented in reaching a satisfactory solution for transmitting electrical power out of the canyon, as mentioned in subsection (a) above.

The heights of the rim towers were determined by an acceptable conductor clearance under the bridge and over the canyon rim edge. The structures are located at safe distances from the canyon rim, consistent with foundation safety, adequate conductor spacing, and span length limitations. A minimum of 25 feet was permitted from the intercept of the canyon wall plane with the ground surface to the tower column legs. These requirements necessitated a cantilever design concept for the conductor attachment beams on the structures. From the resolution of these requisites, effective outlines of the structures were established with the most efficient use of both ground and air space.

The structures were also designed to withstand a 100-m.p.h. wind, plus an increase in wind pressure of 10 percent due to structure height, with an exposure factor of 1.7 applied simultaneously to both columns. The analysis was performed for all possible combinations of intact and broken wire assumptions, including full dead end on either side of the structures, plus maximum wind from any direction and with a factor of safety of 1.65.

Based on preliminary design computations, several types of built-up sections, using high-strength structural steel angles and plates bolted together, were tried and compared with the extra-high-strength steels. The use of the extra-high-strength steels resulted in a substantial savings in weight of material and fabrication and erection time.

The proper use of the three different strengths of steel resulted in far more economical structures than normally could be attained with one type of steel. Weight saved by the extra-high-strength steels was 50 percent in those portions of the structures where they were used. The weight reduction resulted in a 20 percent savings in the total cost of the structures.

The structures were designed for the tabulated loads shown on figure 206. The tower portion of the structures was analyzed as an indeterminate, three-story, single-bay portal frame. The cantilever

portion was analyzed as indeterminate frames in both the plan and elevation views.

The reactions from the analysis of the cantilever portion of the structure were applied to the tower column as additional loads; also, the moment reaction from the cantilever frame in plan caused a torsional load on the tower columns.

Another very difficult and highly indeterminate problem was the torsional distribution at the top of the columns. After many studies were made on the torsional rigidity of the column versus the bending rigidity of the beam, a distribution of one-third of the torsion to the column and two-thirds to the beam was decided upon. The variable moment of inertia of the columns and the effect of sidesway were taken into account in the analysis of the tower and cantilever.

After careful consideration of the geological conditions in the area, it was decided to assume the base of the structure as being fully fixed. Using the results of the frame analysis and treating all the beams, columns, and cantilever parts as free bodies, all the forces on these free bodies were obtained for the resolution of stress diagrams.

The entire analysis up to and including the stress diagrams was performed for unit loads on the structures. This permitted the use of these analyses for all the various combinations of loads without repeating any of the analysis for the different cases. The beam-to-column and cantilever-to-tower connections are highly indeterminate and many solutions of these indeterminate connections were made using all possible combinations of loads.

The use of an extra-high-strength steel (100,000-p.s.i. yield point) required the development of a new column design equation. Using the secant formula a curve was developed to establish the relationship between slenderness ratio and ultimate stress, taking into account a reduction of 25 percent in yield point to 75,000 pounds per square inch.

To obtain the equation used for design, two straight-line segments were constructed tangent to the column design curve. The equations of these two straight lines, relating a range of ultimate stresses to a range of slenderness ratios, were used for the design equations. The cutoff point for the maximum ultimate stress was made either at l/r equal to 50 or a stress of 54,800 pounds per square inch.

The design requirements for members of high-strength ASTM A 440 and A 36 materials are

consistent with the requirements of the Bureau's Design Standards No. 10, Transmission Structures. A program developed by the Bureau for the electronic computer was available for use in determining the moments and shears for the numerous cases in the horizontal frame of the cantilever, and was used to check manual computations.

Because of the zero coefficient of friction between galvanized members, all structural joints were designed as shear connections using 7/8-inch-diameter ASTM A 325 bolts with recessed nuts tightened to a torque of 190 pound-feet to insure tight connections. The recessed nuts insured the exclusion of bolt threads from the shear plane and were locked in place with locknuts.

The allowable unit bolt stresses used were 40,000 pounds per square inch in shear and 80,000 pounds per square inch in bearing with an ultimate single shear load value of 22,600 pounds per bolt. Bearing values on materials were 12,100 pounds on a 3/16-inch thickness, 16,200 pounds on 1/4 inch, 20,300 pounds on 5/16 inch, and 24,300 pounds on 3/8 inch.

Hot-dipped galvanizing was used on the A 440 and A 36 materials, and coatings of zinc dust-zinc oxide paint on the extra-high-strength material were used to prevent corrosion, thereby extending structure life and minimizing structure maintenance.

For inspection and maintenance, an engaged ladder was provided on each tower for the full length of one of the columns and on both ground-wire peaks. A rest platform was provided at the 90-foot level, and inspection and maintenance platforms at the 135- and 170-foot levels. The platforms are completely encircled with a 3-1/2-foot-high wire fence for safety of personnel.

(c) *230-Kilovolt Rim Tower C4-T1.*—The same sag tension studies as mentioned for the conductors, in subsections (a) and (b) above were required for the 230-kilovolt circuit in order to maintain safe electrical clearances and to obtain the loads imposed on the tower.

This tower was designed to accommodate the conductors in a vertical configuration. This configuration served the dual purpose of providing reasonable sideswing clearances to the canyon wall, and providing conductor attachments such that it was possible to turn on a 90° line angle for the canyon crossing span without having to allow for electrical clearances through the structure, as was the case for the 345-kilovolt rim towers. Horizontal configuration

would have required the use of two taller towers for accomplishing the same results.

The tower was designed for the tabulated loads shown on figure 211. Stress diagrams were drawn for each of the loads separately and combined for the various conditions to obtain the maximum stress in all members. This tower is unique in that the wire loads as applied to the tower imposes torsional loads at all three crossarm levels.

The design requirements for these members are consistent with the requirements of the Bureau's Design Standards No. 10, Transmission Structures. The leg angles are high-strength structural steel angles in accordance with ASTM A 440 and the web system and crossarms are standard strength A-36 material.

This tower was also provided with an encaged ladder and inspection and maintenance platforms as described under subsection (b) above.

(d) *Model Aids Design.*—A three-dimensional scale model of Glen Canyon features was built by the Bureau's engineering laboratories. The model projects the spatial relationships of major elements of the unit—powerplant, switchyard, bridge, and transformer circuit structures.

The model was used to check the planned solution to the difficult space problem of positioning the catenaries of conductors from the powerplant to the rim towers. A fine-link chain was suspended between the model rim towers and powerplant takeoff brackets to simulate the catenaries of the conductors and check all critical electrical clearances, tower heights, phase configurations, and rock trimming along the edges of canyon rims. Templates representing the maximum sideswing of conductors under transverse windloading were also used to check critical electrical clearances from the conductor sideswing positions to the canyon walls. For these checks to be valid, it was necessary that the model be of greater than normal accuracy with respect to topography and positioning of critical structures. Close checks between the model and calculations demonstrated that this effort was worthwhile.

110. STEEL SWITCHYARD STRUCTURES. The 345-kilovolt switchyard is the first Bureau switchyard which encompasses this high voltage. Therefore, all of the steel structures were newly designed for this first usage at Glen Canyon.

The several structure outlines were determined by the increased requirements for electrical clearances and

heavy electrical equipment loads. These outlines are consistent with the existing structure outlines for previously designed 230- and 138-kilovolt switchyards.

The switchyard structures are of hot-dip galvanized structural steel, field assembled with high-strength bolted connections. The major structures were designed to withstand the loads imposed by conductors and overhead ground wires, wind and dead loads, and the loads imposed by the supported electrical equipment. The minor structures were designed for wind and dead loads and the weight of the supported equipment.

The takeoff structures and the transformer structures were designed for the tabulated loads shown on the drawings and also for the National Electrical Safety Code medium loading conditions of 1/4-inch radial ice at 57 pounds per cubic foot at 15° F. and a wind pressure of 8 pounds per square foot. The structures were analyzed as multiple-bay single-story portal frames in the transverse direction and as cantilevers in the longitudinal direction.

The maximum stresses in the individual space frame-type towers were obtained by combining unit stress diagrams for the various conditions of loadings including vertical loads, dead loads, and horizontal torsional shears produced by torsional moments of unbalanced longitudinal wires.

Wire tensions for conductors, ground wires, and tension buses were determined for the most severe condition of wind and temperatures as shown on figures 206, 209, 212, and 213. The wires of the approach spans of transmission lines and transformer circuits which anchor to the switchyard structures were slacked off to approximately one-half to two-thirds of the maximum tensions used throughout the lines in order to effect economies in the switchyard structures. This was permissible because the switchyard approach spans were not critical with respect to electrical clearances to the lower level of strain buses.

Stringing instructions for conductors and ground wires were calculated to insure that the design loads of the structures will not be exceeded (figs. 214 and 215). Tensions for conductors and ground wires within the switchyards were established by the following criteria:

- (1) Strength of wires, insulators, and hardware.
- (2) Limitation of tension at normal temperatures to avoid vibration in the wires.

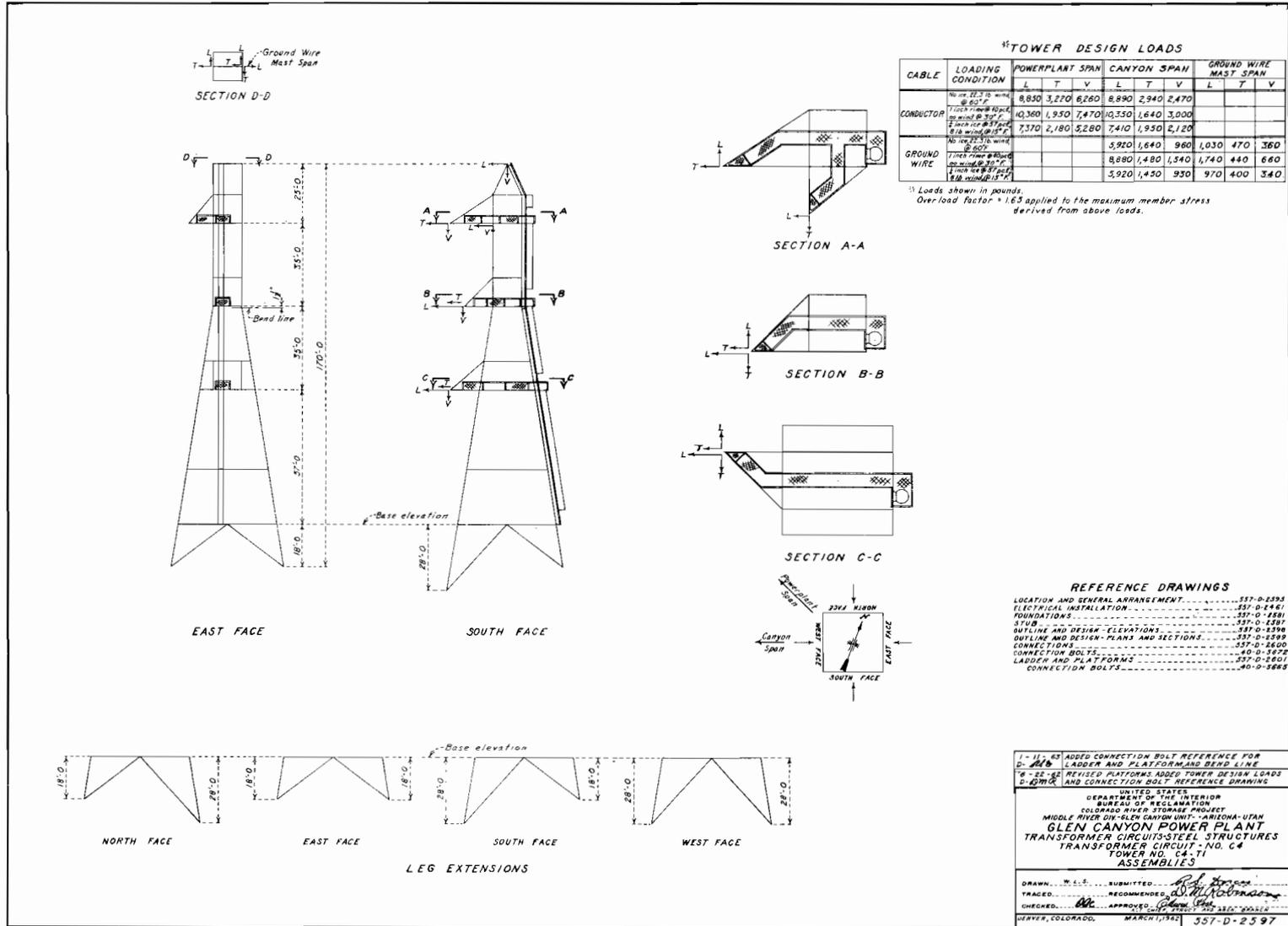


Figure 211.—Transformer circuits steel structures—Assemblies of tower No. C4-T1.

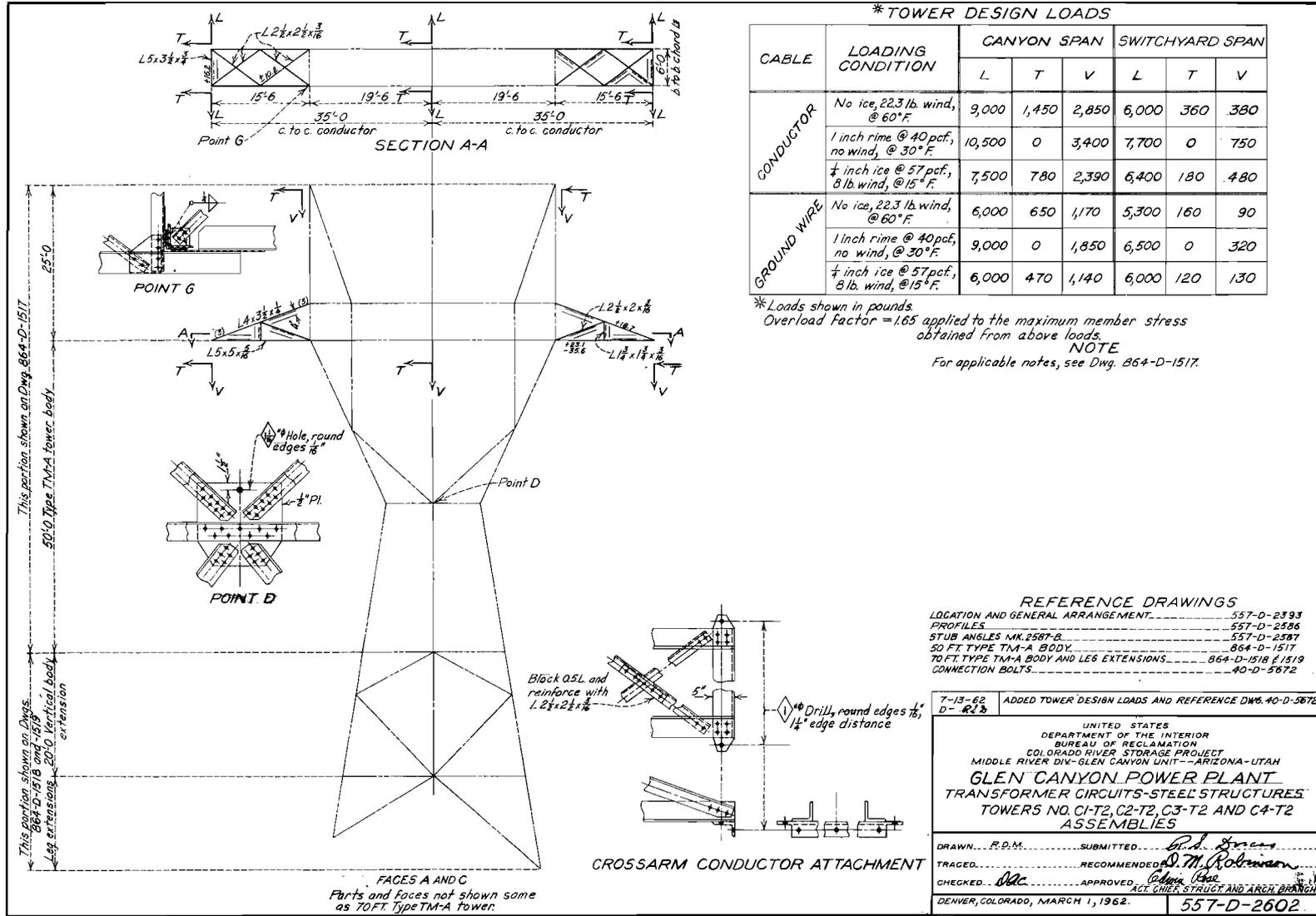


Figure 212.—Transformer circuits steel structures—Assemblies of towers C1-T2, C2-T2, C3-T2, and C4-T2.

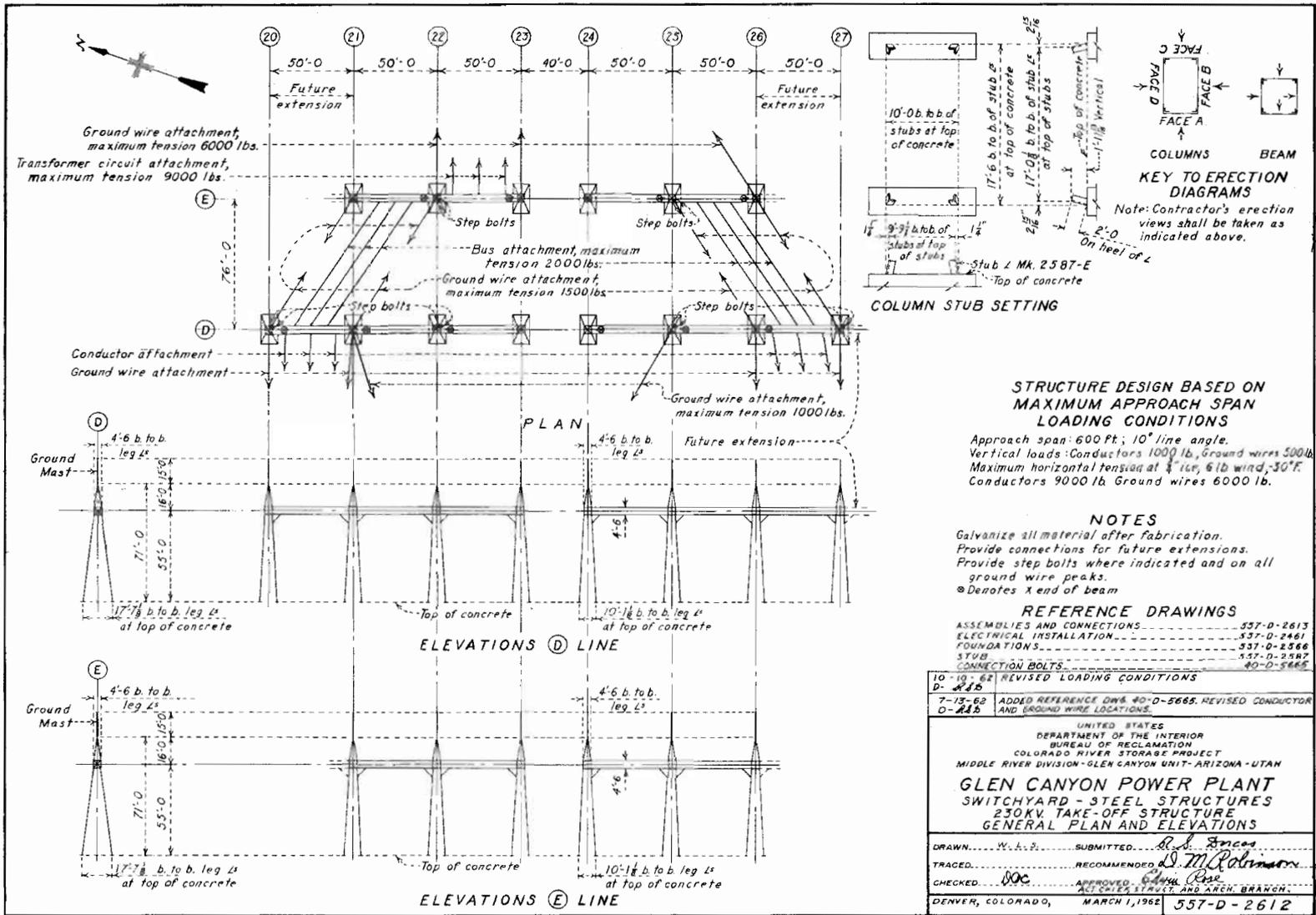


Figure 213.—Switchyard 230-kilovolt steel takeoff structure—General plan and elevations.

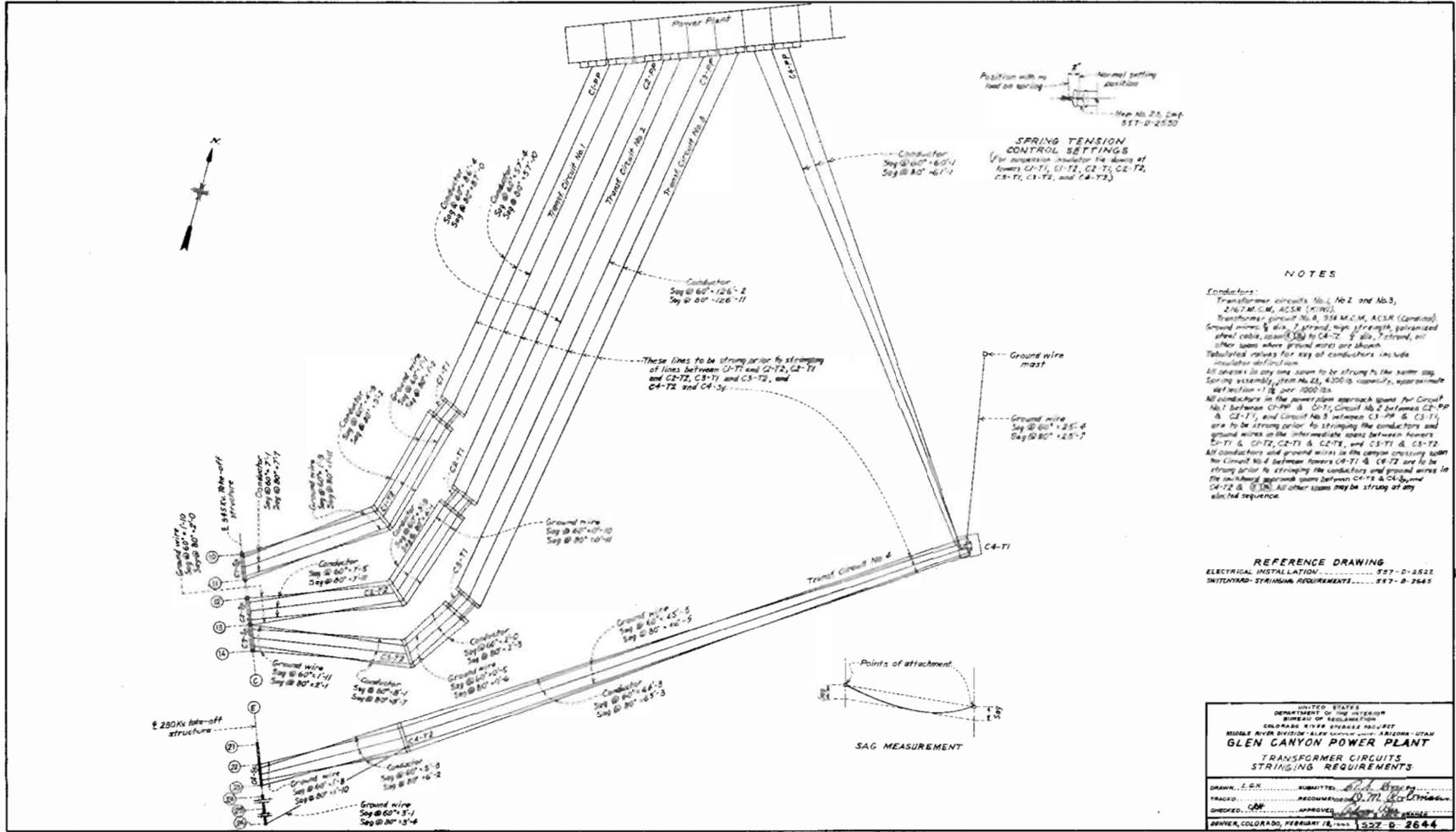


Figure 214.—Transformer circuits stringing requirements.

- (3) Economy of the supporting structures.
- (4) Electrical clearances.
- (5) Avoidance of unsightly sags at maximum temperatures considering the weights of insulators and taps.

In the conductor stringing operation the powerplant spans were strung prior to stringing backup spans between the rim towers and switchyard approach towers. This eliminated any undue loads on the switchyard approach towers from possible rim tower deflections resulting from powerplant span loads.

Owing to changes in power commitments, the 138-kilovolt switchyard and corresponding transformer circuits were deleted from the specifications requirements.

B. ELECTRICAL

111. REQUIREMENTS AND GENERAL DESCRIPTION. The switchyard is composed of 345-, 230-, 69-, 24.9-, and 4.16-kilovolt structures and space for a future 138-kilovolt structure within a fenced area located on the canyon rim approximately 850 feet southwest of the right dam abutment. The elevation of the switchyard is approximately 3,885 feet above sea level. The transformer circuits extend from the transformer deck of the powerplant to the switchyard and consist of three 345- and one 230-kilovolt overhead lines. The general arrangement of the switchyard is shown on figure 216 and that of the transformer circuits on figure 217. The switching arrangement and principal equipment ratings and procurement data are shown on figure 218.

112. GENERAL DESIGN. The main buswork for the 345- and 230-kilovolt installations is of the strain-type design, providing for an ultimate breaker and one-half switching arrangement. Initial operation is essentially as ring buses. The typical general arrangement of these installations is shown on figures 219 and 220, and the arrangement of the main autotransformer bank installation is shown on figures 221 and 222.

The buswork for the 69- and 25-kilovolt installations is of the rigid-type design with main and transfer buses. The general arrangement of these installations including the 69/25-kilovolt power transformer installation and power supplies for station service and other auxiliaries is shown in plan on figures 223 and 224. Typical details of the takeoffs on the

transformer deck and tower connections for the transformer circuits are shown on figures 225 and 226.

The control and low-voltage power cables are run in cable trenches through the switchyard. The location and details of the cable trenches are shown on figure 227. The cable trenches have removable aluminum plate covers throughout their entire length. The control cables and alternate station-service power supply run from the powerplant to the switchyard by means of the cable tunnel which joins the cable trench at the north end of the switchyard.

113. INSULATION, COORDINATION, AND LIGHTNING AND SWITCHING SURGE PROTECTION. The electrical insulation and protective devices were selected and coordinated to provide a safe margin of insulation strength above the maximum abnormal voltages permitted by the protective equipment during lightning, switching, and short-circuit surges.

All 345-, 230-, and 69-kilovolt lines and circuits are protected by two overhead ground wires terminated on peaks of the structures above the conductor takeoff levels, except the portion of the four transformer circuits between the powerplant and the canyon rim towers. This portion of the transformer circuits was considered to be adequately protected from lightning by the Glen Canyon Bridge, under which they pass, and the rim towers. Additional overhead ground wires have been provided to shield all buswork which would not otherwise be shielded.

Lightning arresters are mounted on or adjacent to all equipment having wound-type internal construction and all insulated cables having voltage ratings exceeding 600 volts, to dissipate lightning surges.

114. GROUNDING SYSTEM. The protective grounding system in the switchyard consists of 3/4-inch by 20-foot copperweld ground rods installed around the perimeter of the switchyard and around each lightning arrester installation. The ground rods are tied together by a network of 500,000-circular-mil A.W.G. bare copper cable buried 6 to 18 inches below grade. All equipment and steel structures, including the fence, are connected to the ground mat. A ground bus consisting of two 500,000-circular-mil A.W.G. copper cables extends through the cable tunnel to connect the switchyard ground mat with the powerplant ground mat. The switchyard key grounding plan is shown on figure 228.

SWITCHES				TRANSFORMERS AND COUPLING CAPACITORS			TRANSFORMERS AND COUPLING CAPACITORS			CIRCUIT BREAKERS AND POWER FUSES								
DESIGNATION	AMP	KV	INVITATION NO.	DESIGNATION	KV	INVITATION NO.	DESIGNATION	KV	INVITATION NO.	DESIGNATION	INTERRUPTING CAPACITY	AMP	KV	INVITATION NO.				
WU1A, WU1B, WU3A, WU3B, YU1A, YU1B, YU1D, YU3A, YU3B, YU3D,	1,600	345	DS-5860 (10)	K1A, K3A, K5A	345	DS-5780 (1)	Q2A, Q4A, Q6A (300/600-5)	15	(D) 90,642-A (5)	JU1A, JU1B	25,000 MVA	1,600	345	DS-5721 (11)				
YU1C - ZU1B	1,600	345	DS-5860 (9)	KU5A	345	DS-5784 (1), DS-6473(1)	Q8A (400/800-5)	15	(D) 90,642-A (4)	JU1C, JU3A								
YU3C - ZU3B	1,600	345	DS-5860 (11)	VU1A1, VU1B2, VU1B3, VU3A2, VU3A3	345	(D) 90,635-A (2)				JU3B, JU3C								
WU5C	1,600	345	DS-5860 (11)	VU1B1, VU3A1	345	(D) 90,635-A (1)	KV2F	2.4	DC-5853									
				K7A	230	DS-5780 (2)												
WZ5A, WZ6A, YZ5A, YZ6A, YZ7B,	1,600	230	DS-5860 (7)	QZ5A (300/600-5)	230	(D) 90,642-A (1)	LIGHTNING ARRESTERS			JZ5A, JZ5B	20,000 MVA	1,600	230	DS-6287 (1)				
YZ5B - ZZ5A	1,600	230	DS-5860 (6)	VZ5A1, VZ6A1	230	(D) 90,635-A (3)	① STATION TYPE	276	DS-5780 (1)	JZ6A, JZ6B								
YZ5C - ZZ5B				VZ5A2, VZ5A3, VZ6A2, VZ6A3	230	(D) 90,635-A (4)	② STATION TYPE	276	DS-5784 (1)	③ STATION TYPE	195	DS-5780 (2)						
YZ6B - ZZ6A				VZ7A, VZ7B (138,000-115//69.0)	230	(D) 90,641-A (1)	④ STATION TYPE	195	DS-5784 (1)	④ STATION TYPE	195	DS-5784 (1)						
YZ6C - ZZ6B				WZ5C	1,600	230	DS-5860 (11)	KW1A	69	DS-6164 (1)	⑤ STATION TYPE	195	(D) 90,647-A (2)					
					QW1A, QW3A (75/150-5)	69	(D) 90,720-A (2)	⑥ STATION TYPE	60	DS-6164 (1)	JW1A, JW3A	2,500 MVA	1,200	69	(D) 90,700-A (1)			
WW1B	600	69	(D) 90,708-A (1)	VW1A1, VW3A (40,250-115//67.08)	69	(D) 90,720-A (1)	⑦ INTERMEDIATE TYPE	60	(D) 90,715-A (1)	⑧ INTERMEDIATE TYPE	60	(D) 90,723-A (1)						
WW1A, YW1B, YW3B,	600	69	(D) 90,708-A (2)		KW1A	69	DS-6164 (1)	⑨ STATION TYPE	30	DS-5875 (2)								
YW1A - ZW1A	600	69	(D) 90,708-A (3)		QW1A, QW3A (75/150-5)	69	(D) 90,720-A (2)	⑩ STATION TYPE	30	DS-5784 (1)	JV2A, JV3A, JV4A, JV5A	1,500 MVA	1,200	34.5	DS-5816 (2)			
					VW1A1, VW3A (40,250-115//67.08)	69	(D) 90,720-A (1)	⑪ STATION TYPE	30	(D) 90,647-A (1)								
WV1A, WV1D, WV2A, WV2C, WV3A, WV4A, WV5A, WV5B, YV2A, YV2B, YV3A, YV3B, YV4A, YV4B,	1,200	23	DS-5860 (12)		KV1A	25	DS-5875 (2)	⑫ STATION TYPE	30	DS-6164 (1)	FV2A	14,000 AMP	25E	34.5	DS-5860 (13)			
WV1B	1,200	23	DS-5860 (3)		KV1B		(D) 90,646-A (1)	⑬ INTERMEDIATE TYPE	60	(D) 90,715-A (1)	FV2B	14,000 AMP	20E	34.5	DS-5860 (14)			
WV1C	1,200	23	DS-5860 (1)		KV2A	25	DS-5875 (1)	⑭ INTERMEDIATE TYPE	60	(D) 90,723-A (1)	FV2C	14,000 AMP	100N	34.5	(D) 90,724-A (1)			
WV1F, WV1G	2,000	23	DS-5860 (5)		KV2B	25	(D) 90,639-A (1)	⑮ STATION TYPE	30	DS-5875 (1)	FV202	14,000 AMP	7E	34.5	(D) 90,724-A (1)			
WV2B	1,200	23	DS-5860 (4)		KV2C	25	(D) 90,639-A (2)	⑯ INTERMEDIATE TYPE	25	DS-5875 (1)	FV2D3	14,000 AMP	7E	34.5	(D) 90,708-A (14)			
XV1A	1,200	23	DS-5860 (2)		KV2D	25	DS-6293 (1)	⑰ STATION TYPE	30	(D) 90,722-A (1)	FV2E		150N	7.2	(D) 90,722-A (12)			
					KV2E	25	(D) 90,706-A (1)	⑱ STATION TYPE	30	DS-6164 (1)								
					QV2A (150/300-5)	25	(D) 90,642-A (3)	⑳ INTERMEDIATE TYPE	3	DC-5853								
					QV3A, QV4A (200/400-5)	25	(D) 90,642-A (2)	㉑ INTERMEDIATE TYPE	3	(D) 90,715-A (2)								
					VV5A (14,400-120//72)	25	(D) 90,641-A (1)	㉒ INTERMEDIATE TYPE	3	(D) 90,726-A (1)								
								WAVE TRAPS										
								DESIGNATION	AMP	INVITATION NO.								
								TU3A	1,200	(D) 92,050-A								

7-9-69	CHANGED DESIGNATION
8-2-	
10-17-68	RETRACED AND REPLACED JZ5A, 5B, 6A, AND 6B. CORRECTED KUSA DATA.
9-30-65	CORRECTED KV2D RATING. COMPLETED INV. NO'S FOR TABLES.
D-6.W.C.	
ALWAYS THINK SAFETY	
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION COLORADO RIVER STORAGE PROJECT GLLEN CANYON POWER PLANT & SW'YD SWITCHING DIAGRAM	
DRAWN: J.L.L. SUBMITTED: D.C. Millard	
TRACED: L.L.M. RECOMMENDED: M.H. Kight	
CHECKED: S.W.C. APPROVED: K.B. Keener	
CHIEF DESIGNING ENGINEER	
DENVER, COLORADO, MAY 18, 1956	
557-D-11	

Figure 218.—Glen Canyon Powerplant and Switchyard—Switching diagram. (Sheet 1 of 2.) From drawing No. 557-D-11.

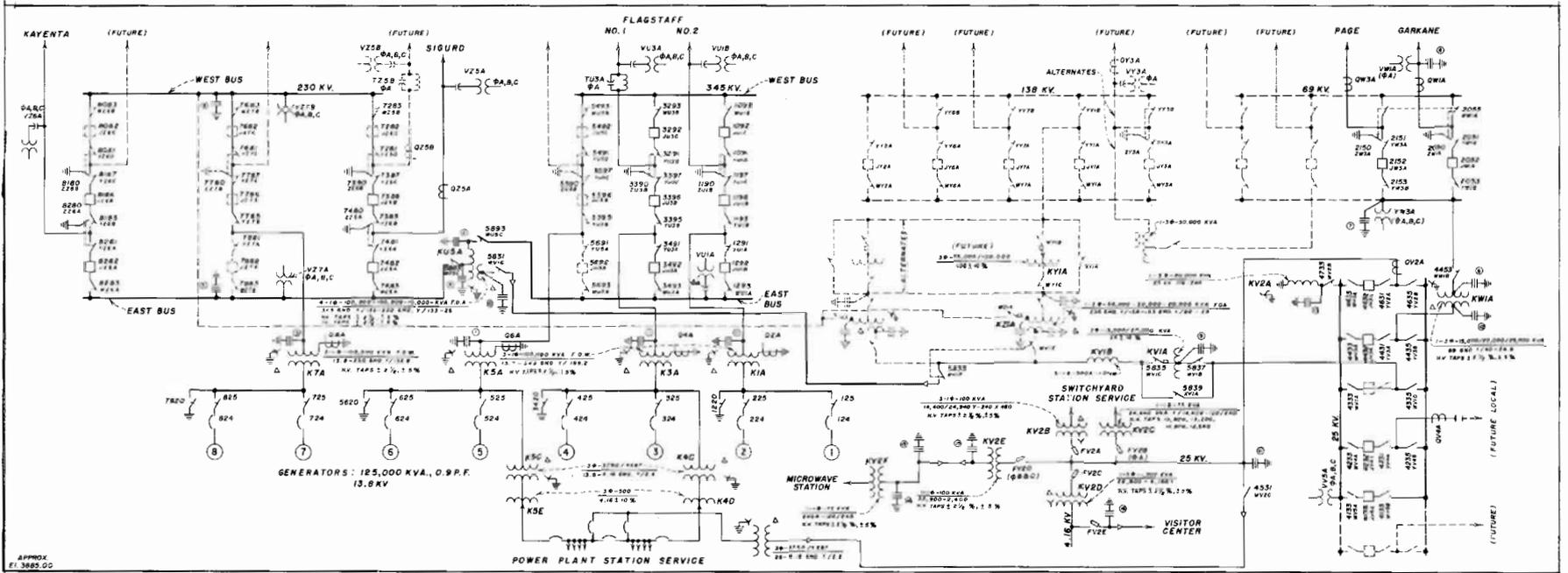


Figure 218.—Glen Canyon Powerplant and Switchyard—Switching diagram. (Sheet 2 of 2.) From drawing No. 557-D-11.

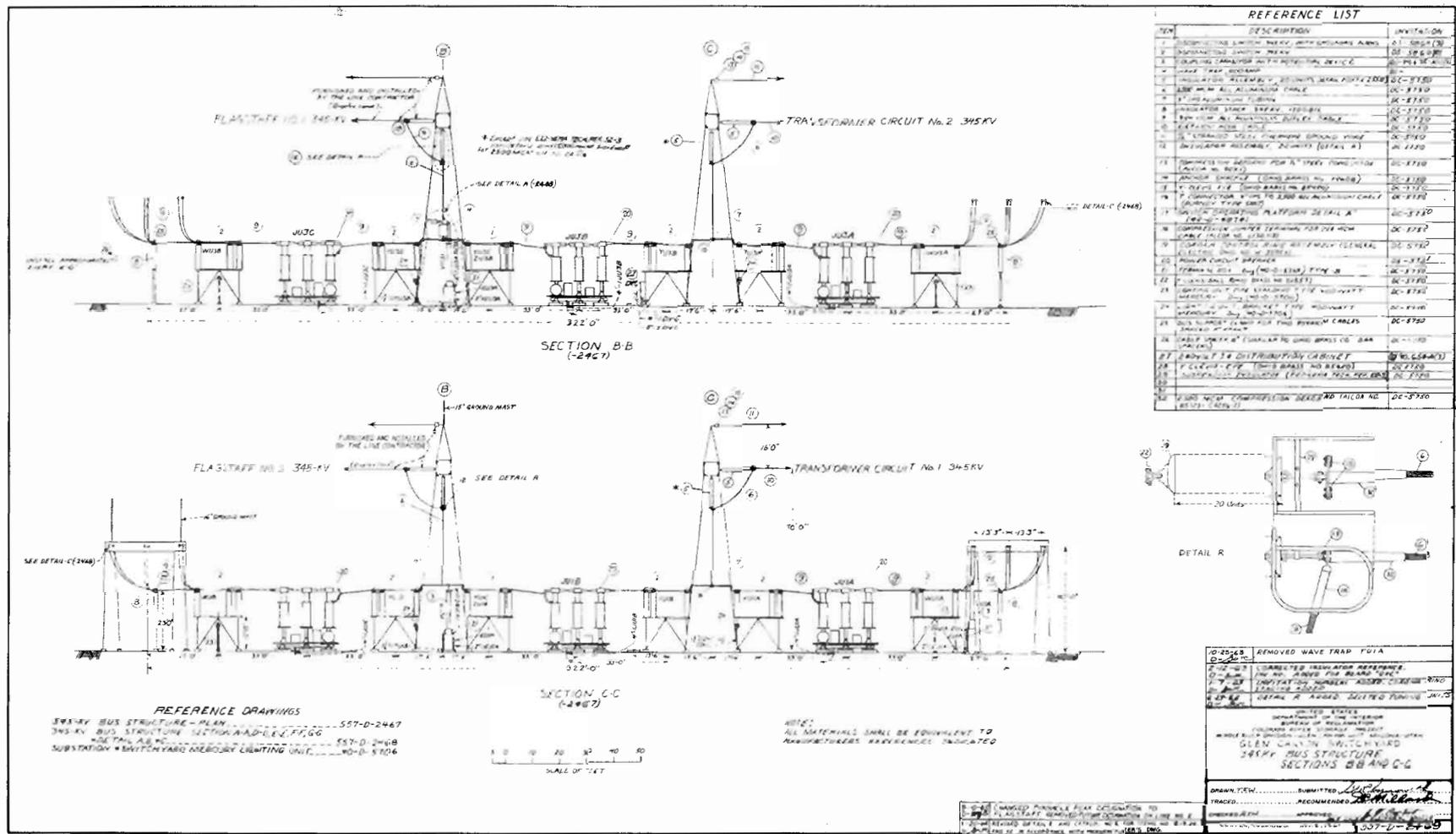


Figure 220.—Switchyard 345-kilovolt bus structure—Sections B-B and C-C.

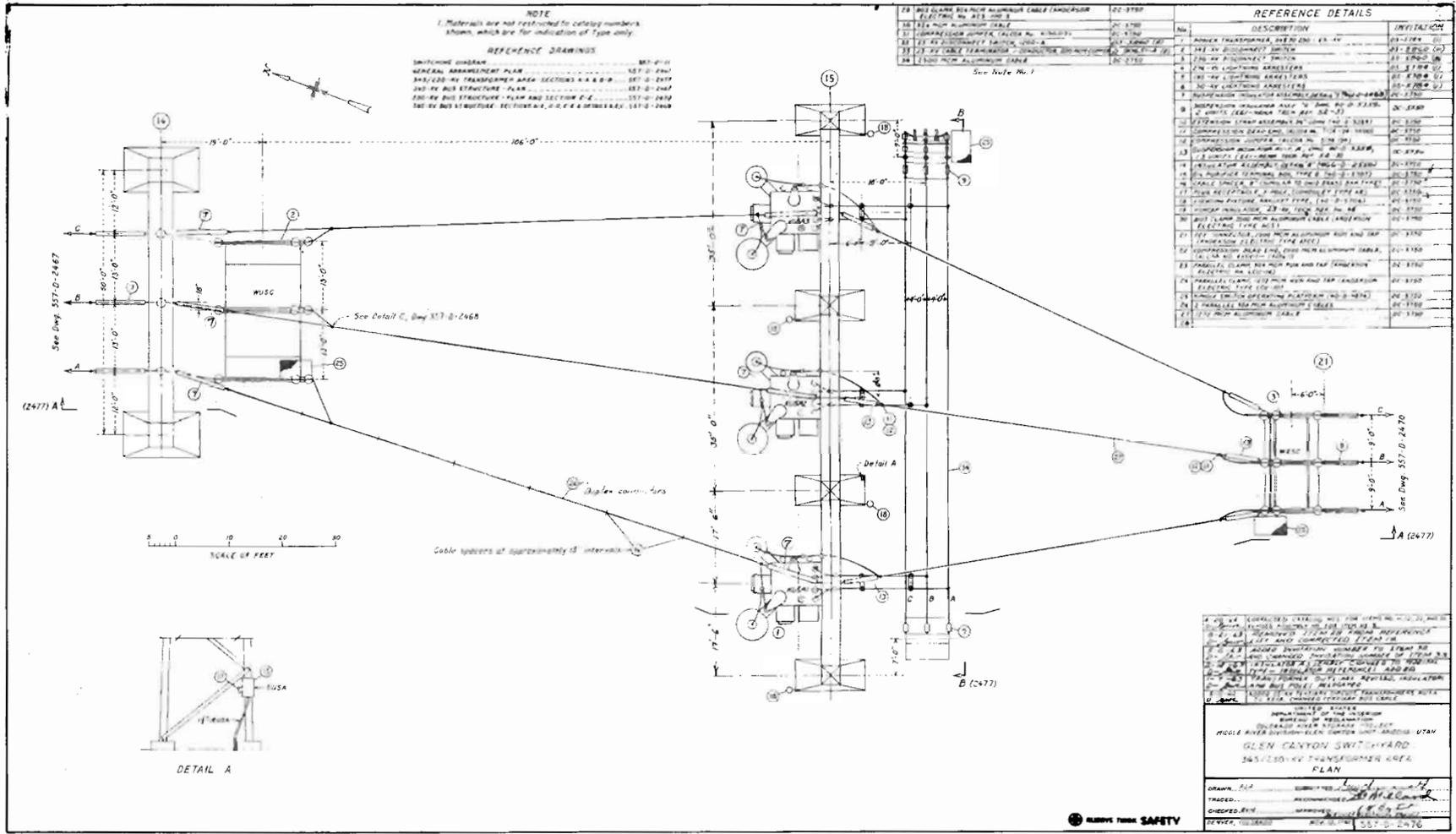


Figure 221.—Switchyard 345/230-kilovolt transformer area—Plan.

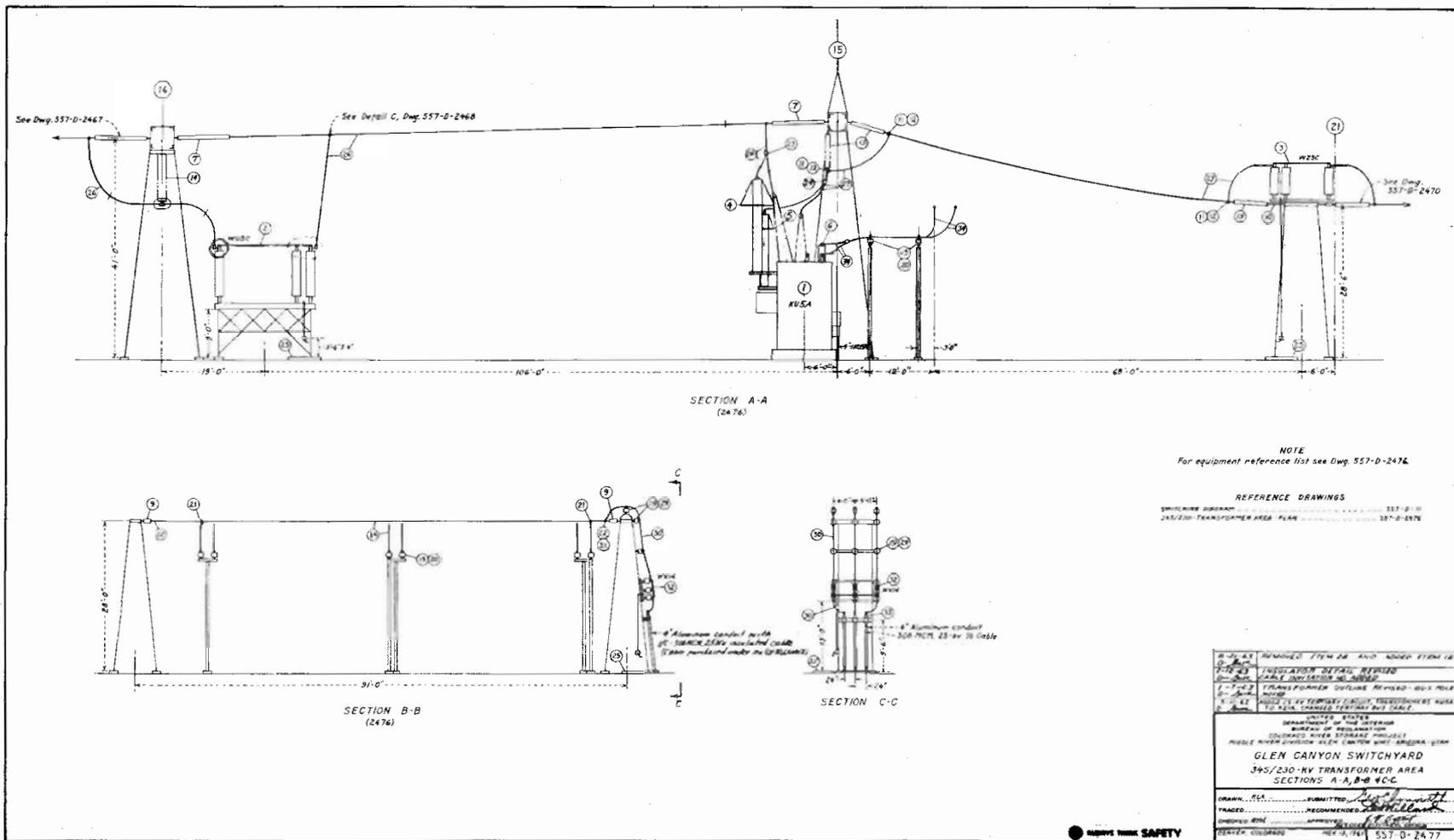


Figure 222.—Switchyard 345/230-kilovolt transformer area—Sections A-A, B-B, and C-C.

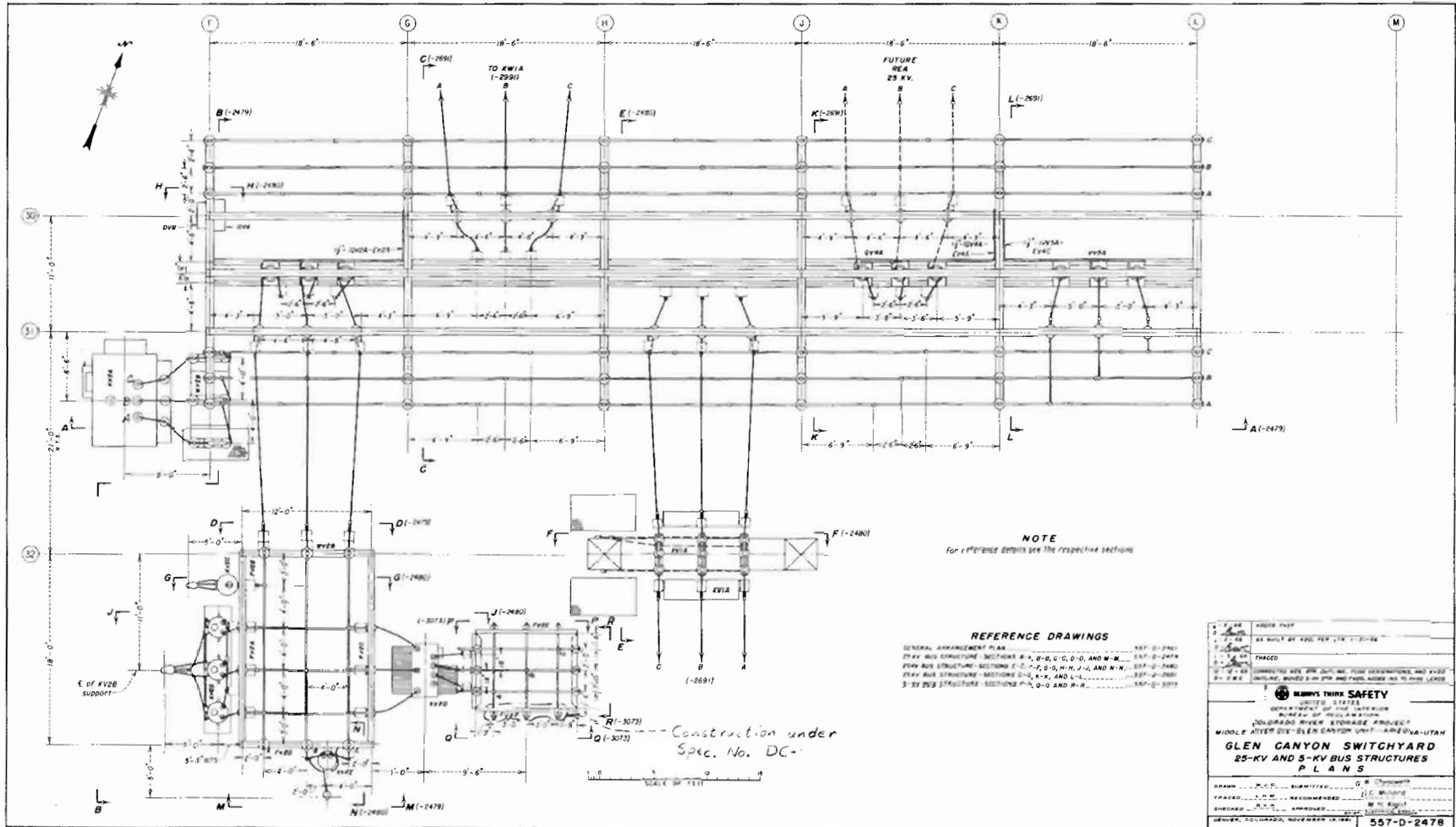


Figure 223.—Switchyard 25- and 5-kilovolt bus structures—Plans.

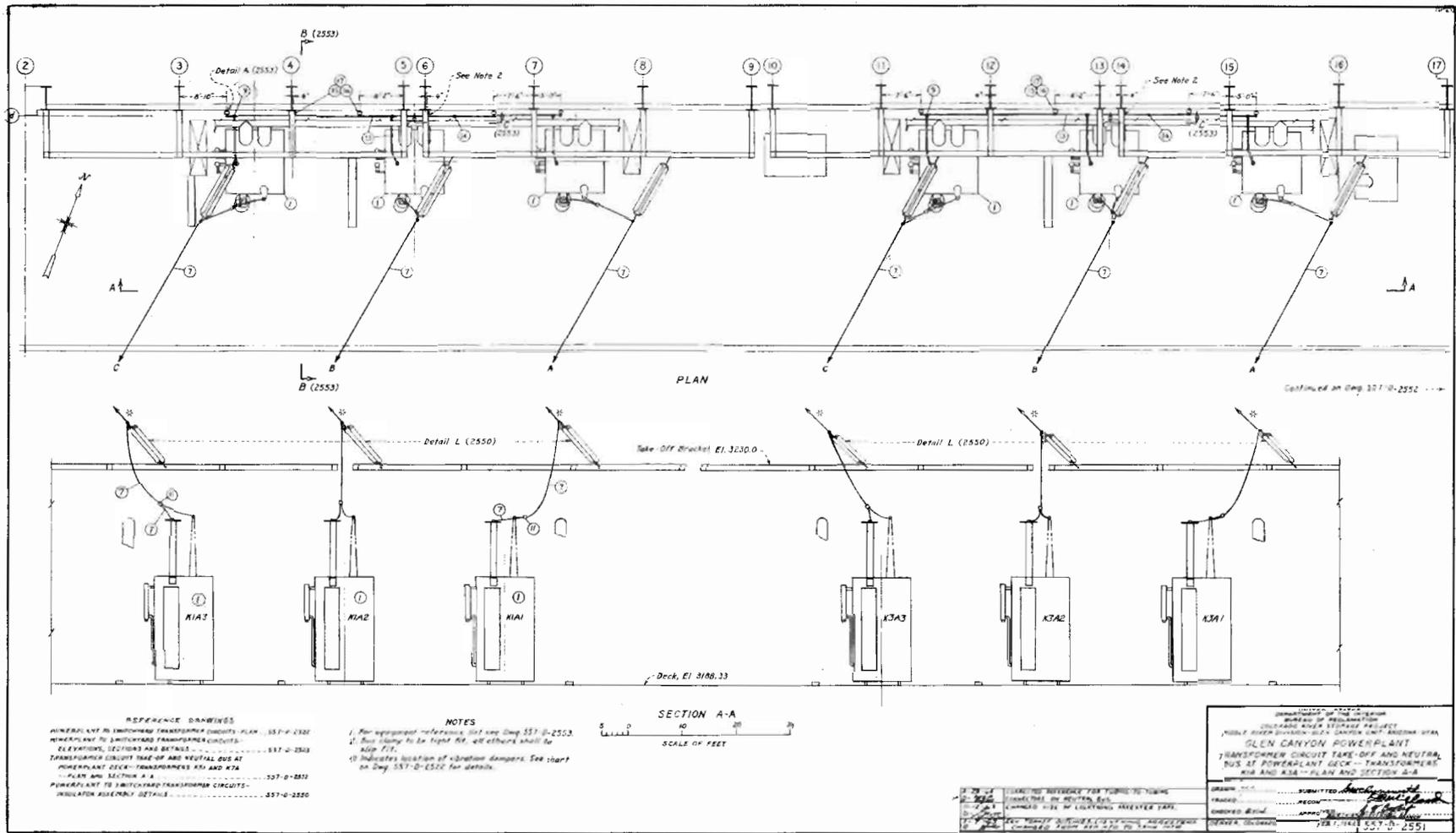


Figure 225.—Transformer circuit take-off and neutral bus at powerplant deck, transformers K1A and K3A—Plan and section A-A.

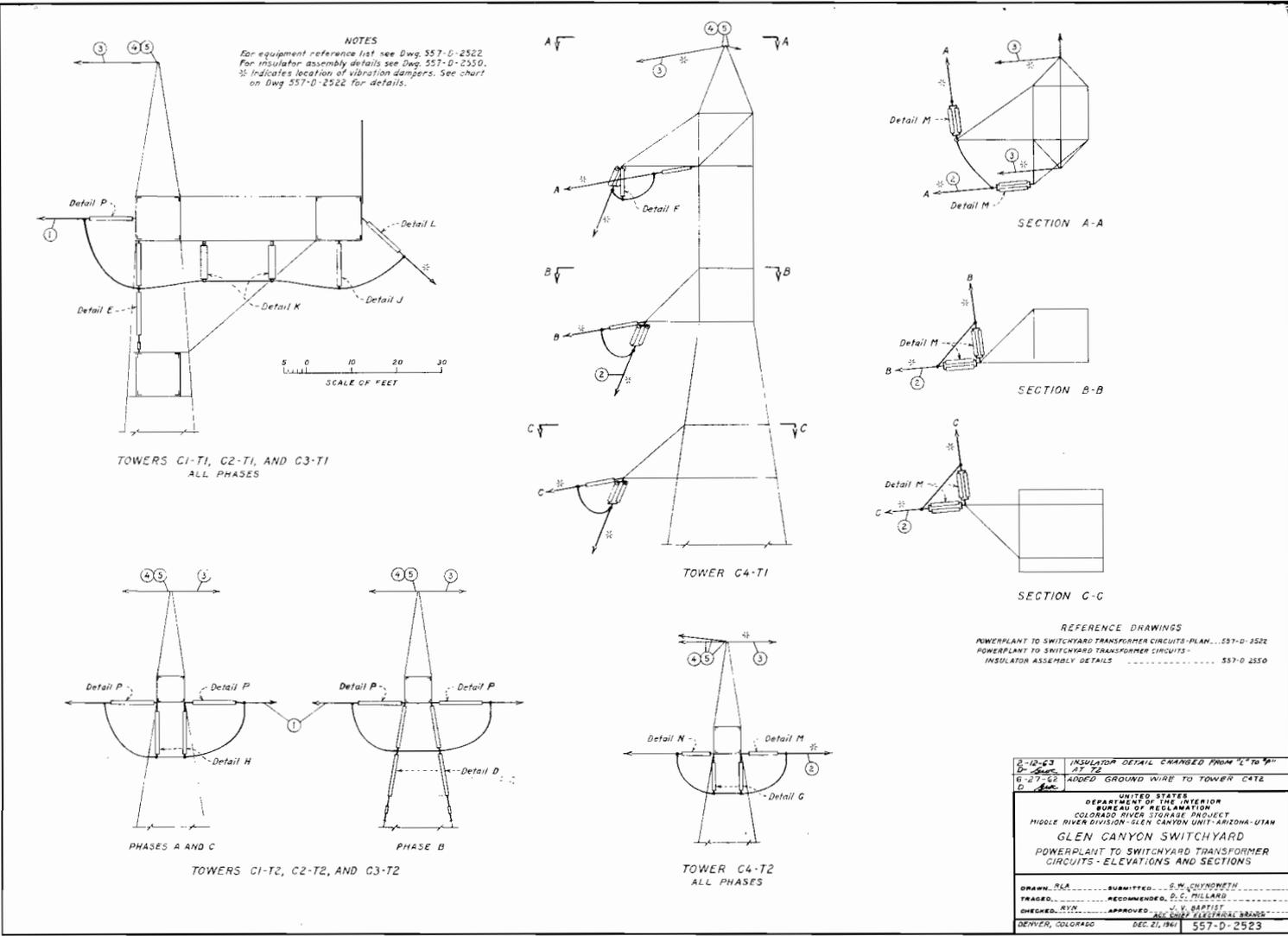


Figure 226.—Powerplant to switchyard transformer circuits—Elevations and sections.

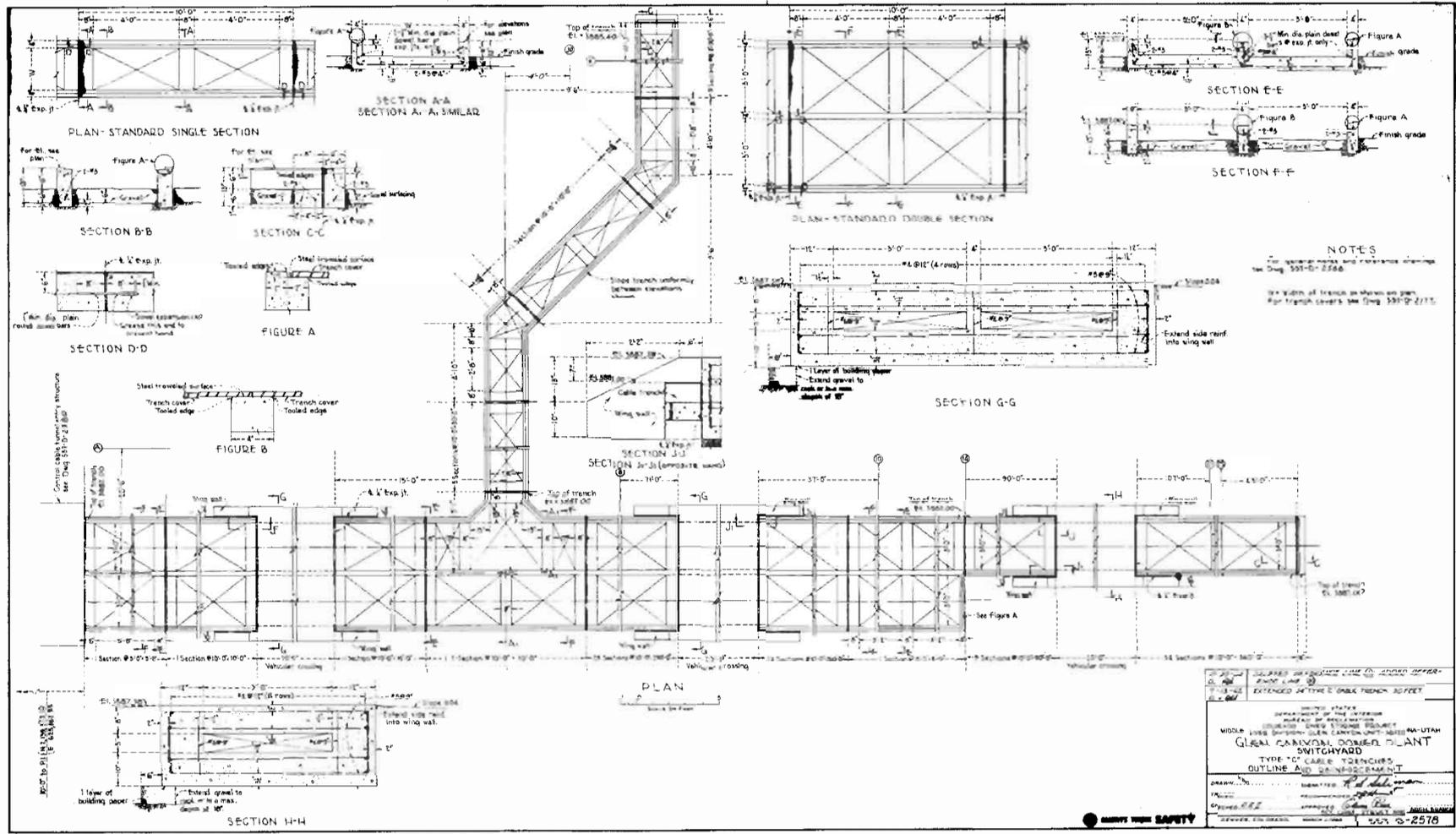


Figure 227.—Switchyard Type C cable trenches—Outline and reinforcement.

115. **SERVICE FACILITIES.** Since the switchyard is located comparatively near the powerplant, a service building was not provided in the switchyard.

116. **SPECIAL PROBLEMS.** The major problem in design of the switchyard was the lack of firm commitments for the power generated at Glen Canyon Powerplant at the time the completion contract had to be awarded. The specifications were issued with plans for a 230/138-kilovolt transformer with delivery to the city of Page and future delivery to Garkane Electric Association at 138 kilovolts. This was later modified to have Page supplied through Arizona Public Service Co.

with delivery at 25 kilovolts. The 230/138-kilovolt transformer and the 138-kilovolt yard were deleted from initial installation and the 25-kilovolt switchyard enlarged. After the 25-kilovolt switchyard had been installed, both the Arizona Public Service and Garkane Electric Association decided to take delivery at 69 kilovolts. At this stage of construction, the most economical way to accomplish this delivery was to step up power from the 25-kilovolt bus. Later, if a requirement develops, a 230/138-kilovolt transformer with delivery at 138 kilovolts and a 138/69-kilovolt transformer may be provided to carry the additional load.