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EFFECT OF INCREASED ELECTRIC LOADS
ON PRIMARY SUBSTATION EQUIPMENT
IN 100-R, C, D, E, F, AND H AREAS

By

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and

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EFFECT OF INCREASED ELECTRIC LOADS
ON PRIMARY SUBSTATION EQUIPMENT
IN 100-B, C, D, DR, F and H AREAS

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1.0 PURPOSE

The loading on the primary transformers which step down the 230 kv transmission voltage to a distribution voltage of 13.8 kv, at 100-B-C, 100-D-DR, 100-F, and 100-H Areas will be increased by the synchronous motors now being installed in those areas under Project CG-558. This report summarizes:

- (A) The changes in electric loads (both kw and power factor) which will result when the new motors are placed in service and certain older motors are withdrawn from service. Electric loads are tabulated in section 4.0 for each area for present conditions, the planned changes and the post-CG-558 conditions.
- (B) The reduction of distribution voltage during the starting of individual 4500 hp synchronous motors. Since the synchronous motors will be started across the line as induction motors, the starting current will be high, and at a low power factor. Voltage drops are calculated for the starting of a synchronous motor, with one and then with two transformer banks paralleled.
- (C) The current-interrupting capacity of switchgear vs. the maximum short-circuit current which could occur with separate transformers and with two primary transformers in parallel.

2.0 RESULTS OF THE STUDY

- 2.1 The primary transformers will be dependent on their forced-air cooling systems to meet the maximum continuous loads. The highest ratings obtainable by such cooling will be needed to meet the anticipated loads on some of the transformers, and all transformers will rely on forced cooling for a substantial portion of the time.
- 2.2 In the 100-B and C areas, served from 151-B Substation, the transformer capacity is adequate for the post-CG-558 load if all three primary transformers are in service. Two transformers would be overloaded beyond the maximum fan-cooled ratings if called on to carry the combined post-CG-558 load of the two areas but would carry the operating load of one area plus the standby load of the other. This fact was recognized in the planning stage of Project CG-558.
- 2.3 In the 100-D and DR areas, served from the 151-D Substation, the load is within the capacity of the three transformers which will be available but it exceeds the combined fan-cooled rating of two transformers. If the 100-D and 100-H 13.8 kv tie line were to supply power to two 4500 hp synchronous motors, the remaining load approximates the combined fan-cooled rating of two transformers.

The third transformer, soon to be installed, is not adequate to supply power to eight synchronous motors all running at rated excitation (0.8 leading PF). The rating of this transformer is adequate

for seven motors at rated excitation, or eight motors at about .92 power factor, leading.

- 2.4 In 100-F Area, served from 151-F Substation, the load is within the capacity of the two transformers, but it exceeds the fan-cooled rating of one transformer. Transformer capacity is insufficient to sustain operation of the reactor with one bank out of service.
- 2.5 In 100-H Area, served from 151-H Substation, the load is within the capacity of the two transformers, but it exceeds the fan-cooled rating of one transformer. If the 100-D-100-H 13.8 kv tie line were to supply power to two 4500 hp synchronous motors, one transformer would be sufficient to carry the remaining load.
- 2.6 Starting a 4500 hp synchronous motor from a single transformer reduces the distribution bus voltage by 10 to 15% depending on the amount and the power factor of the load already carried by the same transformer. Both experience and analysis of voltage-sensitive protective devices in the reactor areas indicate that no "scrams" should result during the 30-35 second duration of this voltage reduction, provided the system voltage is initially near the normal value.

Starting a 4500 hp synchronous motor with two primary transformers in parallel reduces the distribution bus voltage by 5 to 8% depending on load already carried by the transformers.

The voltage reduction will be greatest during the starting of the first motor. If some synchronous motors are already running they will help to maintain the voltage on their respective buses during the brief overload periods involved in starting additional motors.

- 2.7 Some of the original circuit breakers which control individual motor circuits could be over-stressed if a maximum short circuit should occur while those circuits were receiving power from two paralleled transformers.
- 2.8 Based on the information listed above recommendations are contained in section 7.0 of this report relating to:
 - a) Paralleling of transformers
 - b) Current-interrupting capacities of breakers
 - c) Spare transformer capacity
 - d) Advance try-outs of transformer forced-air cooling

3.0 RATINGS OF TRANSFORMERS

In general the primary transformers are rated as follows:

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- (a) 15,000 kva with 40° C temperature rise or 18,750 kva with 55° C rise, self-cooled with the full complement of 16 radiators.
- (b) 25,000 kva, 55° C rise, forced-air-cooled by operating 12 of the 24 cooling fans.
- (c) 31,250 kva, 55° C rise, forced-air-cooled by operating all of the 24 cooling fans.

On the older transformers, purchased prior to 1950, the new 31,250 kva rating provided by the manufacturer will not be supported by his guarantee. Because these transformers are far beyond the warranty period, the manufacturer will not guarantee ratings obtained by the later addition of forced cooling. An identical unit being furnished to 100-D area on Project CG-558 has a guaranteed rating of 31,250 kva.

The following list shows the actual nameplate rating on each transformer which will be available after CG-558 is completed:

100-B Bank #1 18,750/31,250 kva, 55° C rise OA/FA, purchased 1943
Bank #2 18,750/31,250 kva, 55° C rise OA/FA, purchased 1943
Bank #3 18,750/25,000/31,250 kva, 55° C rise OA/FA/FA,
purchased 1951

100-D Bank #1 18,750/31,250 kva, 55° C rise OA/FA, purchased 1943
Bank #2 18,750/31,250 kva, 55° C rise OA/FA, purchased 1943
Bank #3 18,750/25,000/31,250, 55° C rise, OA/FA/FA,
purchased 1955

100 H Bank #1 18,750/31,250 kva, 55° C rise, OA/FA, purchased 1948
Bank #2 18,750/31,250 kva, 55° C rise, OA/FA, purchased 1948

100 F Bank #1 18,750/31,250 kva, 55° C rise, OA/FA, purchased 1943
Bank #2 18,750/31,250 kva, 55° C rise, OA/FA, purchased 1943

200 Bank #1 15,000 kva, 40° C rise, OA, purchased 1943 (no fans)
Area Bank #2 18,750 kva, 55° C rise, OA, purchased 1948 (no fans)

Each of these transformers relies on 24 fans to cool the oil in 16 radiators. These fans allow the transformers to carry loads greatly exceeding their self-cooled rating.

The 18,750/25,000/31,250 kva rating indicates that the fan controls have been arranged to energize half of the fans for an intermediate rating of 25,000 kva. The remaining half of the fans are energized to attain the maximum rating of 31,250 kva. The fans are controlled by a double switch thermostat.

The 18,750/31,250 kva rating indicates that the fan controls have been arranged to energize all 24 fans by a single thermostat to attain the 31,250 kva rating.

The fans and motors are of a design used extensively by the General Electric Company Power Transformer Department over the past ten or more years, and have a good record. They have not, however, been through extensive operating experience at this installation.

4.0 TRANSFORMER LOADS BY AREAS

4.1 Tabulation of Transformer Loads

For each area affected by Project CG-558 the electric loads are summarized for each transformer bank. The load tabulations are stated for the feeders and motors normally connected to each transformer bank. It is anticipated that these tabulations and totals may be modified slightly after completion of this report since electric loads are sometimes shifted from one transformer bank to another. Load on each transformer bank is tabulated for the following conditions:

- (a) The present loads on the primary transformers reflect the maximum load which can be placed on each feeder, i.e., with all motors running.
- (b) The planned changes in loads reflect those loads which will either be removed or added to the primary transformer banks because of Project CG-558. The loads assumed for the new pumping facilities are based on the full load ratings of the motors since no actual load experience is available.
- (c) The post CG-558 loads reflect the maximum expected load on each feeder which will have to be carried by the primary transformer bank.

The loadings therefore include operational spares and standby units. In this manner the maximum load on each transformer bank can be determined. The normal area load is determined by totalizing the maximum transformer loads and then deducting the load represented by the operational spares. A load analysis is included for each affected area for both the present and post CG-558 loads.

The tabulation of the present loads was made in order to compare the calculated values with actual values. These actual values of load by areas were recorded by the Electrical Utility Section on November 30, 1955 and represent load on a typical day with all reactors in operation; the calculated totals by areas agree reasonably well with these records.

4.2 Summary of Area Loads

4.2.1 100-B-C Area

The present loads calculated for this area agree closely with the actual load recorded for the area on November 30, 1955. The present load, after subtracting probable operating spares from the total possible load, was calculated to be 46,350 kw and the recorded load was 45,200 kw.

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Feeder	Bldg	Load	Present			Planned Change			Planned Total		
			kw	kva	kvar	kw	kva	kvar	kw	kva	kvar
L-1	105-B 190-B	Misc. Light & Power 6-800 HP Motors	3950	4150	-1660	(Load to be removed) 3800	4100	1660	150	150	--
L-9	182-B 183-B 184-B	1-1000 HP Export 2-450 HP Export 3-200 HP Process to be deactivated				(Load to be added) 200	200	--	3360	3680	-1480
		2-700 HP Process 1-200 HP Backwash 1-60 HP 184 Water 1-700 HP Process to be added	3160	3480	-1480						
L-10	181-B	8-450 HP Process to be reduced to six 1-450 HP Purex 4-600 HP Process to be added	3240	3600	-1575	(Load to be added) 1200	1360	-590	4440	4960	-2165
L-14 L-15	190-C 190-C	1-3500 HP Ind. Motor 1-3500 HP Ind. Motor	2740 2740	2950 2950	-1080 -1080				2740 2740	2950 2950	-1080 -1080
L-72	105-C	Fans, Light & Power	270	300	-130				270	300	-130
L-81 L-83	190-B 190-B	1-4500 HP Syn. Motor 1-4500 HP Syn. Motor				(Load to be added) 3600 3600	4500 4500	42700 42700	3600 3600	4500 4500	42700 42700
			16100	17530	-7005	4800		41070 to 46470	20900	21500 to 20900	-5935 to -535

Table 1. Maximum Loading on Transformer Bank #1 151-B Substation

• Minus indicates a lagging power factor. Plus indicates a leading power factor.

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Feeder	Bldg.	Load	Present			Planned Change			Planned Total		
			kw	kva	kvar	kw	kva	kvar	kw	kva	kvar
L-3	181-B plus Army Line	8-450 HP River Pumps (to be reduced to 6) 1-450 HP (Furex) 4-600 HP To be added	3240	3600	-1575	(Load 1200	(Load to be added) 1360	-590	4440	4960	-2165
L-2	105-B 190-B	Fans, Light & Power 6-800 HP Motors To be removed	500 3400	500 3800	-- -1660	(Load 3400	(Load to be removed) 3800	-1660	500	500	--
L-8	182-B 183 184-B	1-1000 HP Export 1-1000 HP Export 1-450 HP Export 4-200 HP Process to be deactivated 3-700 HP Process 1-200 HP Backwash 1-300 HP High Tank	4580	5250	-2280	(Load 640	(Load to be removed) 720	- 320	3040	4530	-1960
L-18 L-19	190-C 190-C	1-3500 HP Motor Ind. 1-3500 HP Motor Ind.	2740 2740	2950 2950	-1080 -1080				2740 2740	2950 2950	-1080 -1080
L-71	183-C	3-450 HP Motors 1-300 HP pl. Lt. & Power 1-450 HP (to be added)	1320	1500	- 640	(Load 360	(Load to be added) 400	- 175	1680	1900	- 815
L-82 L-84	190-B 190-B	1-4500 HP Syn. Motor 1-4500 HP Syn. Motor				3600 3600	4500 4500	2700 2700	3600 3600	4500 4500	2700 2700
			18520	20550	-8315	4720	(Load to be added)	1215 to 16615	22880	23900 to 22800	-7100 -1700

* Minus indicates a lagging power factor, plus indicates a leading power factor.

Table 2. Maximum Loading on Transformer Bank #2 151-B Substation

Feeder Bldg	Load	Present			Planned Change			Planned Total		
		kw	kva	kvar	kw	kva	kvar	kw	kva	kvar
L-11	190-C	2740	2950	-1080				2740	2950	-1080
L-12	190-C	2740	2950	-1080				2740	2950	-1080
L-13	190-C	2740	2950	-1080				2740	2950	-1080
L-20	190-C	2740	2950	-1080				2740	2950	-1080
L-21	190-C	2740	2950	-1080				2740	2950	-1080
L-22	190-C	2740	2950	-1080				2740	2950	-1080
L-73	105-C	400	400	--				400	400	--
L-74	183-C	1200	1360	- 580				1200	1360	- 580
L-75	190-C	150	150	--				150	150	--
L-85	190-B				(Load to be added)	4500	42700	3600	4500	42700
L-86	190-B					4500	42700	3600	4500	42700
L-87	190-B					4500	42700	3600	4500	42700
L-88	190-B					4500	42700	3600	4500	42700
		18190	19610	-7060	14400	18000	410800	32590	33300	-7060 to 43740

Table 3. Maximum Loading on Transformer Bank #3 151-B Substation

• Minus indicates a leading power factor, plus indicates a lagging power factor.

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Present Loads (as of Nov. 30, 1955)

Tabulation of Operational Spares

<u>BLDG.</u>	<u>LOADS</u>	<u>SERVICE</u>	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>
181-B	1-450 HP	River Pump	360	400	175
182-B	1-1000 HP	Export Pump	800	890	390
	3-450 HP	Export Pump	1080	1200	525
	1-200 HP	Reservoir Pump	160	180	80
183-B	1-200 HP	Backwash	160	130	30
	1-700 HP	Process Pump	560	630	270
183-C	1-450 HP	Process/Backwash	360	400	175
	1-300 HP	Filtered Water	240	280	115
190-C	1-3500 HP	190-C Process Pump	<u>2740</u>	<u>2950</u>	<u>1090</u>
			6460	7110	2890

Tabulation of Total Area Loads

	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>
Transformer Bank #1	16,100	17,530	-7005
Transformer Bank #2	18,520	20,550	-8315
Transformer Bank #3	<u>18,190</u>	<u>19,610</u>	<u>-7000</u>
	52,810	57,690	-22,320
• Deduct Operational Spares	<u>6,460</u>	<u>7,110</u>	<u>-2,890</u>
Total Present Load	46,350	50,580	-19,430

Load recorded 11/30/55 = 45,200 KW

LOAD ANALYSIS - B-C AREA

PCST CG-558 LOADS

Tabulation of Operational Spares

<u>BLDG.</u>	<u>LOADS</u>	<u>SERVICE</u>	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>
181-B	2-450 HP	River Pump	360	400	-175
182-B	1-1000 HP	Export Pump	800	890	-390
	3-450 HP	Export Pumps	1080	1200	-525
183-B	1-200 HP	Backwash Pump	160	130	- 80
	1-700 HP	Process Pump	560	630	-270
183-C	1-450 HP	Process/Backwash	360	400	-175
	1-300 HP	Filtered Water	240	280	-115
190-C	1-3500 HP	190-C Process Pump	2740	2950	-1080
190-B	1-4500 HP	190-B Process Pump	3600 9900	4500	42700 -110 to -2310

Tabulation of Total Area Loads

	<u>Unity pf*</u>			<u>0.8 pf*</u>	
	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>	<u>KVA</u>	<u>KVAR</u>
Transformer Bank #1	20,900	21,600	-5935	20,900	- 535
Transformer Bank #2	22,880	23,900	-7100	22,880	-1700
Transformer Bank #3	32,590	33,300	-7060	32,800	-3740
Total Bank Loads	76,370	78,900	-20,095	76,370	-1505
Operational Spares	9,900		-2810		- 110
Total Expected Load	66,470	68,600	-17,285	66,470	-1615

* Power factor of each synchronous motor.

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Feeder	Bldg	Load	Present			Planned Change			Planned Total		
			kw	kva	kvar	kw	kva	kvar	kw	kva	kvar
L-3	105-D	7-800 HP Motors									
	100-D	150 KVA Misc. Lt. & Motors	3690	4100	-1660	(Load to be removed) 3600	4000	-1620	90	100	-40
L-6	105-DR	Building Power 1000 KVA Transformer	170	170	0	(No change)			170	170	0
L-7	190-DR	3-800 HP Motors Fdr. 1A Station Service	1720	1900	-770	(All load removed) 1720	1900	-770			
L-14	190-DR	3-800 HP Motors Fdr. 2B Reduced to 300 KVA Trans.	1530	1700	-600	(Load to be removed) 1440	1600	-1650	90	100	-40
L-17	182-D	1-1000 HP Export									
	183-D	1-450 HP Export									
	184-D	1-420 HP Condenser Water 4-200 HP Process (to be deactivated)	4050	4500	-1950	(Load to be removed) 640	720	-320	3410	3750	-1630
		3-700 HP Process 1-200 HP Backwash 1-60 HP 184 Water									
L-18	181-D	4-450 HP Process (to be deactivated)				(Load to be added) 2160	2450	-1050	5400	6000	-2625
		1-450 HP Purex 2-900 HP Process 5-900 HP Process (to be added)	3240	3600	-1575						
L-72	190-DR	Four				(Load to be added) 3600	4500	7200	3600	4500	7200
L-74	190-DR	4500 HP Synchronous				3600	4500	7200	3600	4500	7200
L-82	190-D	Motors				3600	4500	7200	3600	4500	7200
L-84	100-D	(to be added)				3600	4500	7200	3600	4500	7200
			14400	15970	-6645	79160		72310 to 71310	23560	23,900 to 24,400	-4335 to -6465

Table 4. Maximum Loading on Transformer Bank #1 151-D Substation

* Minus indicates a lagging power factor, plus indicates a leading power factor.

Feeder	Bldg	Load	Present			Planned Change				Planned Total		
			kw	kva	kvar	kw	kva	kvar		kw	kva	kvar
L-1	185-D 189-D	Experimental Test Equip.	1400	1400	0	(No change)				1400	1400	0
L-4	105- 190-D	7-800 HP Motors 105 Load 2000 KVA Trans.	3600 1800	4000 2000	-1620 - 810	(Load to be removed) 3600 4000 -1620				1800	2000	-810
L-5	181-D	4-450 HP Process (to be removed) 2-900 HP (to be added) 5-900 HP (to be added)	2880	3200	1400	(Load to be added) 2160 2400 -1050				5040	5600	-2450
L-8	190-DR	4-800 HP Motors (to be removed)	2100	2340	- 950	(Load to be removed) 2100 2340 - 950						
L-13	190-DR	4-800 HP 183-DR feeder reduced to 600 KVA Trans.	2200	2440	- 990	(Load to be removed) 1975 2190 - 890				225	250	- 100
L-15	105-DR	Building Power 1000 KVA Trans.	305	340	- 140	(No change)				305	340	- 140
L-16	182-D 183-D	1-1000 HP Export 1-450 HP Export 5-200 HP Process (to be deactivated) 2-700 HP Process 2-200 HP Backwash 1-450 HP H1 Tank) to be 1-700 HP Process) added	3660	4210	-1840	(Load to be removed) 240 270 - 130				3420	3940	-1710
L-71 L-73 L-81 L-83	190-DR 190-DR 190-D 190-D	4500 HP Syn. Motors (to be added)	17945	19930	-7750	(Load to be added) 3600 4500 f2700 3600 4500 f2700 3600 4500 f2700 3600 4500 f2700				26950 27,400 to 27,600	4500 4500 4500 4500	f2700 f2700 f2700 f2700

* Minus indicates a lagging power factor, plus indicates a leading power factor.

Table 5. Maximum Loading on Transformer Bank #2 151-D Substation.

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Feeder	Bldg	Load	Present			Planned Change				Planned Total		
			kw	kva	kvar	kw	kva	kvar	kw	kva	kvar	kvar
L-75	190-DR	4500 HP Syn. Motors (to be added)				3600	4500	2700	3600	4500	2700	
L-76	190-DR	4500 HP Syn. Motors (to be added)				3600	4500	2700	3600	4500	2700	
L-77	190-DR	4500 HP Syn. Motors (to be added)				3600	4500	2700	3600	4500	2700	
L-78	190-DR	4500 HP Syn. Motors (to be added)				3600	4500	2700	3600	4500	2700	
L-85	190-D	4500 HP Syn. Motors (to be added)				3600	4500	2700	3600	4500	2700	
L-86	190-D	4500 HP Syn. Motors (to be added)				3600	4500	2700	3600	4500	2700	
L-87	190-D	4500 HP Syn. Motors (to be added)				3600	4500	2700	3600	4500	2700	
L-88	190-D	4500 HP Syn. Motors (to be added)				3600	4500	2700	3600	4500	2700	
									28800	28,800 to 36,000	0 to 21600	

* Minus indicates a lagging power factor, plus indicates a leading power factor.

Table C. Maximum Loading on Transformer Bank #3 151-D Substation

LOAD ANALYSIS D-DR AREA

Present Loads (as of Nov. 30, 1955)

Tabulation of Operational Spares

BIDG.	LOAD	SERVICE	KW	KVA	KVAR
181-D	2-450 HP	River Pump	720	800	350
182-D	1-1000 HP	Export Pump	800	890	-390
	2-450 HP	Export Pump	720	800	-350
	1-400 HP	Condenser Pump	320	360	-150
	1-200 HP	Reservoir Pump	160	180	-80
183-D	1-700 HP	Process Pump	560	630	-270
	1-200 HP	Backwash Pump	160	180	-80
190-DN	2-800 HP	Process Pump	1050	1190	-500
190-D	1-800 HP	Process Pump	525	585	-250
		Totals	5015	5615	-2425

Tabulation of Total Area Loads

	KW	KVA	KVAR
Transformer Bank #1	14,400	15,970	-6645
Transformer Bank #2	17,945	19,930	-7750
Transformer Bank #3	---	---	---
	32,345	35,900	-14,395
	32,345	35,900	-14,395
Deduct Operational Spares	5,015	5,615	-2,425
Total Present Load	27,330	30,285	-11,970

Load recorded 11/30/55 - was 25,400 kw.

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Page 18LOAD ANALYSIS D-DR AREAPost CG-558 Loads

Tabulation of Operational Spares

<u>BLDG.</u>	<u>LOAD</u>	<u>SERVICE</u>	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>
181-D	2-900 HP	River Pump	1440	1600	-700
182-D	1-1000 HP	Export Pump	800	890	-390
	2-450 HP	Export Pump	720	800	-350
	1-400 HP	Condenser Pump	320	360	-155
183-D	1-700 HP	Process Pump	560	630	-270
	1-200 HP	Backwash Pump	160	180	-80
190-D	1-4500 HP	Process Pump	3600	4500	-2700
190-DR	1-4500 HP	Process Pump	3600	4500	-2700
	Totals		11,200		-1945 to -3455

Tabulation of Total Area Load	<u>Unity pf*</u>			<u>0.9 pf*</u>	
	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>	<u>KVA</u>	<u>KVAR</u>
Transformer Bank #1	23,560	23,900	-4335	24,400	-6465
Transformer Bank #2	26,950	27,400	-5210	27,600	-5590
Transformer Bank #3	28,800	28,800	0	36,000	-21,600
	79,310	79,800	-9545	86,150	-33,655
Operational Spares	11,200		-1945		-3,455
Total Expected Load	68,110	68,500	-7600	74,500	-30,200

*Power factor of each synchronous motor.

Feeder	Bldg	Load	Present			Planned Change				Planned Total		
			kw	kva	kvar	kw	kva	kvar	(Load to be removed)	kw	kva	kvar
L3	105-190-F	6-800 HP Process (to be Ltg. & Power removed)	3190	3550	-1440	3100	3450	-1400		90	100	-40
L15	182-F 183-F 184-F	1-1000 HP Export 4-200 HP Process (To be deactivated) 2-700 HP Process 1-200 HP Backwash 1-700 HP Process (To be added)	2620	3050	-1330	(Load to be removed) 80	90	-50		2540	2960	-1280
L16	181-F	3-450 HP Process 3-450 HP Process (To be added)	1080	1200	525	(Load to be added) 1080	1200	-525		2160	2400	-1050
L62 L64 L66 L68	190-F 190-F 190-F 190-F	4500 HP Syn. Motor 4500 HP Syn. Motor 4500 HP Syn. Motor 4500 HP Syn. Motor				3600 3600 3600 3600	4500 4500 4500 4500	f2700 f2700 f2700 f2700		3600 3600 3600 3600	4500 4500 4500 4500	f2700 f2700 f2700 f2700
			6890	7800	-3295	f12300	--	f925 to f11725		19190	19,300 to 21,000	-2370 to f8430

* Minus indicates a lagging power factor, plus indicates a leading power factor.

Table 7. Maximum Load on Transformer Bank #1 151-F Substation

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Feeder	Bldg	Load	Present				Planned Change				Planned Total		
			kw	kva	kvar		kw	kva	kvar		kw	kva	kvar
L1	189F	Light & Power	25	25	--		0	0	0		25	25	--
L2	105- 190F	Misc. Light & Power 6-800 HP Process	4620	5140	-2090		(Load to be removed) 3100	to be removed) 3450	-1400		1520	1690	-690
L5	161F	3-450 HP Process 1-450 HP Process (To be added)	1080	1200	-525		(Load to be added) 360	to be added) 400	- 175		1440	1600	-700
L4	182F 183F 184F	1-1000 HP Export 3-200 HP Process (To be deactivated) 2-700 HP Process 1-200 HP Backwash 1-60 HP Filter Water 1-700 HP Process) To be 1-300 HP H1 Tank) added.	2930	32850	-1430		(Load to be added) 320	to be added) 370	- 145		3250	3655	1575
L61 L63 L65 L67	190F 190F 190F 190F	4500 HP Syn. Motor 4500 HP Syn. Motor 4500 HP Syn. Motor 4500 HP Syn. Motor					3600 3600 3600 3600 (To be added)	4500 4500 4500 4500	42700 42700 42700 42700		3600 3600 3600 3600	4500 4500 4500 4500	42700 42700 42700 42700
			8655	9650	-4045		11980	--	41080 to 411880		20635	20800 to 22000	-2965 to 47835

* Minus indicates a lagging power factor, plus indicates a leading power factor.

Table 8. Maximum Loading on Transformer Bank #2 151-P Substation

LOAD ANALYSIS - F AREA

• Present Load (as of Nov. 30, 1955)

Tabulation of Operational Spares

<u>Bldg.</u>	<u>Load</u>	<u>Service</u>	<u>KV</u>	<u>KVA</u>	<u>KVAR</u>
182-F	2-1000 HP	Export Pump	800	890	-390
	1-400 HP	Condensate Pump	320	360	-155
	1-200 HP	Reservoir Pump	160	180	- 80
183-F	1-200 HP	Backwash Pump	160	180	- 80
			1440	1610	-705

Tabulation of Total Area Loads

	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>
Transformer Bank #1	6890	7600	-3295
Bank #2	8655	9650	-4045
	15545	17450	-7340
Operational Spares	1440	1610	705
Total Present Load	14105	15840	-6635

Load recorded 11/30/56 was 14,000 kw.

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LOAD ANALYSIS - F AREA

POST-CG-553 LOADS

Tabulation of Operational Spares

<u>Bldg.</u>	<u>Load</u>	<u>Service</u>	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>
151-F	1-450 HP	River Pump	360	400	-175
152-F	1-1000 HP	Export Pump	800	890	-390
	1-400 HP	Condensate Pump	320	360	-155
153-F	1-700 HP	Process Pump	560	630	-270
	1-200 HP	Backwash Pump	160	180	-80
190-F	1-4500 HP	Process Pump	3600	4500	-2700
			5800		-1070 to -1630

Tabulation of Total Area Loads

	<u>Unity p.f.*</u>			<u>0.8 p.f.*</u>	
	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>	<u>KVA</u>	<u>KVAR</u>
Transformer Bank #1	19190	19300	-2370	21000	-78430
Bank #2	20635	20800	-2965	22000	-7875
Operational Spares	39825	40200	-5335	42800	-16265
	5800		-1070		-1630
Total Expected Load	34025	34300	-4265	37000	-14635

* Power factor of each synchronous motor.

Feeder	Bldg	Load	Present			Planned Change			Planned Total		
			kw	kva	kvar	kw	kva	kvar	kw	kva	kvar
L1	105	1000/1250 KVA Bldg. Serv.	330	330	--	0	0	0	330	330	0
L3	190	4-800 HP (to be removed)	2100	2340	-1030	(Load to be removed) 2100	2340	-1030	0	0	0
L5	190	4-800 HP (to be removed) Sta. Serv. 300 KVA Trans.	2100	2440	-1070	(Load to be removed) 2100	2440	-1030	0	100	-40
L7	184	1000/1250 Transformers	490	540	-240	0	0	0	490	540	-240
L9	183	2-300 KVA Trans. Sta. Serv.									
		2-700 Process 1-700 Process (To be added) 1-300 H1 Tank (To be added) 1-200 Backwash	1540	1710	-170	(Load to be added) 800	910	-390	2340	2710	-1140
L11	182	1-1000 HP Export 4-200 HP Process (To be deactivated) 1-400 HP Condensate	1960	2170	-865	(Load to be removed) 640	720	-320	1320	1450	-545
L13	181	4-450 HP to be deleted 4-600 HP to be added	1440	1600	-700	(Load to be added) 480	560	-240	1920	2160	-940
L51	190	4-500 HP Syn. Motor				(Load to be added) 3600	4500	42700	3600	4500	42700
L53	190	4-500 HP Syn. Motor				3600	4500	42700	3600	4500	42700
L55	190	4-500 HP Syn. Motor				3600	4500	42700	3600	4500	42700
L57	190	4-500 HP Syn. Motor				3600	4500	42700	3600	4500	42700
			10050	11130	-4655	10840		41750 to 412550	20890	21050 to 22400	-2905 to 47895

* Minus indicates a lagging power factor, plus indicates a leading power factor.

Table 9. Maximum Load on Transformer Bank #1 151-H Substation.

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Feeder	Bldg	Load	Present			Planned Change			Planned Total		
			kw	kva	kvar	kw	kva	kvar	kw	kva	kvar
L2	105	1000/1250 KVA Trans.	400	400	0	0	0	0	400	400	0
L4	190	4-800 HP (remove) Sta. Serv. 300 KVA Trans.	2190	2440	-1070	(Load to be removed) 2190	2440	-1070	0	0	0
L6	190	4-800 HP (remove)	2100	2340	-800	(Load to be removed) 2100	2240	-850	0	100	-40
L8	183	3-700 HP 1-200 HP (Backwash)	1840	2070	-890	0	0	0	1840	2070	890
L10	182	1-1000 HP Export 5-200 (To be deactivated)	1600	1790	-790	0	0	0	1600	1790	-790
L12	181	4-450 (To be removed) 5-600 (To be added)	1440	1600	-700	(Load to be added) 960	1100	-475	2400	2700	-1175
L52	190	4500 HP Syn. Motor				3600	4500	42700	3600	4500	
L54	190	4500 HP Syn. Motor				3600	4500	42700	3600	4500	
L56	190	4500 HP Syn. Motor				3600	4500	42700	3600	4500	
L58	190	4500 HP Syn. Motor				3600	4500	42700	3600	4500	
			9570	10640	-4340	41160		41445 to 412245	20730	20940 to 22150	-2895 to 47905

• minus indicates a lagging power factor, plus indicates a leading power factor.

Table 10. Maximum Loading on Transformer Bank #2 151-H Substation

LOAD ANALYSIS - H AREA

Present Loads - (as of Nov. 30, 1955)

Tabulation of Operational Spares:

<u>Bldg.</u>	<u>Load</u>	<u>Service</u>	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>
181-H	1-450 HP	River Pump	360	400	-175
182-H	1-1000 HP	Export Pump	800	890	-390
	1-400 HP	Condensate Pump	320	360	-155
	1-200 HP	Reservoir Pump	160	180	- 80
183-H	1-700 HP	Process Pump	560	630	-270
	1-200 HP	Reservoir Pump	160	180	- 80
190-H	1-800 HP	Process Pump	525	585	-250
			2885	3225	-1400

Tabulation of Total Area Loads

	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>
Transformer Bank #1	10050	11130	-4655
Transformer Bank #2	9570	10640	-4340
	19620	21770	-8995
Operational Spares	2885	3225	-1400
Total Present Loads	16735	18545	-7595

Load recorded 11/30/55 was 16,600 kw

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LOAD ANALYSIS - H AREA

POST CG-558 LOADS

Tabulation of Operational Spares

<u>Bldg.</u>	<u>Load •</u>	<u>Service</u>	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>
181-H	1-600 HP	River Pump	480	540	- 235
182-H	1-1000 HP	Export Pump	800	890	- 390
	1-400 HP	Condensate Pump	320	360	- 155
183-H	1-700 HP	Process Pump	560	630	- 270
	1-200 HP •	Backwash Pump	160	180	- 80
190-H	1-4500 HP	Process Pump	3600	4500	/2700
			5920		-1130 to /1570

Tabulation of Total Area Loads

	Unity p.f. *			0.8 p.f. *	
	<u>KW</u>	<u>KVA</u>	<u>KVAR</u>	<u>KVA</u>	<u>KVAR</u>
Transformer Bank #1	20890	21050	-2905	22400	/ 7895
Transformer Bank #2	20730	20940	-2895	22150	/ 7905
Operational Spares	41620 5920	42000	-5800 -1130	44500	15800 - 1570
Total Expected Load	35700	36000	-4670	38300	/14230

* Power factor of each synchronous motor.

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After completion of project CG-558 the total 100-B-C area load was calculated to be 66,470 kw after deducting the most probable operating spares. The seven synchronous motors which will normally be operating can produce 18,900 reactive kva with maximum excitation on the field, i.e., 0.8 leading power factor. This is sufficient to offset most of the inductive (lagging power factor) load requirements in the area. The corresponding total of transformer loadings will be 66,470 kva. If the field excitation of the synchronous motors were reduced to 1.0 power factor, all inductive loads would be supplied through the transformers and the total kva load for the area would increase to 68,600 kva. These loadings require all three transformers to be in service during normal operation of both reactors. Transformer outages for servicing will have to be scheduled to coincide with reactor shutdown periods.

It should be noted that transformer bank #3 may carry maximum kilowatt load of 32,590 kw. The reactive adjustment can produce loading as high as 33,400 kva, an overload of seven percent. Since one 3500 hp induction motor and one 4500 hp synchronous motor are usually held in reserve, overloading of the transformer can be prevented by selecting these spare units from the motors connected to transformer bank #3. Loadings on this transformer bank are discussed in considerable detail in document HW-40572.¹

4.2.2 100-D-DR Area

The present load in the 100-D-DR area is carried by two transformer banks, and a third bank is being installed during Project CG-558 modifications. The existing load was calculated to be 27,330 kw after deducting the most probable operating spares. This agrees reasonably well with the recorded load of 25,400 kw. The total loading of 30,285 kva for the area can be carried by one transformer bank based on its fan-cooled rating of 31,250 kva.

After completion of project CG-558, the total D-DR area load was calculated to be 68,110 kw after deducting the most probable operating spares.

The leading reactive kva supplied by 14 synchronous motors can be varied from zero to 37,800 kvar by adjustment of the field excitation. Since 100-DR area has a low ratio of inductive to synchronous load, the major portion of this leading kva will be utilized in other areas. The total area load will vary

¹ Baker, DS, "Operation of Synchronous Motor: Effect of Excitation on Hanford Electrical System" HW-40572, May 1956 (Unclassified)

from 68,500 kva to 74,500 kva as the motor field excitation is increased from minimum (1.0 pf) to maximum (0.8 leading pf).

With one transformer out of service, the anticipated area load of 68,110 kw would exceed the ratings of the two remaining transformers. The 100-D to 100-H tie Line described in section 5.4 has adequate capacity to carry two synchronous motors, so that the total area load could be reduced by 7200 kw. The resultant load of 60,910 kw at unity (1.0) power factor is approximately equal to 62,500 kva, the combined rating of two transformers, and could possibly be carried by them. This possibility would have to be verified by actual loadings measured on the transformers during normal operation.

Transformer capacity adequate for the two motors will normally be available from either transformer bank at 100-H area.

By scheduling transformer and circuit breaker maintenance outages to coincide with normal reactor shutdown periods, the problem of normal operation with two transformer banks could be avoided.

Transformer bank #3, which is currently being installed, is scheduled to feed eight synchronous motors, four each serving D and DR areas. When all motors on this bank are running, the kilowatt load will be 28,800 kw. If the motors are fully excited at 0.8 leading power factor, the transformer will be carrying 36,000 kva, an overload of 15 percent. Therefore the full reactive output of eight motors cannot be obtained if all are connected to the transformer. The transformer loading with seven motors operating at rated excitation (0.8 leading pf) will be 32,500 kva. Eight motors can be operated with excitation reduced to 0.92 leading power factor without exceeding the rating of the transformer.

4.2.3 100-F Area

The present load in 100-F area was calculated to be 14,105 kw after deducting the most probable operating spares. This figure agrees closely with the load of 14,000 kw recorded for the area.

After completion of project CG-558, the increased area load is calculated to be 34,025 kw after deducting the operational spares. Motor field excitation can be varied to produce from zero to 13,900 reactive kva. Since 100-F area has a small ratio of inductive to synchronous load, the major portion of the reactive supply will be utilized in other areas. The total area load will vary from 34,300 kva to 37,000 kva as the field excitation is increased from minimum (1.0 pf) to maximum (0.8 leading pf). Normal operation of the reactor is expected to require two transformer banks to be in service.

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4.2.4 100-H Area

The present load in 100-H area was calculated to be 16,735 kw after deducting the most probable operating spares. These figures agree closely with the load of 16,600 kw recorded for the area.

The increased area load after completion of project CG-558 was calculated to be 35,700 kw after deducting the operational spares. Motor field excitation can be varied to produce from zero to 18,900 reactive kva. Since 100-H area has a small ratio of inductive to synchronous load, the major portion of the reactive supply will be utilized in other areas. The total area load will vary from 36,000 kva to 38,300 kva as the field excitation is increased from minimum (1.0 pf) to maximum (0.8 leading pf). For normal operation of the reactor it is expected that the load will require two transformer banks to be in service.

With one transformer out of service, the anticipated area load of 35,700 kw would exceed the rating of the remaining transformer. If two synchronous motors received power over the 100-D-100-H tie line, the resultant area load of 28,500 kw would be within the rating of one transformer. Transformer capacity adequate for these two motors will normally be available at 100-D Area, but their loadings should be checked to determine which bank has sufficient capacity to carry the increased load.

5.0 EFFECTS OF VOLTAGE REDUCTIONS DURING STARTING OF 4500 HP SYNCHRONOUS MOTORS

Starting a 4500 hp synchronous motor across the line, i.e., by applying full voltage, produces an inrush current approximately six times rated current or nearly 1200 amperes. Since the starting power factor is approximately 11 percent, a substantial drop in terminal voltage will result. Approximately 96 percent of this voltage drop is across the 230/13.8 kv primary transformer and the remaining four percent drop is across the secondary feeder cables.

5.1 Motor Starting from One Transformer

Figure 1 shows a plot of voltage regulation vs the starting kva of the synchronous motors for a range of initial transformer loads for starting with a single transformer bank. Initial loads consist of miscellaneous induction motors, lighting and power loads exclusive of synchronous motor loads, and are assumed to operate at an average power factor of 90 percent lagging. The curves are plotted for the successive starting of synchronous motors and with the transformer loaded initially to 0, 20, 40, 60, and 80 percent of the 31,250 kva transformer rating. The load of each synchronous motor operating in synchronism at full speed, is taken at 3600 kw, and 2700 kvar leading, corresponding to rated excitation of the motors. The actual conditions during starting may vary slightly from these assumptions, but such variations would not change the voltage drops noticeably.

Figure 1 indicates that the maximum voltage drop is 14.3 percent when the first synchronous motor is started on one transformer bank. This was confirmed by field observation when the first unit was started at 190-B building in December 1955. The voltage was depressed from 13,800 volts to 11,700 volts or 15 percent. The voltage drop during starting is not affected appreciably by the magnitude of the load already carried by the transformer. This voltage drop does, however, increase rapidly if the power factor of the resultant load lags below unity power factor. In other words there will be less voltage change if the initial load includes synchronous motors running at a leading power factor; and the starting of succeeding motors will result in a lesser voltage drop as indicated in Figure 1.

5.2 Motor Starting From Two Paralleled Transformers

From both calculation and actual measurement the voltage drops 7-8 percent when one 4500 hp motor is started from two primary transformers connected in parallel. Figure 1 shows a plot of voltage regulation vs starting KVA for a range of initial transformer loads for two transformers in parallel. The curves are plotted in the same manner described in the preceding section. The largest voltage drop will be experienced when starting the first motor. Starting of succeeding motors will cause smaller drops because the synchronous motor improves the power factor of the transformer load. With a smaller voltage drop, the acceleration of the motors will be slightly faster.

The greatest advantage of paralleling two transformers will occur if a group of 4500 hp motors are to be started in sequence at a time when the Bonneville system voltage is at its minimum, equivalent to 13000-13200 secondary circuit voltage. In this case the voltage before starting a motor might be a little below the rated voltages of the various motors (13,200, 4160 or 2300), but with two transformers the net voltage at the motor terminals during starting would still be about 90 percent of rated voltage or higher. This is recognized by AIEE Standards as an allowable condition for continuous operation, and is therefore conservative as a temporary condition during motor starting.

Determination of paralleling two transformers is, of course, within the province of the Manufacturing Department, and involves other considerations such as the ability of switchgear to withstand the greater short-circuit current which could flow from the combination of two transformers.

5.3 Effect of Voltage Drop on Plant Electrical Equipment

The drop in voltage during the starting of a 4500 hp synchronous motor ranges between 7-15 percent and lasts 30-35 seconds. The effect of this voltage drop on system voltage-sensitive devices is discussed in the following paragraphs.

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5.3.1 Undervoltage Relays

- (a) Reactor Scram Circuits - In the reactor scram circuits at 105-B, C, D, DR, F, and H, definite-time undervoltage relays monitor the voltage on each incoming line to the building, the 151 substation bus voltage (these relays are located in the 190 buildings) and the horizontal rod power supply at 105 C and H only. These relays are set to drop out at 65 percent of normal voltage and will scram the reactor after a 15-17 cycle time delay, i.e., a fraction of one second.

- (b) Motor Feeder Undervoltage Relays - Undervoltage relays located at the 151 buildings will trip the synchronous motors. These relays have inverse-time characteristics and will trip the motors in 10-20 seconds if the voltage decays to 77 percent of normal (tap setting 93 volts).

The relays will trip in a shorter time for greater drop in voltage, with a minimum trip time of 1/2 second with complete loss of voltage.

- (c) Voltage relays at other locations - Voltage relays at other locations in the area will, in general, not be affected until the voltage falls to 80 percent of normal voltage or lower.

5.3.2 Pile Beckman Monitor Instruments

When the first synchronous motor was started at 190-B the voltage drop caused tripping of a Beckman instrument at 105-B. The investigation that followed this incident revealed that due to circuit conditions, the instrument was operating initially at 105 volts. The drop in voltage due to starting the motor caused the instrument voltage to drop below 90 volts which is the limit of stability for instruments of this type. Subsequent changes in the field have corrected this condition so that the instruments normally have 120 volts applied. Starting from 120 volts, a 15% reduction leaves 104 volts, which is safely above the minimum value of 90 volts.

5.3.3 Miscellaneous Electromagnetic Devices

Examples of devices in this category are contactors, relays and motor control equipment. These devices generally pick up on 70-80 percent of rated voltage and drop out at 50-60 percent of rated voltage. These devices should not be affected by a 15 percent voltage drop.

5.3.4 Effect on Other Motors

If a sequence of 4500 hp motors at B-C areas are started on one transformer which also feeds some of the 3500 hp induction motors at 141-C building, such motors will have to operate at

about 85% of normal voltage during a series of short intervals. Although the 190-C motors are said to be closely rated temperature-wise, no adverse effects are anticipated.

Specifically:

- a) The 190-C motors have sufficiently high maximum running torque, plus very low full-load slip, so that almost no change of speed and no danger of torque breakdown will result from 15 percent voltage reduction.
- b) Although primary current will increase by about 17 percent the additional heating effect during 30-35 seconds starting time of the new synchronous motors will be minor.
- c) If the 4500 hp motors are started at intervals of a few minutes instead of in quick succession, the operation of the 3500 hp motors below normal voltage should not cause any significant increase in heating of these motors.

5.4 Motor Starting Over 151-D to 151-H Tie Line

Between the 151-D and 151-H substations, there is a tie line connecting the 13.8 kv buses. The line consists of approximately 3.5 miles of double circuit 13.8 kv construction with #4/0 copper conductors. The line is connected to the 151-D and 151-H substation buses by 215 feet and 180 feet, respectively, of 750 MCM cable run in underground duct. The line has a nominal rating of 12,000 kva at 0.8 power factor and could be used to carry the running load of two synchronous motors.

If a 4500 hp synchronous motor in one area were to be started over the tie line, backed up by only a single transformer bank in the other area, the voltage drop at the terminals of the motor would be 25%. This voltage drop exceeds the limits of good practice. If the tie line were backed by two transformers, the total drop would be approximately 20%. The bus voltage is normally about 13.8 kv, which is 105% of the 13.2 kv nameplate rating of the 4500 hp motors. Under these favorable conditions a motor starting from the tie line would have at its terminals about 85% of its rated voltage. (The original specifications called for successful starting at 85% of rated voltage.) Thus it appears feasible, under the conditions stated above, to start a 4500 hp synchronous motor with power transmitted from the other area via the tie line. The starting of the second motor would be easier since the first motor could supply a portion of the reactive current required during the starting cycle.

6.0 SWITCHGEAR CAPACITY

The electric power supplied through the primary transformers is transformed from 230 kv to the 13.8 kv distribution voltage and distributed to the load centers in each area by the 13.8 kv switchgear at the 151

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substation in each area. Since the original installation was completed, these switchgear installations have been modified by the various expansion projects such as the 100-DR water plant, the 100-C water plant, the 100-H area and now the project CG-558 Reactor Plant Modifications. The ratings and capabilities of these switchgear installations differ from area to area and it is necessary to examine each installation to determine whether these ratings will be exceeded, especially the current-interrupting rating.

To determine whether the ratings are adequate for the post-CG-558 loads it is necessary to determine the maximum current or kva which can flow during an assumed short circuit. For a fault or short circuit on a 13.8 kv distribution feeder, current will flow from two sources, the BPA system and the synchronous motors. The BPA system will contribute a maximum of 180,000 kva to the 13.8 kv distribution system through one transformer bank, and 342,500 kva with two transformers paralleled. Each synchronous motor will contribute, at most, 13,200 kva to a fault of this type. A three phase "bolted" fault was assumed in order to determine the maximum duty which might be imposed on the breakers.

6.1 100-B-C Area

6.1.1 Switchgear Ratings

The original installation at 151-B substation included two incoming lines and six distribution feeders each consisting of two breakers per feeder. This equipment is Westinghouse metal-clad switchgear with type B oil circuit breakers which are rated 15 kv and 250,000 kv maximum interrupting capacity.

Additions in 1951 and 1955 included the installation of one incoming line and five distribution feeders each consisting of two breakers per feeder; 18 feeder breakers for the eight 4500 hp synchronous and the ten 3500 hp induction motors; and two bus tie breakers. This equipment is Westinghouse metal-clad switchgear with type 150-DR-500A air circuit breakers rated 13.8 kv, and 500,000 kva maximum interrupting capacity.

6.1.2 Interrupting Duty

With transformer bank #1 or 2 in service, the original equipment will normally have two synchronous motors connected. The maximum fault kva will be 206,400 kva, well within the 250,000 kva rating.

With transformer bank #3 in service, the new equipment will normally have four synchronous motors connected. The maximum fault kva will be 232,800 kva, which is within the 500,000 kva rating. Bus tie breakers will normally be open so that none of the original equipment is energized by Bank #3. A simplified one-line diagram of 151-B substation showing fault kva sources is shown in Fig. 2.

With transformer banks #1 and 2 in parallel, the original equipment will now have two fault kva sources from BPA, as well as four motors connected. The maximum fault kva will be 395,300 kva, which is greater than the switchgear rating of 250,000.

With transformer banks #1 and 3 or #2 and 3 paralleled, six motors will contribute to a fault, for a maximum of 421,700 kva. This exceeds the rating of 250,000 kva for the original equipment, but is within the rating of 500,000 kva for the new equipment.

The current interrupting ratings will not be exceeded on any breakers when operated from one transformer bank. However, the ratings of the breakers in the original installation could be exceeded when operating with any two transformer banks in parallel if a maximum short circuit should occur within circuits served by one of these older breakers.

6.2 100-D-DR Area

6.2.1 Switchgear Ratings

The original installation at 151-D substation included two incoming lines and 14 distribution feeders each consisting of two breakers per feeder. This equipment is Westinghouse metal-clad switchgear with type B oil circuit breakers rated 15 kv and 250,000 kva maximum interrupting capacity.

The Project CG-558 addition in 1955 included the installation of an incoming line and a tie line feeder to 100-H, each consisting of two breakers per feeder as well as feeder breakers for the eight 4500 hp synchronous motors and two bus tie breakers. This equipment is I-T-E Company metal-clad switchgear with type 15HV-500 air circuit breakers rated 13.8 kv and 500,000 kva maximum interrupting capacity.

6.2.2 Interrupting Duty

With either transformer bank #1 or 2 in service, the original equipment will normally have four synchronous motors connected. The maximum fault kva will be 232,800 kva, which is within the 250,000 kva rating of the switchgear involved. A simplified one-line diagram of 151-D substation showing fault kva sources is shown in Fig. 3.

With transformer bank #3 in service, the new equipment will normally have eight motors connected. The maximum fault kva will be 285,600 kva which is within the breaker rating of 500,000 kva. The bus tie breakers will normally be open so that no original equipment is energized by bank #3.

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[REDACTED]

With transformer banks #1 and 2 in parallel, the original equipment will now have two fault kva sources from BPA and eight motors connected. The maximum fault kva will be 448,100 kva which is considerably greater than the breaker rating of 250,000 kva.

With transformer banks #1 and 3 or #2 and 3 in parallel there will be two fault kva sources from BPA and 12 synchronous motors connected. The maximum fault kva will be 500,000 kva which is considerably greater than the breaker rating of 250,000 kva.

The current interrupting ratings will not be exceeded on any breakers when operated from one transformer bank. However, the ratings of the breakers in the original installation could be exceeded when operating with any two transformer banks in parallel should a maximum short circuit occur within circuits served by one of these older breakers.

6.3 100-F Area

6.3.1 Switchgear Ratings

The original installation at 151-F substation included two incoming lines and 12 distribution feeders each consisting of two breakers per feeder. This equipment is Westinghouse metal-clad switchgear with type B oil circuit breakers rated 15 kv and 250,000 kva interrupting capacity.

The new equipment included the installation of eight feeders for the 4500 hp synchronous motors. This equipment is General Electric Company metal-clad switchgear with type AM-13.8-500 air circuit breakers rated 13.8 kv and 500,000 kva interrupting capacity.

6.3.2 Interrupting Duty

With either transformer bank in service, each bus will normally have four motors connected. The maximum fault kva will be 232,800 kv which is within the 250,000 kva rating of the original breakers.

With the two banks in parallel, the equipment will have eight motors connected to the same bus. The maximum fault kva will be 448,100 kva which is considerably greater than the breaker rating of 250,000 kva but within the rating of 500,000 kva. A simplified one line diagram of the 151-F substation showing fault kva sources is shown in Fig. 4.

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The current interrupting ratings will not be exceeded on any breaker when operated from one transformer bank. However, the ratings of the breakers in the original installation could be exceeded when operating with the transformer banks in parallel if a maximum short circuit should occur within circuits served by one of these older breakers.

6.4 100-H Area

6.4.1 Switchgear Ratings

The original installation at 151-H substation included two incoming lines and 15 distribution feeders each consisting of two breakers per feeder. The new equipment now being installed under project CG-558 includes two bus tie breakers and two feeder breakers for 4500 hp motors. All of the equipment is General Electric Company metal-clad switchgear with type AM-13.8-500 air circuit breakers rated 13.8 kv and 500,000 kva interrupting capacity.

6.4.2 Interrupting Duty

With either transformer bank in service, each bus will normally have four motors connected. The maximum fault kva will be 232,800 kva which is within the breaker rating of 500,000 kva.

With the two banks in parallel, the connected equipment will have eight motors to the same bus. The maximum fault kva will be 448,100 kva which is within the breaker rating of 500,000 kva. A simplified one line diagram of the 151-H substation showing fault kva sources is shown in Fig. 5.

The current interrupting ratings of all breakers in the substation are adequate for parallel operation of two transformers.

6.5 Summary of Interrupting Ratings

Review of the preceding paragraphs reveals that current-interrupting ratings will not be exceeded on any breakers when operated from one transformer bank. However, with the exception of 100-H Area, the ratings of the older breakers in the installation could be exceeded when operating with two transformer banks in parallel if a maximum short circuit should occur within the leads controlled by one of these older breakers. At 100-H area the ratings of all breakers are adequate for parallel operation of two transformers.

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7.0 RECOMMENDATIONS

7.1 Parallel Operat.on of Transformers

The desirability of paralleling primary transformers to reduce voltage drop during motor starting is tempered by the increase of the possible short circuit current which exceeds the ratings of some of the older breakers. Further study is needed to determine equipment modifications which would best resolve this problem, but the following approaches can be suggested:

- 7.1.1 Transformers may be paralleled while starting the large motors, but separated for continued operation. This merely continues the practice which must be followed in switching electric loads from one transformer to another.
- 7.1.2 Re-arrange equipment so that each of the lower-capacity feeder breakers would be protected by a main-line breaker of larger capacity. The lower-capacity breaker could then be arranged to remain closed momentarily, in event of a short-circuit, which would be cleared by the larger breaker. Cascade operation of this type is commonly used where high concentrations of power exists.
- 7.1.3 Any further major plant modifications to increase reactor output will undoubtedly require further transformer capacity. At such time the lower-capacity breakers will clearly need replacement. A survey looking towards such changes is timely.
- 7.1.4 The possibility of obtaining contact assemblies of higher interruptive capacity for some of the present breakers merits investigation.

7.2 Experience with Fans for Transformer Cooling

As mentioned earlier in this report, the cooling fans and motors are of a design which has been built and applied successfully in large quantities by the manufacturer. Nevertheless it would be advisable to build up a background of operating experience with these fans before the completion of the CG-558 project requires the higher transformer ratings which depend on forced cooling. It is assumed that adequate spares will be available for replacement of defective fans.

7.3 Arrangement of Synchronous Motor Loads

- 7.3.1 At 100-B Area transformer #3 will be loaded slightly beyond the maximum fan-cooled rating by the projected loading. Consideration should be given to diverting some of this load to transformer #1 or #2 which will be less heavily loaded.

- 7.3.2 At 100-D, transformer #3 will be overloaded by eight synchronous motors if they are operated at full excitation to deliver their full capability of leading reactive kva. Rather than sacrifice this capacity, better balance is obtainable if part of this load can be diverted to transformer #1 or #2.

7.4 Spare Capacity of Transformers

- 7.4.1 In each area covered by the CG-558 project all of the primary transformers are needed for full-capacity operation of the reactor plants. As pointed out above, one transformer of the same rating is available as a spare in the 200 Area and has been considered as a possible replacement for emergency use in the 100 Areas. This unit has the full complement of 16 radiators, but does not have any fans installed.
- 7.4.2 The increased loads will make full plant operation dependent on forced cooling of the transformers. This has not been the case until now. As load increases develop, it is assumed that initial operation of the transformers will be observed closely to insure that safe temperatures are not exceeded; this applies particularly to the older transformers which will not have the manufacturer's guarantee behind the maximum fan-cooled rating.
- 7.4.3 The 230 volt circuits for the transformer-cooling fans are sufficiently isolated from the high-voltage parts, so that defective fans could be replaced during normal operation. However, operating practice will presumably determine whether fans may be replaced while the transformer is energized. Since the only spare primary transformer is in the 200 Area, this point merits consideration.
- 7.4.4 A study at this time could determine a transformer rating to be standardized as further capacity increases may be required. The 100-K Areas now use transformers rated 30,000/40,000/50,000 kva, which might prove a desirable size. Recognizing that delivery time on large transformers is very long, consideration might be given to getting additional capacity on order. Each such unit would effectively double the capacity of the present primary transformers, and thereby create a much more flexible situation in spare units.

8.0 ACKNOWLEDGEMENT

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FIGURE 2. 151-B SUBSTATION

FIGURE 3. 151-C SUBSTATION

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FIGURE 4. 151-F SUBSTATION

FIGURE 5. 151-H SUBSTATION

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