M-139

OFFICE MEMORANDUM • STANFORD UNIVERSITY

DATE: November 14, 1959

To : Bill Kirk

FROM : Jane Post

SUBJECT:

I am enclosing herewith the ditto masters and all extra copies of the report by Dr. Neal on the changes in the last review by John Blume Associates and copies of the report itself which are attached. I have distributed copies of same to the following people:

Ginzton
Neal
Panofsky
C. Jones
Turner
Edwards
Goerz
Lebacqz
Snyder
Copenhagen

cc: Dr. Neal

FILE COPY
PROJECT M

November 9, 1959

To: Project M Files

From: R. B. Neal

Subject: Review by John A. Blume & Associates

A list of 40 questions was prepared by W. M. Brobeck (whose firm is serving as consultant to Blume). These were discussed at several meetings among Blume, Brobeck and Stanford personnel and the Check List of Specifications dated 10/30/59 was issued by Brobeck as a summary of these discussions.

The following comments are intended to elaborate upon some of these specifications as given by Brobeck in his 10/30/59 memorandum. It should be emphasized throughout that these specifications were set down for purposes of cost estimating and do not necessarily represent final design commitments.

a) Item 1: The 40 guns (one for each 250 foot sector) will be used for phasing purposes and for operation when low energy beams are required.

b) Item 13: The maximum water pressure for the klystrons has been reduced to 100 psi. The output temperature must be held to 75° C maximum.

c) Item 14: It is quite possible that thyratron or ignitron switching tubes will be used instead of spark gaps. However, cost estimates will continue to be predicated upon the use of spark gaps. The air supply will probably be less expensive if divided into independent sectors and if exhausted to atmosphere rather than recirculated.

d) Item 17: Inflectors at the 250 ft. points are no longer specified. The hollow cathode guns replace them.

e) Item 18: 45 Bev magnets were called for in the earlier version. This rating has been changed to 25 Bev since this is higher than the maximum no-load energy (24 Bev) expected during Phase I operation.

f) Item 21: Cost estimates of the vacuum system will be predicated upon the design shown in the original Brobeck review. However, for purposes of comparison, costs of a vacuum system with the main high vacuum pumps in the accelerator tunnel will be obtained. The former system (main pumps in klystron tunnel and transverse manifolds between tunnels) is considered preferable from the point of view of operation and maintenance.

g) Item 23: 82 gal/min. would be indicated per 10 feet of accelerator pipe on the basis of extrapolating the figures given in the original Stanford proposal to the new rf average power specifications (21.6 kw in Stage II). A calculation based on a 2° C temperature rise of the cooling water shows that 41 gal/min. are required. In Stage I, the power from each klystron will be split 4 ways so that only about 10 gal/min. will be required per 10 foot accelerator section. The tunnel cooling water system pipe sizes should be established on the basis of 40 gal/min. per 10 foot section but the cooling tower, recirculating pump requirements etc. should be based on 10 gal/min. per section with provisions for later additions as needed in Stage II. The cooling water system should be divided into sectors if this proves to be more economical.

h) Item 27: This is a change from the original Brobeck specification which gave required atmosphere in tunnel as 74° F dry bulb, 45% relative humidity, 200 men in tunnel, 1/3 air change per hour minimum, and dust-free air supply.

i) Item 31: A 10-foot accelerator section for each of 10 test cells will probably not be desired but other equipment needed will likely be of equivalent cost.

j) Item 35: The question of using inflammable insulating fluids in the tunnels has not yet been settled. Blume Associates will look into the cost of equipment needed for reducing or containing fire hazards.

k) Item 38: These beam elevations are somewhat different from the numbers previously used which were 3 feet to floor in the accelerator tunnel, 5 feet in the switch yard and end station, and 8 feet in the spectrometer area. The increased height (4 feet) in the accelerator tunnel is to allow greater maximum tunnel offset (due to drift or to earthquakes) and to improve ease of installation. The increased height in the switchyard, etc. (to 8 feet) is to accommodate larger magnets and supporting structures.

The feasibility of locating the D.C. supplies for the klystron modulators outside the tunnel is being investigated by Blume-Brobeck. They suggest that this might result in substantial savings in tunnel and air conditioning costs, and might also allow for easier operation and maintenance of the supplies. Several alternate plans are possible: 1) all the supplies might be located at the target end, 2) the supplies might be broken up into 3 groups such that one group would be at the gun end, one in the center, and one at the target end of the klystron tunnel (all 3 groups external to the tunnel), or 3) the supplies might be dispersed so that each supply would be located directly above the section of tunnel which it services. Relative costs of cabling and housing are important in making a choice among these alternatives.

RBN:jp

WILLIAM M. BROBECK & ASSOCIATES

STANFORD LINEAR ACCELERATOR
Job: 200-58-R
By: WMB
Page 1
Date: 10/30/59

Check List for Specifications Of Two-Mile Linear Accelerator As of October 1959

* Indicates changes from Brobeck Report of June 1958

1.* There are 39 hollow cathode electron guns along accelerator in addition to the main injector.

2.* The Klystron factory is not required. Klystrons will be obtained from commercial suppliers. A Klystron research facility of approximately 4000 sq. ft. will be required.

3.* Maximum DC power input to Klystron tubes:
17.5 MW for Stage I
71.0 MW for Stage II
Rectifier efficiency assumed - 95%. Modulator efficiency assumed - 90%.

4.* 240 Klystrons for Stage I and 960 Klystrons for Stage II. (This will require a change in the original equipment layout which was based on 920 Klystrons.)

5.* Maximum beam energy of Stage I unloaded - 24 Bev; loaded - 22 Bev. Stage II - 48 and 44 Bev.

6.* Average beam current 15-30 microamps for Stage I; 30-60 microamps for Stage II.
Average beam power 0.3-0.6 MW for Stage I; 1.2-2.4 MW for Stage II.

7.* RF pulse length to be 2.5 microseconds.

8.* The maximum pulse repetition rate is to be 360 pulses per second for both Stage I and Stage II and for all outputs from 6 MW to 24 MW peak RF per Klystron.

9. The accelerator length is to be 10,000 ft. 10 ft. per section (250 ft.) to be reserved for auxiliary equipment.

10. For requirements of Stage II beyond those of Stage I:
Wiring to and including disconnecting means, piping to and including shut-off valves, tunnel space and building sites are to be provided. Equipment is not to be provided except as required to permit change-over as specified in Item 16.

11.* Klystron cubicle auxiliary power requirements:
Misc. auxiliaries:

Klystron heaters: 400 Watts maximum, 250 Watts Normal.
Sector supply continuously variable from 30 to 100% voltage.
Voltage at cubicle to be held constant ± 2% of any set value.
Klystron focusing by means of permanent magnets.

12.* Klystron high voltage DC range 19.5-30.7 KV. Adjustable in 5% steps by tap changing with ± 5% induction regulator. One power supply to be used for each 24 Klystrons.

13.* Klystron cubicle cooling water requirement: 5 GPM demineralized water; pressure drop - 50 psi; 43 KW dissipation. Supply temperature may vary from 70 F to 90 F or may exceed 90 F if more economical. Maximum pressure - 200 psi.

14.* Klystron spark gap air requirement:
50 CFM - 5 psi drop through load; clean not saturated air.
Heat to air - 1 KW/gap. Suggest a separate supply and exhaust to outside for each 250 ft. section. Corrosion due to ozone should be checked.

15. Series tube (possibly a triode) to be used to limit pulse line charging current and to prevent reverse power flow.

16. Changes from Stage I to Stage II are to be accomplished without interruption of operation for more than a few hours at a time.

17.* Phase adjustment as described in Brobeck Report, i.e.
Slotted lines between adjacent cubicles;
Phase meters to compare voltages on probes of adjacent slotted lines;
Hollow cathode gun and deflector for each 250 ft. sector.

18.* There are to be 3 bending and 3 quadruple magnets to produce 2 left-hand deflected beams of 25 Bev for Stage I. No magnets for right hand deflection included.

19. Space provision is to be made for 200 and 600 ft. radius spectrometers.

20. Focusing, degaussing and steering requirements are unchanged since the Brobeck Report. (Described in Appendix I - p 10)

21. (Vacuum System Specs. still being discussed)

22.* The Klystron cubicle heat loss to air is dependent upon the water temperature level - to be determined by engineers.

23.* The accelerator pipe cooling water flow is to be 40 gal/min with temperature rise of 2 C** for each 10 ft. section. Supply temperatures are to hold within ± 1 F of constant temperature over the entire length. The operating temperature of supply is to be selected on the basis of economics.

** Approximate

24.* The Klystron maximum peak RF output is to be 24 MW.

25.* In the end station there are to be switchgear and distribution system for 2650 KW miscellaneous experimental power plus 3900 KW AC supply to the motor generator sets. (MG sets are not included.)

26. A demineralized water cooling system is to be provided for power specified under Item 25.

27. The required atmosphere in the tunnel is to be of general comfort for personnel. There will be 200 men in the tunnel during construction and 40 men or less during operation.

28. End station building:
    400 x 500 feet.
    55 ft. floor to highest position of crane hooks.
    Floor area covered by 100 ton cranes with 15 ton auxiliaries.
    Floorload capacity 2500 lbs/ft^2 except where required by primary shielding.
    Provision for three beams on 106 and 161 ft. spacing.

29. End station shielding:
    Transverse to beam 35 ft. of earth of 112 lbs/ft^3 or equal.
    In line with beam 45 ft. of earth of 112 lbs/ft^3 or equal.

30. Any structures required on the surface above the tunnel must not adversely affect the value of property for residential purposes. No objectionable noise should be produced.

31. There are to be 10 Klystron life test stands and 10 component test cells each comprising one Klystron and a 10 foot section of accelerator pipe are to be provided.

32. Special ventilation or air conditioning is required in:
    Control rooms
    Electronic (RF) research rooms
    Accelerator pipe electroforming room
    Klystron disassembly rooms
    Gauge room (approx. 2000 ft^2)

33. Beam stops are to be provided for three deflected beams. Beam stops consist of concrete blocks 50 x 50 ft. in plane and extending 25 ft. above the plane of the beam or cyclinder of steel 10 ft. in diameter, 30 feet long and 6 feet in diameter with a 9 foot tapered extension. (Fig. II-C-3 of Stanford 1957 proposal.)

34.* A test accelerator 160 ft. long powered by 4 Klystrons with power supplies of Stage II repetition rate, pulse length and peak output is to be included.

35.* The Klystron modulators use transformer oil as insulation. The power transformers are air cooled.

36. A single PG&E power circuit is adequate.

37. Emergency power must be available to supply electrical power and cooling to vacuum pumps**, lighting, fire protection, communication and electroforming tanks in case of general power failure. Some transportation equipment should also be kept operable during power failure.

38.* Centerline of beam clearance is as follows:
    In tunnels - 4 ft. to floor.
    In switchyard and end station - 8 ft. to floor.
    In 600 ft. spectrometer area - 8 ft. to future floor.

39.* Convenience outlets in Klystron tunnel approx. 1 KW per 10 ft.

40.* RF terminating load at end of each 10 ft. section - one-third of RF power dissipated in load.

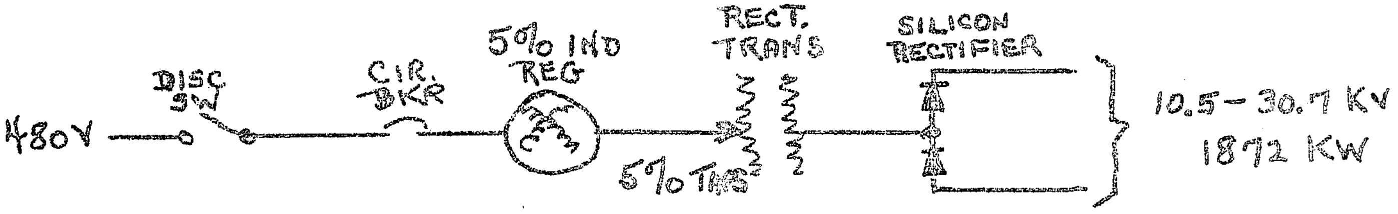
** Not incl. roughing pumps

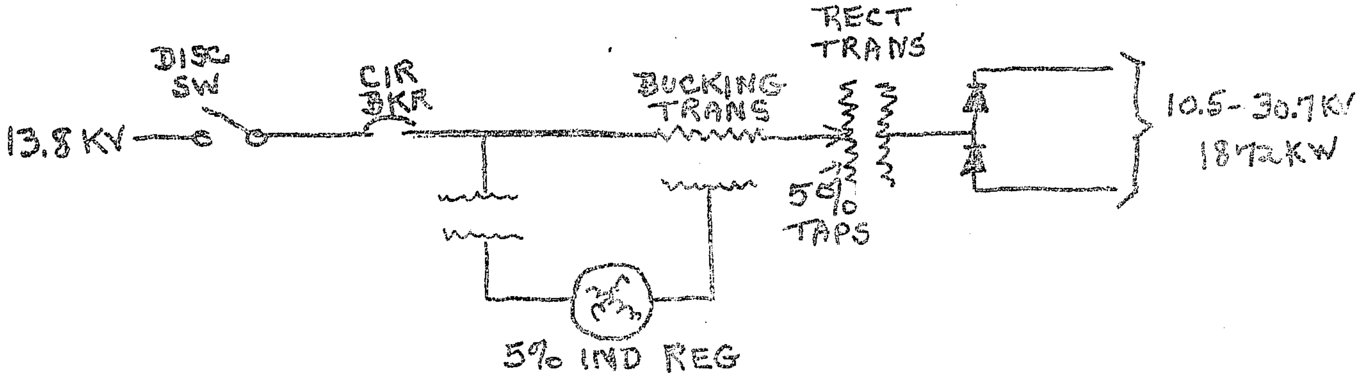
WILLIAM M. BROBECK & ASSOCIATES

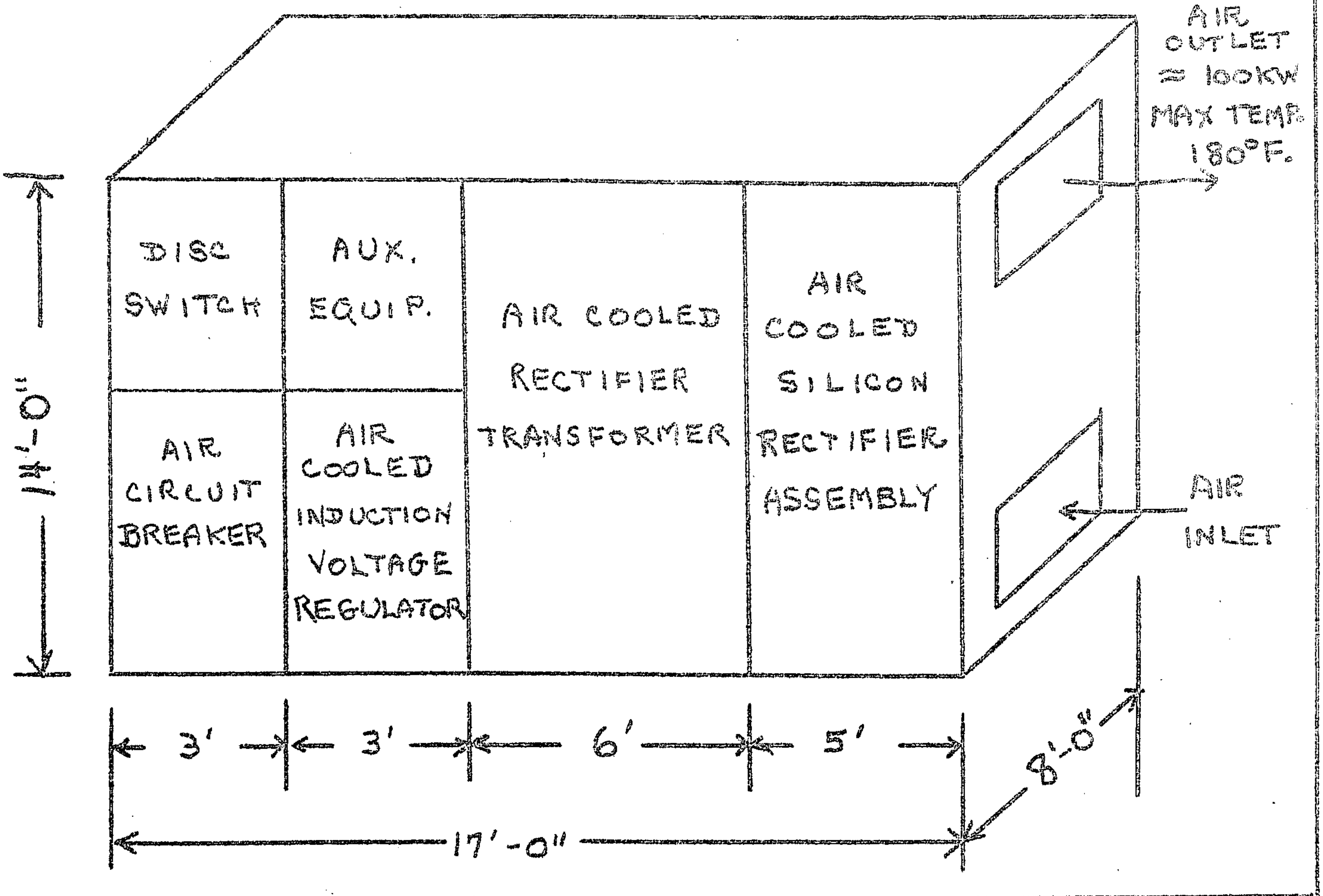
POWER SUPPLY 30.7 KV JOB: STANFORD

OUTLINE

DATE 10/31/59





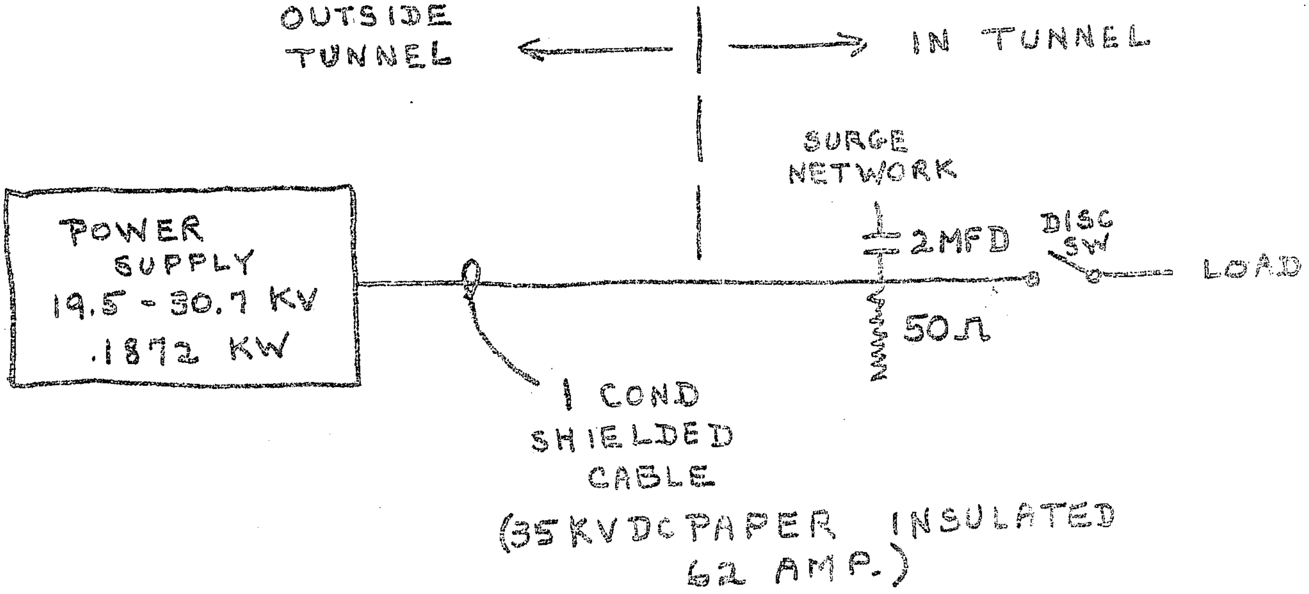


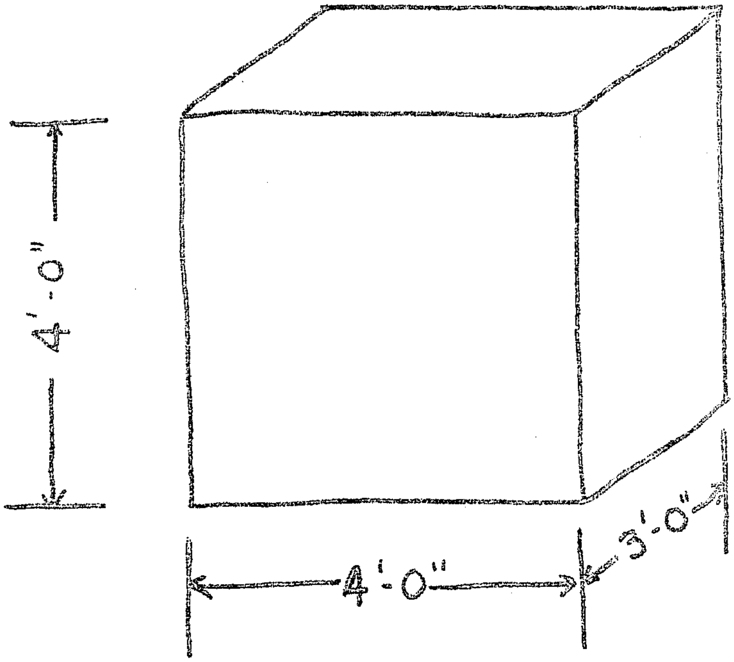
WILLIAM M. BRUBECK & ASSOCIATES

POWER SUPPLY – OUTDOOR CASE JOB: 200-58

TERMINATION BOX

DATE 10/31/59





TERMINATION BOX OUTLINE

HEAT LIBERATED 2000 WATTS

WILLIAM M. BROBECK & ASSOCIATES

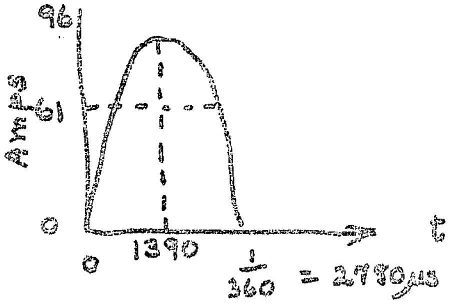
JOB: 200-58

DC TRANSMISSION TO MODULATORS

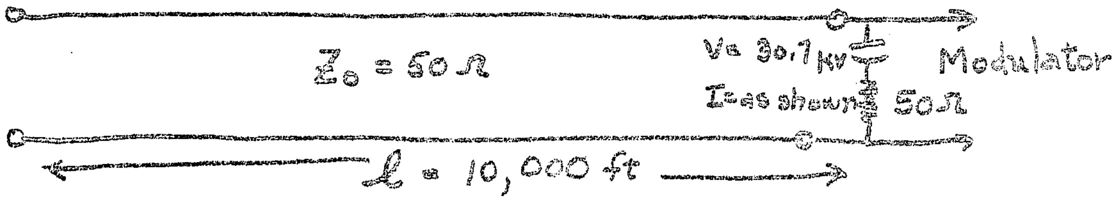
DATE 10/31/59

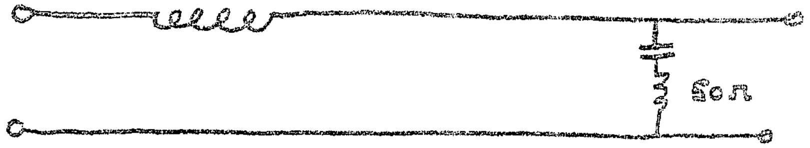
Voltage	19.5 - 30.7 KV
Current	61 amps
Power	1.872 MW.

Current wave shape



Surge Network.





$$L = \frac{Z_0 \tan \beta l}{\omega} \simeq Z_0 \frac{l}{c} = \frac{50 \times 10^4}{9.9 \times 10^8}$$

$$= 5.1 \times 10^{-4} \text{ henries } (510 \mu h)$$

f_0 should be about 510c

$$\therefore C = \frac{1}{\omega_0^2 L} = \frac{1}{(2\pi\, 5000)^2 \times 510 \times 10^{-6}} = 1.98 \mu f.$$

Suppose we use 50Ω termination & 2μf.

Max transient voltage = 61 amps × 50Ω = 3050 volts

Ringing frequency is 5KC.

Ripple voltage for 3φ full wave = 4.3% V_{DC}

= 1.32 KV

Ripple current in 50Ω resistor is:

$$i_r = \frac{1.32 \times 10^3}{50 - j\frac{1}{2\pi\, 360 \times 2 \times 10^{-6}}} = 5.95 \text{ amps}$$

$P = i_r^2 R = (5.95)^2\, 50$ = 1880 watts