M-198

PRELIMINARY PERFORMANCE SPECIFICATION FOR DEVELOPMENTAL POWER SUPPLY AND MODULATOR SYSTEM FOR THE STANFORD TWO-MILE ACCELERATOR

CONTENTS

Preliminary Performance Specification For Developmental Power Supply and Modulator System For the Stanford Two-Mile Accelerator

I. GENERAL

A. Introduction

This specification covers the performance requirements for a power supply and modulator system for the "Project M" accelerator. The proposed accelerator is to be approximately 10,000 feet long. In Stage I, 240 klystrons spaced every 40 feet will power the machine. In Stage II, the number of klystrons will be increased to 960, at a spacing of 10 feet. The klystrons will be placed in a long building (the klystron "gallery") which is parallel to and separated from the accelerator tunnel by approximately 35 feet of earth or equivalent radiation shielding. Individual modulators will be used for each klystron.

Since it may be impossible to include all the required information for the development of the power supply and modulator system in a specification of this scope, the contractor will have access to all pertinent system planning through the reports of various planning agencies and through close liaison with the responsible people at Stanford.

B. Scope of Work

These specifications and the contract of which they will be a part call for the following items to be delivered to Stanford:

1. A complete engineering design for the power supply and modulator system including the following items:
   a. Evaluation of possible systems and selection of a preferred system.
   b. Performance calculations (to be specified).
   c. Detailed circuit diagrams.
   d. Detailed mechanical drawings of components and assemblies developed.
   e. Detailed electrical and mechanical parts lists.
   f. Cost estimates for the Stage I system.

2. Three complete plug-in modulator units constructed in accordance with the design established.

3. a. A scaled-down* power supply and dc distribution system capable of supplying power to two modulators for performance testing of the system on the existing Mark IV accelerator at Stanford.

   b. Engineering supervision as required for the installation and test of the two-unit system at Stanford.

4. a. Monthly informal reports of system development progress (5 copies).

   b. A final report to be submitted after completion of the two-unit system tests (5 copies).

   c. Adequate instruction books for all equipment furnished. (2 copies).

C. Pertinent Accelerator and Klystron Parameters

The klystron amplifiers have a microperveance of 2. The 5-cavity design allows an efficiency of 38 per cent; therefore, to obtain the required 24 megawatts of peak output power, a peak input beam power of 63.2 megawatts is required. The modulators will be designed to supply 64 megawatts peak at 248 kv and 258 amperes. (Complete klystron specifications are given in Appendix A.)

The radiofrequency phase-shift through the klystron amplifier at 2856 Mc/sec is a rapid function of anode voltage. As a consequence, permissible ripple, droop, and overshoot on the modulator output pulse is quite small, by existing standards.

One of the design objectives for the accelerator is 24 hour/day operation, 365 days per year. This requirement means that all components must be designed to allow for maintenance during machine operation. The modulators and other components must therefore be designed as plug-in modular units which can be replaced rapidly.

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*Note: It is realized that components for the scaled-down power supply cannot be scaled directly in every case; however, the small supply must be designed in such a way as to represent the larger unit and in particular to permit operating data to be obtained from the system which will make possible an experimental evaluation of performance of the full-scale system.

Power for the project is to be supplied from 110-kv, 3-phase lines. Suitable substations, switch gear, etc., will be provided at the site for distribution to the modulator power supplies. The modulators must be designed so that operation at low repetition frequencies will not upset the power distribution system.

II. SYSTEM DESCRIPTION

A. Introduction

The system now envisaged is shown in Figs. 1 and 2. This system uses a small number of relatively large dc power supplies, each with a dc distribution system powering many modulators. Although the design is not fixed at this date, we have tentatively decided, for simplification of machine control, to divide the 960 loads for Stage II into 30 sectors of 32 klystron positions each. There would be one power supply per sector in Stage II, or 30 power supplies in all. In Stage I, with 240 klystrons operating, 8 power supplies would be needed.

Each power supply will be capable of powering 32 klystrons. The output rating of each supply will be approximately 2630 kilowatts.

A single spare power supply will be used in both stages. This gives permissible down-time of 12.5 per cent and 3.3 per cent, respectively, for power-supply maintenance. Switching provisions for transfer of modulator loads to any power supply will be provided.

Note: Part of the work called for under Section I.B of this specification is a detailed engineering study of the power distribution system. The contractor has complete freedom to recommend system changes. The final choice should be the system which:
(1) Most satisfactorily meets all performance specifications; and
(2) Results in the lowest over-all cost, i.e., initial cost plus operating and maintenance costs for a ten-year operating period.

B. DC Power Supplies

1. General:

The over-all design of the supplies shall satisfy the system requirements as to output-voltage range, current capability, circuit protection, regulation, reliability, ease of maintenance, and efficiency.

2. Electrical:

(a) The system and power supply design shall take into account the ac line stability problem posed when operating at low pulse repetition frequencies. Adequate filtering shall be employed to satisfy the utility system requirements. Proposed designs shall be supported by analysis or analogue measurements showing satisfactory performance capability.

(b) The study will include economic and performance comparison of several voltage-regulation and adjustment systems. Specific systems to be considered are cited below; the contractor may suggest others:

(1) Motor-generator (combination voltage regulation and transient filtering).

(2) The use of induction regulators, saturable reactors, or tap changers, or a combination of these to accommodate line-voltage drift and voltage-adjustment requirements.

(3) The use of grid-controlled rectifiers with grid phase adjustment as a control element.

3. Mechanical:

Suitable mechanical specifications for the power supply will be generated as part of this development program.

C. <u>DC Distribution System</u>

1. In addition to meeting the developed system requirements, the distribution system shall be designed to be easily expandable from Stage I to Stage II, either in whole or in part, merely by the addition of identical components.

D. <u>Type of Modulator Circuit</u>

While the intent of these specifications is to give wide latitude to the designer, it has been determined that a line-type modulator is required to meet our efficiency and economy requirements; therefore only this type of modulator need by considered for the system development.

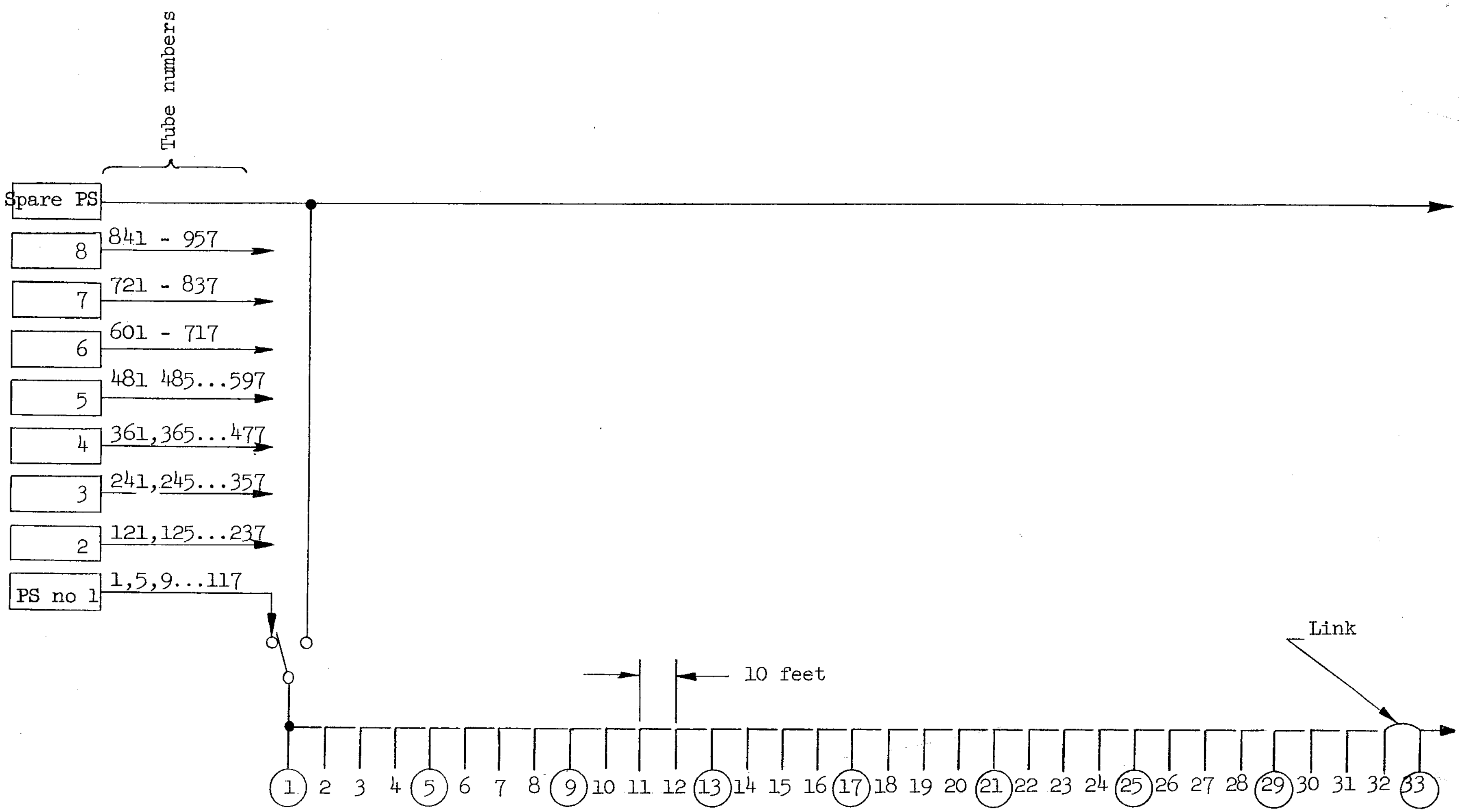

FIG. 1--Stage I dc power system.

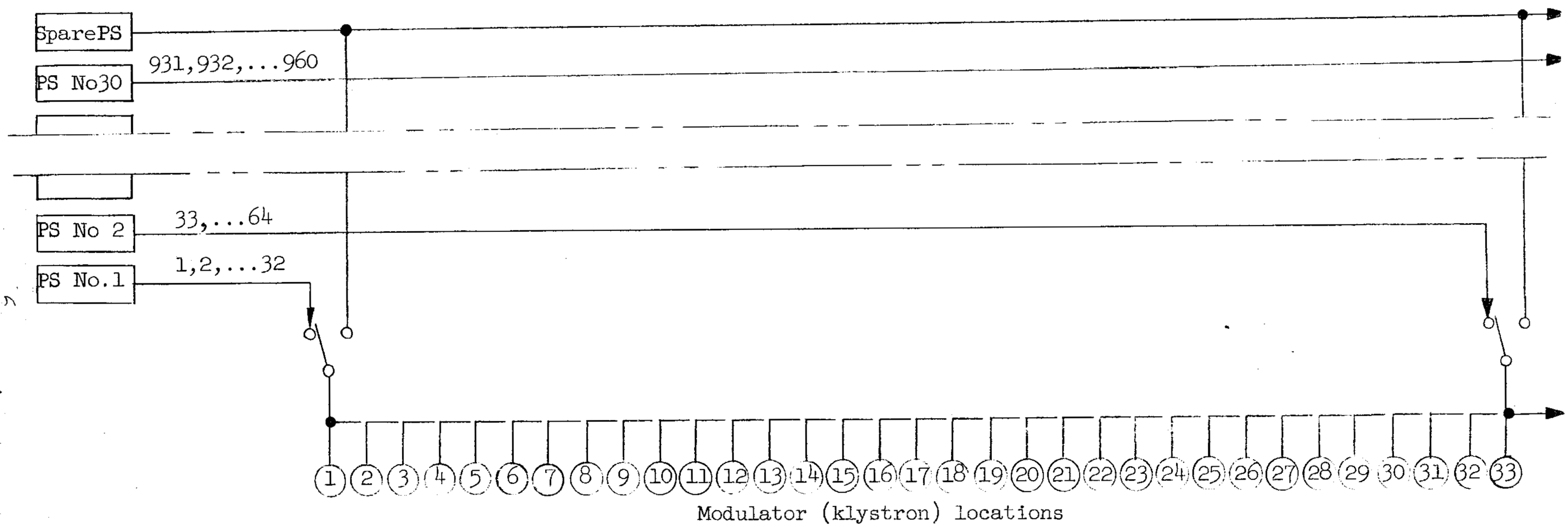

FIG. 2--Stage II dc power system.

A large part of this development program will of necessity be devoted to the modulator component choice and component design required to meet the performance economic and reliability goals outlined in this specification. Attention must be given to the following specific components:

1. The switch
2. The pulse-forming network
3. The charging circuitry
4. The pulse transformer
5. The clipper-circuit components

E. Protection, Transfer, Instrumentation and Control

Part of the work to be performed requires the development of system controls, protection in case of component failure, and adequate system instrumentation.

1. System protection and transfer of supplies and loads:

   a. A fault of long duration in any modulator must remove the modulator from the buss, restore the buss to operating voltage, and signal the operator.

   b. Failure of a power supply must actuate means to transfer the load to a spare power supply and signal the operator.

   c. Intermittent faults of short duration produced by klystron gas bursts must automatically shut down the individual modulator for a predetermined period of time. This fast fault detection system shall recycle a predetermined number of times during a specified period, after which a further fault removes the equipment as in (a) above. The recycling fault system shall be capable of accepting auxillary triggers derived from a 100,000-ohm 100-volt source.

2. Instrumentation and Control

   a. The requirements for central maintenance, remote operation, and replaceable modulator units indicates the following system concepts:

      (1) Individual modulators shall contain no local controls and no local instruments.

(2) Individual modulators shall contain all the transducers required for checking their performance by the use of "plug-in" instrumentation.

(3) The power supplies shall be provided with local and remote instrumentation and control as required.

III. SYSTEM PERFORMANCE SPECIFICATIONS

A. AC Power Source

1. Power for the system is to be supplied by a 3-wire, 3-phase 12-kv distribution system.

2. Phase unbalance will be one per cent or less.

3. The distribution system will be supplied by 25 Mva transformers having the following characteristics:

a. 110 kv primary, 12 kv secondary.

b. Transformer reactance: 12%.

c. Transformer resistance: 0.5%.

d. Regulation: 4% at 95% lagging power-factor and 100% transformer load.

4. It will be required that the system be designed so that acceptable levels of harmonic current (due to rectifier commutation) and subharmonic current (caused by pulsing at low repetition rates) are maintained.

B. Modulator Performance Specifications

1. Electrical

a. Input Power:

(1) DC from buss distribution system at voltage level to be established (probably between 15 and 30 kv.)

(2) AC power input as required for auxiliary purposes such as filaments, etc.

b. Output:

(1)	Peak power output (max)	64 Mw
(2)	Average power output (max)	74 kw
(3)	Output pulse voltage range	158-248 kv
(4)	Output pulse current range	120-258 amps
(5)	Load impedance range	1320-962 ohms
(6)	Pulse length (flat top)	2.50 μsec
(7)	Rise and fall times (max 0-100%)	0.7 μsec

(8) Pulse repetition rate: 60, 120, 180, 240, 300, and 360 cps (to be established by control trigger source)

(9) Pulse height deviation from flatness (max) ± 0.5%

(10) Pulse time jitter (max) ± 10 mμsec

(11) Pulse-to-pulse amplitude jitter (max) ± 0.25%

(12) Pulse amplitude drift (long term) (to be specified)

(13) Klystron filament power 15 volts rms at 15 amps rms

(14) Signals as required for remote operation of the modulator.

(15) Instrumentation outputs as specified in paragraph II.E.2.

2. Mechanical

a. Cooling: The unit shall be completely water cooled. Inlet and outlet water temperatures and flow rate shall be determined jointly with Stanford during the development period.

b. Disconnect: The unit shall be equipped with a single disconnect plug and receptacle assembly which will accomodate all electrical and water connections except the waveguide connection.

c. Klystrons: The klystron amplifier tube is to be considered part of the modulator package. Stanford will furnish the complete klystron mechanical specifications to the contractor.

d. Form of unit: The unit is to be designed for rail transportation within the accelerator site, with integral wheels as part of the assembly. Complete details of the rail system will be furnished to the contractor. The unit must be constructed to withstand the shock and vibration imposed by the transportation system. The shape of the unit and over-all sizes will be determined jointly by Stanford and the contractor early in the contract period.

APPENDIX A

PROJECT M KLYSTRON

Tentative Specifications

Description: Pulsed amplifier klystron, 24-megawatt, microperveance 2, S-band, single-frequency, magnetically focused, double-waveguide output, coax input, liquid-cooled, sealed-off.

			Absolute Ratings			Typical Operating Conditions					
						Operation A			Operation B		
		Units	Max.	Min.	Notes	Max.	Min.	Notes	Max.	Min.	Notes
Filament Voltage	E_f	volts	16	14	4						-
Filament Current	I_f	amps	16	14							
Peak Forward Beam Voltage	e_{py}	kv	270	-	1	195	-	1	248	-	1
Peak Inverse Beam Voltage	e_{px}	kv	60	-	-	40	-	-	50	-	-
Peak Beam Current	i_k	amps	294	265	2	180	163	2	256	234	2
Peak Input Beam Power	p_i	Mw	79	71	5	35	32	5	64	58	5
Pulse Length Beam Voltage	τ_0	μsec	3.2	-	3	3.2	-	-	3.2	-	-
Pulse Repetition Frequency	prf	pps	360	-	-	360	-	-	360	-	-
Average Input Beam Power	P_i	kw	91	82	-	40.5	37	-	74	67	-
Frequency	f	Mc	2856	2856	-	2856	2856	-	2856	2856	-
Peak Drive Power	p_{drive}	watts	240	-	-	240	-	-	240	-	-
Peak Output rf Power	p_{out}	Mw	-	30	8	-	12	8	-	24	8
Pulse Length rf Output	τ_{rf}	μsec	-	2.5	-	-	2.5	-	-	2.5	-
Average Output rf Power	P_{out}	kw	-	27	8	-	10.8	8	-	21.6	8
Efficiency $\left(\frac{\text{peak output rf power}}{\text{peak input beam power}}\right)$	η	°/o	-	38	5	-	35	5	-	38	5
Gain		db	-	51	-	-	47	-	-	50	-
Load		VSWR	1.5:1	-	7	1.5:1	-	7	1.5:1	-	7
Window Pressure		mm Hg	10^{-7}	-	-	10^{-7}	-	-	10^{-7}	-	-
Life		hours				-	2000	6	-	200	6

Cooling: Maximum water pressure 100 psi

Water flow 10 gpm at 50 psi pressure-drop maximum

Water temperature 70° maximum at output.

Drift: P_{out} to change not more than 0.05 percent per °F in inlet water temperature.

Base: Special plug-in socket.

Input: Female coaxial connector, type C (mates with UG-573/U male connector).

Output: 2 waveguides RG-48/U, connecting through special flange.

Cooling connections: Two quick-disconnect type (to be specified).

Phase modulation: Phase modulation produced by stray heater magnetic field to be less than 1°; produced by beam-voltage changes to be less than 6° per percent.

Focusing: By integral permanent magnet.

Radiation: Shielding to be provided around collector and body to reduce X-rays to less than 10 mr/hour 24" from tube axis.

Note 1: Any short transient spike on the voltage pulse shall not exceed 5 percent in magnitude and 0.15 μsec in duration.

Note 2: The limits of acceptable current at operating voltage correspond to variation of ± 5 percent in perveance.

Note 3: Pulse length measured at 70 percent of maximum voltage; minimum of 2.5 μsec flat-top is required.

Note 4: Heater power is expected to be 225 watts.

Note 5: The present requirements on power input and efficiency are conservative. It is hoped that the minimum acceptable efficiency can be increased.

Note 6: It is expected that a minimum life of 5000 hours for operation A and 2000 hours for operation B will be obtainable as improvements in techniques are made. In other words, the presently specified minimum-average-life requirements are only for evaluation purposes.

Note 7: The VSWR of the load connected to each of the two waveguide outputs shall not exceed the specified value.

Note 8: With a load having a VSWR less than 1.2:1 connected to each output, the power in each load shall be within ± 5 percent of one half of the total power output.