M-104

MEMORANDUM NO. 1

December 15, 195[illegible]

FILE COPY PROJECT M

Comparison of Methods of Phasing Long Linear Accelerators
Prepared by the Drive and Phasing Sub-committee for Project M
(For explanations of symbols, see last page)

1	2	3	4	5	6	7	8	9 Wobblers		10
General Description	Type of phasing standard	Mode of operation	Type of Control	Compatibility with Physics	Type of Detector	Numbers of Detectors	Location of Detector	Type	Number	Comments
A. ENERGY MAXIMIZATION										
1. Phasing individual sections of entire machine.										
a. All sections excited. Two signals are obtained which correspond to an individual klystron turned alternately "on" and "off". The maximum signal difference in the proper sense corresponds to proper phase adjustment.	P	I	A, M	0 or 2*	E	1	End Stat.	F	1000	* Physics experiments can be carried on during phasing if suitable detector can be developed.
b. First 250 ft. sector plus one additional klystron. Phase wobble the 1st 250 ft. sector. Adjust individual klystrons in turn for maximum electron energy.	P	I	A, M	0	E	1	End Stat.	ø	1	Beam transmission questionable - Focusing probably required full length.

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2. Phasing of individual sectors. Each 250 ft. sector is phased by energy maximization of that sector. Some sort of electron injection system and electron ejection is necessary. The injection could be a coaxial gun. Possible deflector system could be one of the following:										Final machine phasing must be done by sectors. This requires use of entire machine and is not compatible with physics research. These systems require use of 40 auxiliary guns, however these guns may also be used to provide beams of different energy. At least 1% of the total length of the machine would be used by deflection and injector systems.
a. a.c. magnet & d.c. bias	P	I	M	I	E	40	Acc. Tunnel	T	40	Requires good d.c. bias voltage regulation to prevent deflection of main beam.
b. Pulsed air core magnet	P	I	M	I	E	40	Acc. Tunnel	T	40	Requires approx. 500,000 amps in air core deflection magnet.
c. Pulsed electromagnetic cavity.	P	I	M	I	E	40	Acc. Tunnel	T	40	Probably a traveling-wave deflection system can be designed
d. d.c. magnets	P	I	M	C	E	40	Acc. Tunnel	None	-	It may be possible to use a single d.c. magnet and move to the sector being phased.
B. DIRECT RF PHASE COMPARISON										
1. "Random Walk" (knowing the line length between adj. klystrons, the phase between inputs is compared and adjustments made to give null reading).	S	C	M, A	6	∅	1000	Acc. Tunnel	None		It is necessary to use sector phasing for final energy maximization.

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2. Primitive secondary standard. To be used when klystrons are replaced or when beam voltage changes. A phase measurement is made across the klystron under consideration	S	C	M, A	6	∅	1000	Klys. Tunnel	None	-	Simple method to check phase when klystron is changed or power level changed.
C. PHASING FROM BEAM PHENOMENA										
1. Beam Induction										
a. Beam induces an rf wave in previous section and this is compared with phase of rf entering section - Knowing line lengths it is possible to phase rf into accelerator. RF must be off when measurement is made on previous section.	S	I	M, A	2,4	∅	1000	Acc. Tunnel	None	-	If line lengths are well known this is essentially a primary standard.
b. An auxiliary cavity is placed in front of each 10 ft. section. The rf phase is then derived from the presence of the rf beam in cavity.	S(P)	C	A, M	3	∅	1000	Acc. Tunnel	None	-	Almost a continuous primary standard. Requires large beam current and >1% decrease in accelerator length.
c. Machine is run in electron beam-off condition and rf phase is measured at output of accelerator section - With beam on and klystron under consideration off, the beam induced phase is measured - klystron is phased to 180° out from beam "on" condition.	P	I	M	2,4	∅	1000	Acc. Tun. & Klys. Tun	T(gun) & each Klys.	1000	The beam can be operated but reduced by slight amount, say 1%

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2. Reactive loading										
a. The amount of phase shift in the rf wave caused by the presence of the electric field produced by the beam is measured.	P	I	M	2,4	∅	1000	Acc. Tun. + Klys. Tun.	∅	1000	Sensitivity of method depends on beam current and rf power to section. Double adjustment necessary for use as a primary standard.
3. Resistive loading										
a. RF power reduction by beam loading observations on the output coupler of section being phased.	P	I	A, M	2,3	P	1000	Acc. Tun. + Klys. Tun.	∅	1000	Section under consideration is phase wobbled - several sections can be phased simultaneously.

EXPLANATION OF SYMBOLS

Column 2: <u>Type of Phasing Standard</u>

P = Primary standard - Machine can be phased completely with method.

S = Secondary Standard - Can be used to monitor and to readjust phasing after initial adjustment with primary standard.

Column 3: <u>Mode of Operation</u>

I = Intermittent - Used only when operator believes phasing is required.

C = Continuous - Information required for phasing is continuously obtained.

Column 4: <u>Type of Control</u>

A = Automatic - Suitable for automatic control.

M = Manual - Suitable for manual control.

Column 5: <u>Compatibility with Physics</u>

0 = No physics experiments possible during phasing.

1 = Physics possible but with slight decrease in energy and current due to temporary absence of one 250 foot sector.

2 = Energy and current vary slightly from pulse to pulse due to phase or trigger wobble of a single klystron.

3 = High electron beam current is necessary.

4 = Moderate electron beam current is necessary.

5 = Occasional missing electron beam pulse.

6 = No interference with physics.

Column 6: <u>Type of Detector</u>

E = Electron energy

ϕ = r-f phase.

P = r-f power.

Column 7: <u>Number of Detectors</u>

1000 = one detector per klystron.

40 = one detector per sector (250 ft.).

1 = one detector for entire machine.

Column 8: Type of Wobbler

∅ = r-f phase

T = Trigger (klystron "on-off" control or trigger delay).