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AGS MAIN MAGNET POWER SUPPLY LIMITATIONS OF LONG FLAT TOP OPERATION

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No. 150

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The proposal for the conversion of the AGS to higher intensities called for a one second flat top. This was the requirement imposed when the existing main magnet power supply was purchased. Due to increased sophistication of many present experiments, improved particle detectors and a greatly expanded slow external beam facility, it now becomes desirable to go to flat top times much longer than originally specified. In this regard, a study of the power capabilities of the Siemens main magnet power supply was instituted.

This Tech. Note describes the determination of repetition time as a function of flat top length with momentum as a parameter consistent with maximum rating limitations of the main magnet power supply. The first part determines operating conditions required to maintain seven megawatts into the motor. The second part determines operating conditions for three thousand average amperes in the flat top bank. The third part is a determination of the operating conditions to maintain a dwell time of two tenths of a second.

Two other studies were made of the generator r.m.s. currents under long flat top conditions. The conclusions of these studies were, that because of the reduction of generator currents during flat top, long flat tops favor the generator.

The power supply system losses which determine the amount of power needed to drive the motor comes from primarily three sources. The first is rotating loss due to windage, friction, etc., and usually runs a little less than 1 MW. The second is due to the arc drop in the excitrons. The arc drop across each excitron is fifty volts, therefore, the total system arc drop runs about four hundred volts. This power loss is then equal to four hundred times the average current.

$$1) \qquad P_e = 400 \left(\frac{1}{T}\right) \int_o^T Idt = \frac{400}{T} (9964) (T_R) (T_R + T_F)$$

where $Pe \equiv$ power loss due to arc drop in watts

$T \equiv$ pulse repetition time is sseconds

$T_R \equiv$ duration of rectify time in sseconds

$T_F \equiv$ flat top length in sseconds.

The third source of power loss in the system is the resistive loss and can be determined from the following relationship,

$$2) \qquad P_R = \frac{.25}{T} (9964\ T_R)^2 \left(\frac{2}{3} T_R + T_F\right) \quad .$$

The total power into the motor then becomes

$$3) \qquad P_{in} = P_o + P_R + P_V$$

$$4) \qquad P_{in} = 10^6 + \frac{.25}{T} (9964\ T_R)^2 \left(\frac{2}{3} T_R + T_F\right) + \frac{400}{T} (9964\ T_R) (T_R + T_F) \ .$$

T_R, T and T_F can be determined on either the basis of real time or on the basis of a relative time used at the Siemens power supply. This relative time is called Siemens time and is designated by a prescribed "S" on all time symbols. Siemens time is about eight percent shorter than real time.

The Operators at the Siemens power supply maintain a log of machine parameters. Station operating conditions and readings based on Siemens parameters are recorded into this log twice each shift. Because of this, for ease of checking results it becomes practical to use Siemens time.

"T_R" although it is designated rectify time is a number representing the amount of time it takes the magnet current to rise to its maximum value. It assumes the rate of rise of current is nine thousand nine hundred sixty-four amperes per Siemens second (9,964 A/ssec). "T_R" can be determined by subtracting point zero four zero ssecond from the numbers put into the rectify time cone.

Table I is a check of the validity of the calculations for the motor input power. The log was checked out over the past two years and data for a number of runs entered onto Table I. Actual motor power input (P_{INA}) was also noted. The power input based on the derived relationships was calculated (P_{INC}) and also entered. This allows the calculated values to be compared to the actual values.

Table I. Comparison of Calculated P_{INC} Versus Actual P_{INA} As Taken From Power Room Logs

	T_R+1.38	T_F	P_R	P_F		
T ssec	A+B+C+E ssec	D ssec	$\frac{.25(10^{-6})}{T}\int I^2dt$	$\frac{400(10^{-6})}{T}\int Idt$	P_{INC} (MW)	P_{INA} (MW)
3.018	.697	1.4	4.55	1.45	7.0	6.7
2.589	.698	1	4.13	1.34	6.47	6.3
2.593	.422	0	.15	.12	1.15	1.1
3.024	.697	1.5	4.80	1.52	7.32	7-7.3
3.671	.694	2	4.95	1.54	7.49	7-7.2
1.727	.687	0	1.59	.7	3.28	3.7
1.512	.675	0	1.69	.76	3.45	4
1.395	.675	0	1.84	.82	3.66	4.2
1.404	.682	0	1.9	.84	3.74	4.3
1.787	.233	0	.08	.02	1.03	1

The steady state magnet current required for a steady state power of seven megawatts into the motor can be determined from the following relationship

$$5)\qquad P_{in} = 7(10^6) = 10^6 + .25I^2 + 400I \quad .$$

Solving for I yields a magnet current of 4164 amps which corresponds to a momentum of 23 GeV/c. This means that for any momentum below 23 GeV/c, as far as the limit of seven megawatts into the motor is concerned, there is no limit on flat top length.

Repetition time for seven megawatts into the motor at 25 GeV/c, 28.28 GeV/c and 33 GeV/c was determined as a function of flat top length. The results are displayed in Fig. 1. These numbers are based on a measured magnet current of 5100 amperes and a Gauss clock reading of 28.28 GeV/c. Determination of magnet currents at other momentums do not consider saturation effects in the magnet and assume that the field is directly proportional to current.

The Siemens power supply utilizes VE-601 sealed mercury vapor single anode excitrons as the rectifiers. These excitrons with two of them connected in parallel are configured into a three phase full wave bridge. Two series aiding bridges are connected at each end of the magnet system. The maximum average current rating of the VE-601 is a little over five hundred amperes. The current rating per bridge is therefore six times this value or three thousand amperes. It is this rating which imposes the average current limit of flat top length. As a result, in addition to monitoring motor input power, one must also be cognizant of the average magnet current from the flat top bank. The limiting momentum for a continuous flat top is the momentum for three thousand amperes in the magnet. This momentum can be determined from the following relationship

$$6) \qquad P_{LIM} = 3000 \left(\frac{28.28}{5100}\right) \equiv 16\frac{2}{3} \text{ GeV/c} \quad .$$

For momentums greater than this the appropriate repetition time can be calculated by means of the formula,

$$7) \qquad T = .06 \; P \; T_f$$

where $T \equiv$ repetition time in sseconds

$T_f \equiv$ flat top time in sseconds

$P \equiv$ momentum in GeV/c.

Repetition time for a number of flat top times and momentums was calculated. This data is presented in Table II and plotted in Fig. 2.

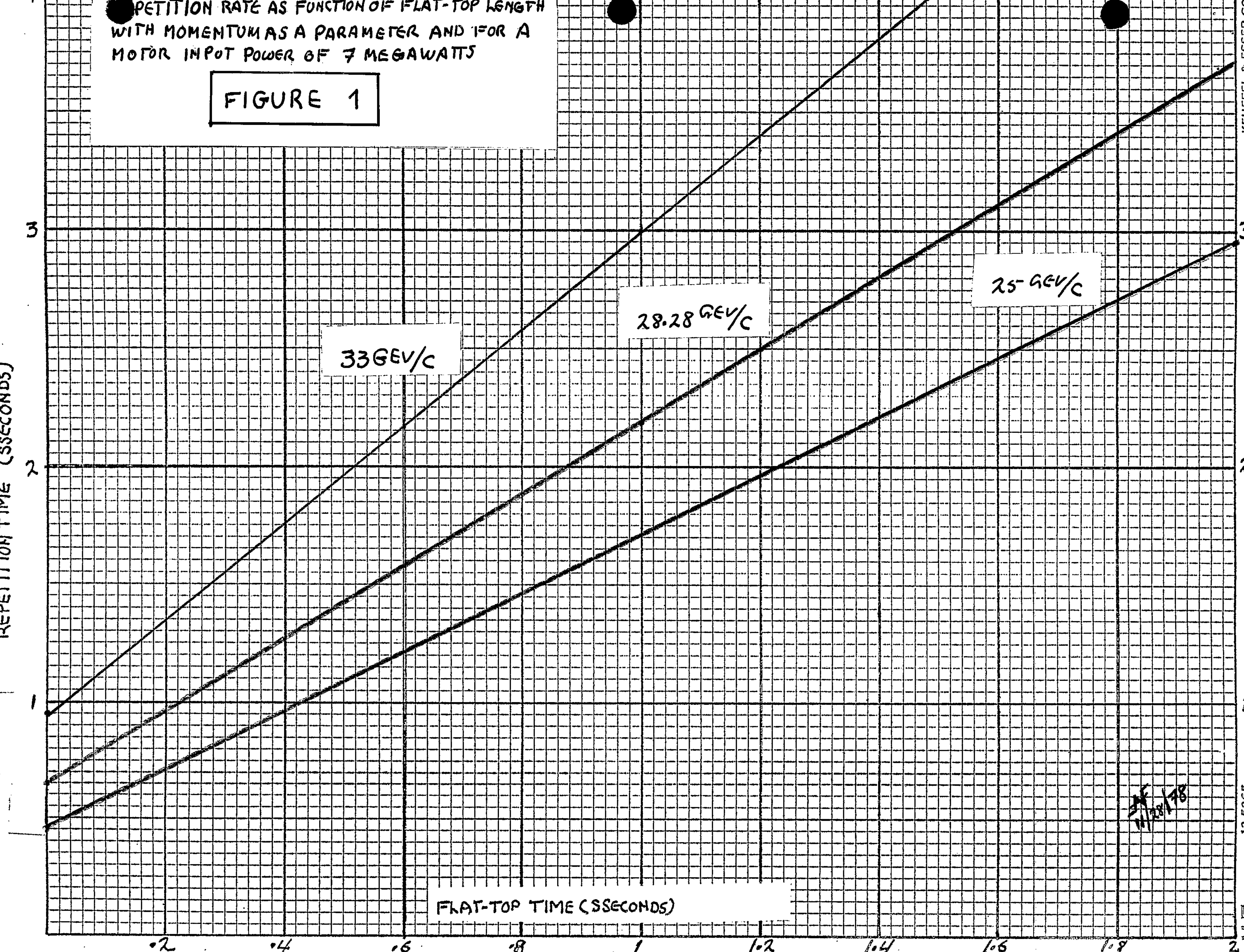
PETITION RATE AS FUNCTION OF FLAT-TOP LENGTH
WITH MOMENTUM AS A PARAMETER AND FOR A
MOTOR INPOT POWER OF 7 MEGAWATTS
FIGURE 1
33GEV/C
28.28 GEV/C
25 GEV/C
REPETITION TIME (SSECONDS)
FLAT-TOP TIME (SSECONDS)
3
2
1
·2
·4
·6
·8
1
1·2
1·4
1·6
1·8
2
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Table II. Repetition Time as a Function of Flat Top Time For Average Flat Top Current of 3000 Amperes

$P(\frac{GeV}{c})$	I(Amps)	T_f(ssecs)	T(ssecs)
28.28	5100	2.0	3.4
25	4509	2	3
		1	1.5
23	4148	2	2.77
		1	1.38
20	3607	2	2.4
		1	1.2

For the AGS it has long been recognized that for dwell times less than 0.2 seconds, drastic retuning of the injection parameters is required. As a result, during the set-up for a run the Siemens timing parameters are selected for a dwell time of 200 msec or 212 smsec. The repetition time for this limitation can be determined from the following relationship

8) $$T = A + B + .252 + T_F + .019\ P$$

where $T \equiv$ repetition time in sseconds

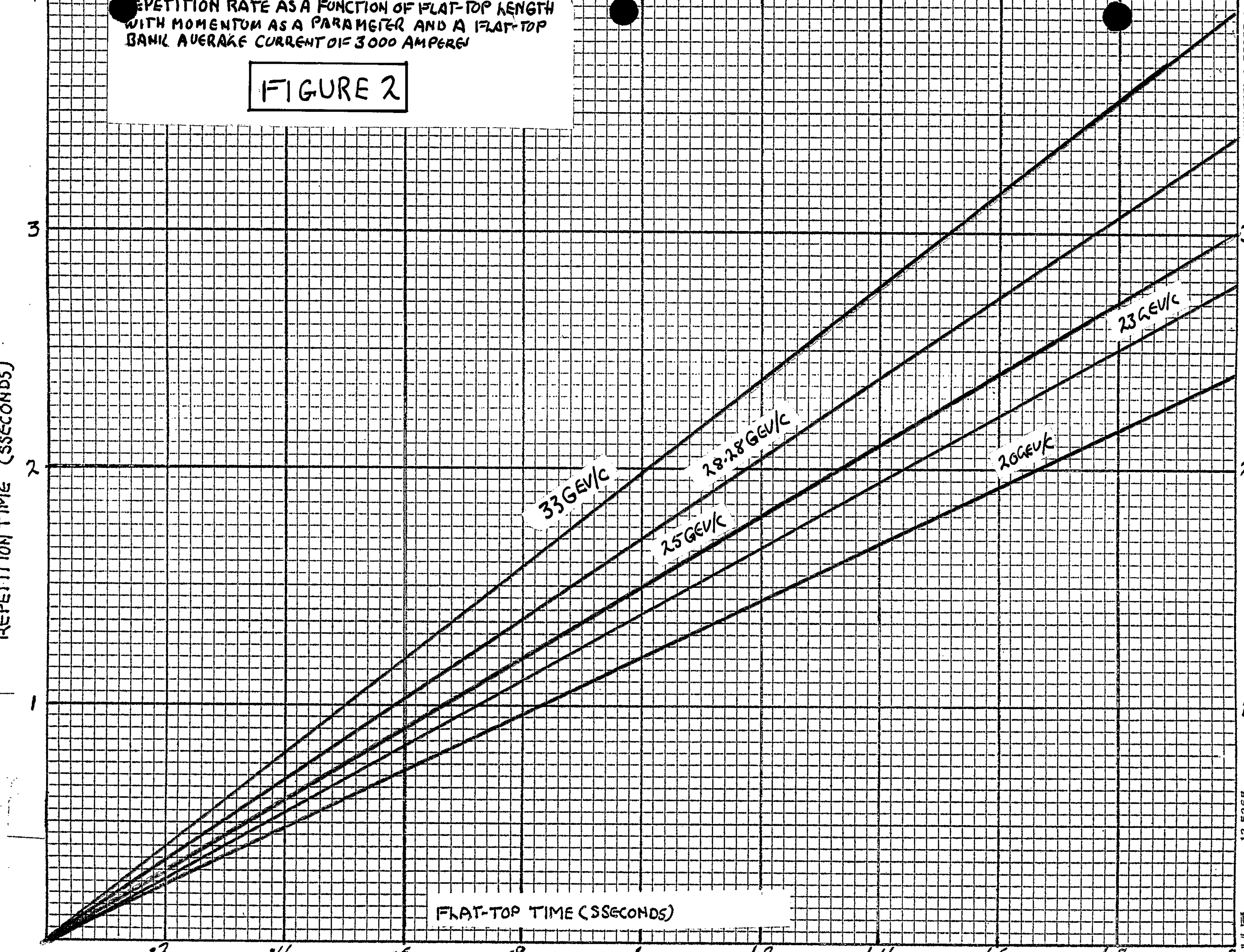
$T_F \equiv$ flat top time in sseconds

$P \equiv$ momentum in GeV/c

$A+B \equiv$ injection porch length in sseconds.

Normally, A+B are set for a total of about .098 ssecs so that the relationship for repetition time as a function of momentum and flat top duration with a .212 ssec dwell time becomes

9) $$T = .35 + T_F + .019\ P\quad .$$



REPETITION RATE AS A FUNCTION OF FLAT-TOP LENGTH WITH MOMENTUM AS A PARAMETER AND A FLAT-TOP BANK AVERAGE CURRENT OF 3000 AMPERES

FIGURE 2

The repetition time under a number of operating conditions for a dwell time was calculated and is presented in Table III. This same data was plotted and is presented in Fig. 3.

Table III. Repetition Time as a Function of Momentum and Flat Top Time For a Dwell Time of 212 Smecs

$P(\frac{GeV}{c})$	T_R(ssecs)	T_F(ssecs)	T(ssecs)
28.28	0.539	2	2.89
		1	1.89
25	0.476	2	2.83
		1	1.83
23	0.438	2	2.79
		1	1.79
20	0.382	2	2.73
		1	1.73

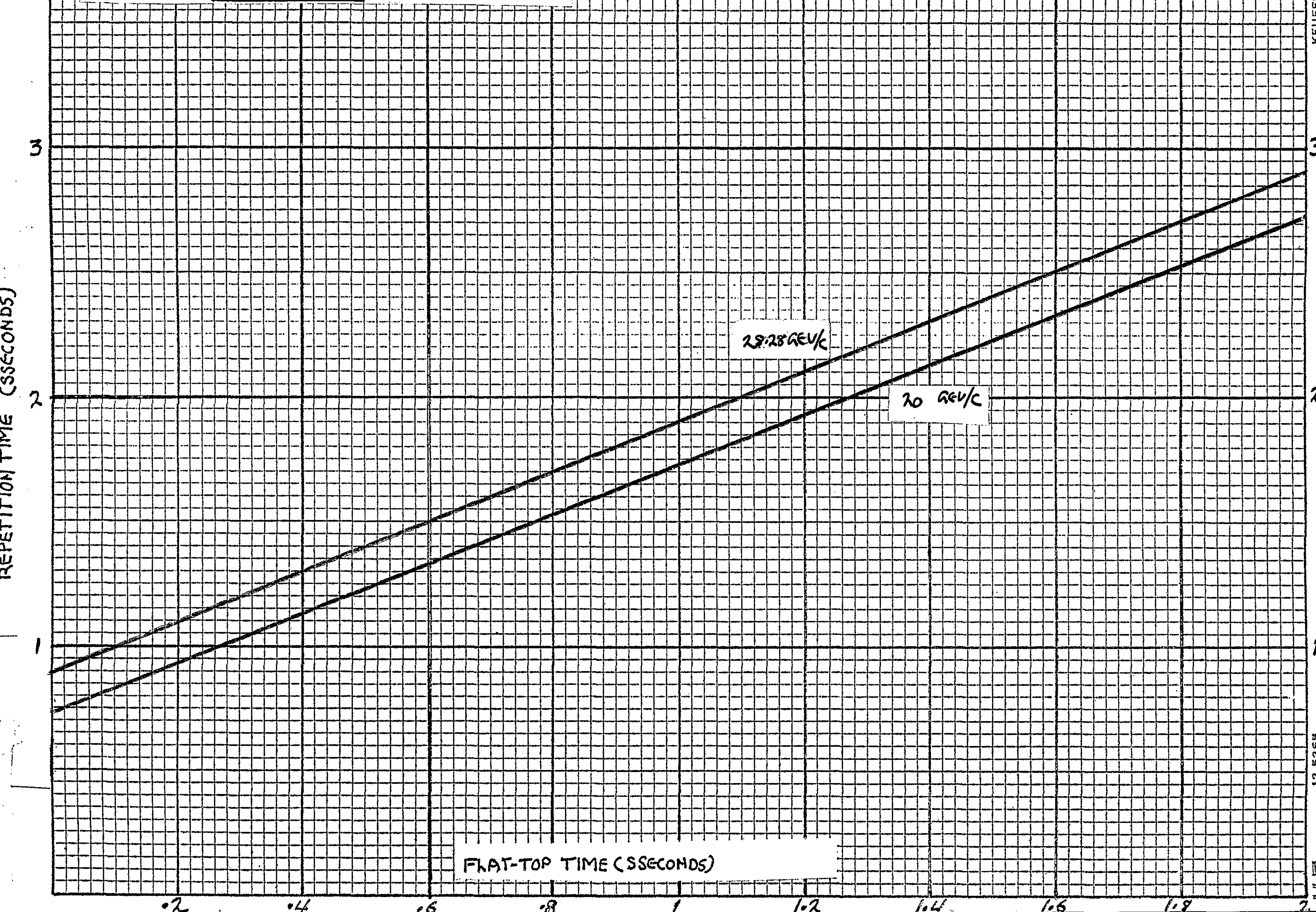
The results of motor power, average flat top current and dwell time limitations are summarized in Fig. 4. It is interesting to note that at high momentums and with long flat tops that motor input power is the limitation that determines the minimum repetition time. At lower momentums and at short flat top times, the dwell time limitation determines the permissible repetition times. At intermediate momentums and with long flat tops, the three thousand ampere average flat top current limitation determines the shortest allowable repetition times.

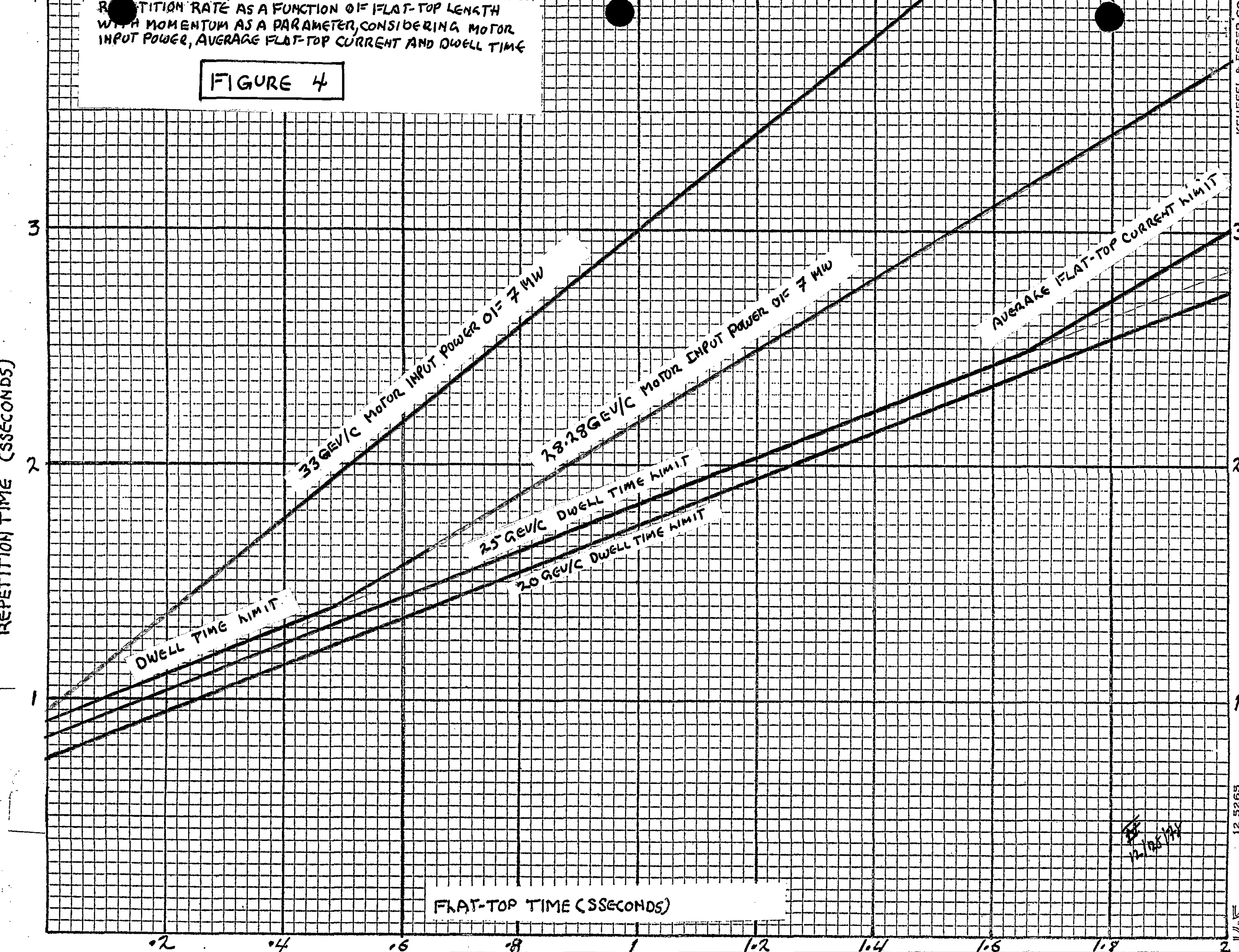
In all modes of operation, the motor power input is a measurable quantity and is continuously monitored at the Siemens power supply main console. As far as dwell time is concerned, this is a measurable quantity and can be monitored at many locations at the AGS complex. This means that as far as these two limitations are concerned, because of the ease of accurately measuring them, the operators can be permitted a certain degree of flexibility when setting the accelerator up for a run.

Average flat top current on the other hand is not directly measurable and as a result, in this regard, the conclusions of the calculated results should be

REPETITION RATE AS A FUNCTION OF FLAT-TOP LENGTH WITH MOMENTUM AS A PARAMETER AND A DWELL TIME OF 212 SMECS

FIGURE 3




REPETITION RATE AS A FUNCTION OF FLAT-TOP LENGTH WITH MOMENTUM AS A PARAMETER, CONSIDERING MOTOR INPUT POWER, AVERAGE FLAT-TOP CURRENT AND DWELL TIME
FIGURE 4
33 GEV/C MOTOR INPUT POWER OF 7 MW
28.28 GEV/C MOTOR INPUT POWER OF 7 MW
AVERAGE FLAT-TOP CURRENT LIMIT
25 GEV/C DWELL TIME LIMIT
20 GEV/C DWELL TIME LIMIT
DWELL TIME LIMIT
REPETITION TIME (SSECONDS)
FLAT-TOP TIME (SSECONDS)
1
2
3
.2
.4
.6
.8
1
1.2
1.4
1.6
1.8
2
12/25/74

strictly adhered to.

In conclusion, it should be pointed out that the main magnet power supply is a very complex and costly installation, and we want to get many more years of reliable service out of it. This can be accomplished if we continue to run this system in a reasonable fashion.

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