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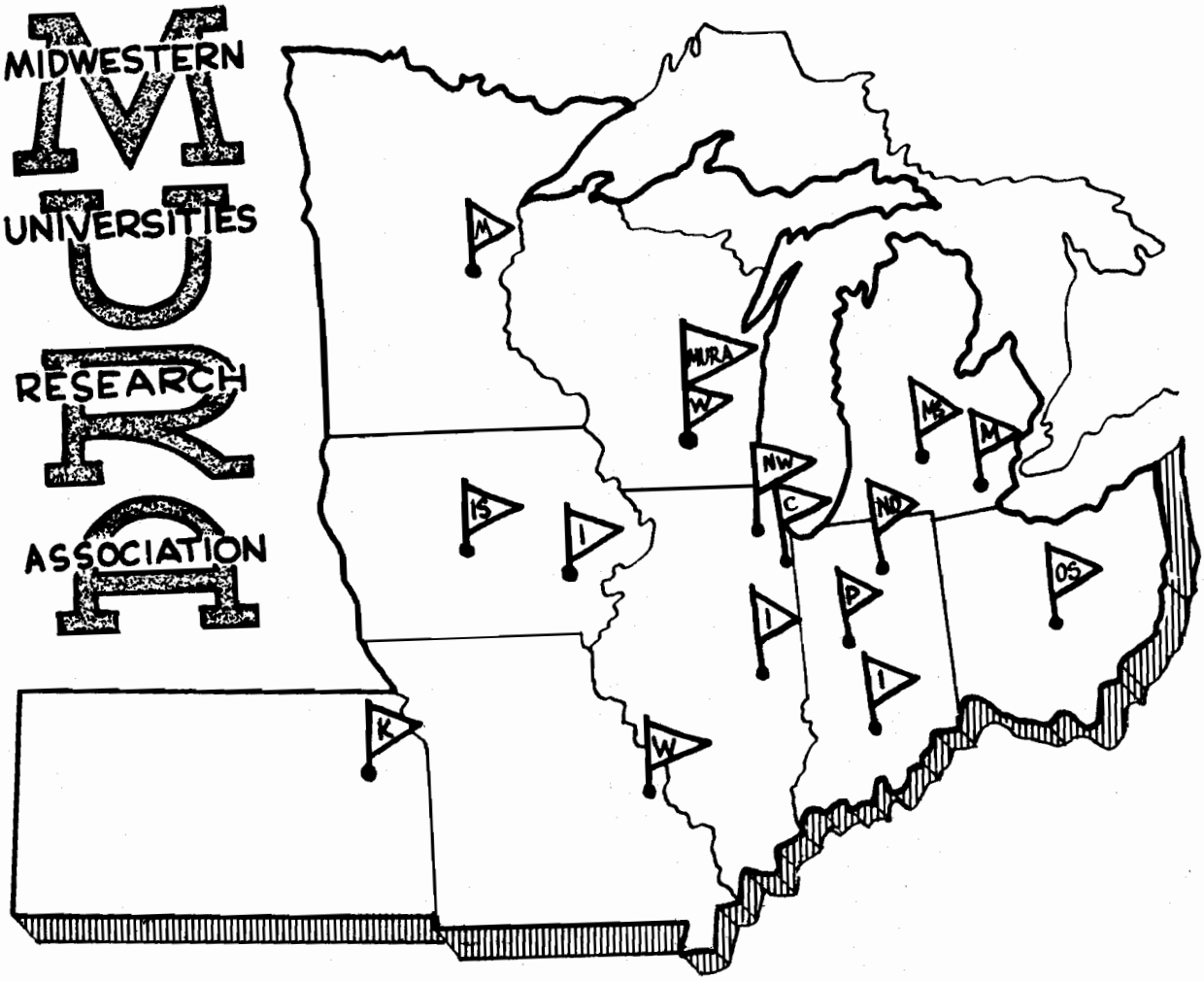


REPORT TTT
(Program 39)
February-March, 1957

NUMBER 225
Internal
(IBM Program)

TTT (Programme 39)
A Programme for RF Study

F. E. Mills
J. N. Snyder

This programme is traceable in part to the memoranda:

A. M. Sessler	to J. N. Snyder	May 16, 1956
A. M. Sessler	to J. N. Snyder	May 17, 1956
F. E. Mills	to J. N. Snyder	Oct. 25, 1956
F. E. Mills	to J. N. Snyder	Feb. 7, 1957
F. E. Mills	to J. N. Snyder	Feb. 7, 1957

TTT represents a strong departure from the typical digital computer program used in this type of study, a prime example of which was the SSS programme recently used on ILLIAC. There an accelerator was regarded as being made up of a fixed number of various "components" (gaps, angles between gaps, etc.) If these various components could have different properties, it was necessary to assemble a master tape made up of the appropriate operating subroutines. In order to be able to depart from the maximum number of components possible it was necessary to provide a complex system of counters. Data necessary to specify each component had to be loaded into fixed storage banks so as to be present on demand by the operating subroutines.

Now with TTT, the index registers of the IBM 704 EDPM have been exploited to the fullest in order to enable a new concept to be introduced. The constitution and properties (i.e. pertinent data) of a given accelerator are listed in order as one proceeds around the machine. This listing is in terms of a set of code and data cards called the SENARIO (the mis-spelling is deliberate and necessary). When this list is read into the computer a master execution programme is assembled on the spot from available internal subroutines. Only now does the operating programme even exist; it is now executed repeatedly to simulate the passage of a particle around and around the accelerator.

An accelerator is regarded as being made up of ANGLES, GAPS, and FOILS. A SENARIO is constructed by listing these on the SENARIO AGENDUM SHEET (or several such sheets if the length warrants it). A sample of such a sheet is attached. This sheet is then in turn stapled to the front of a series of runs which is to exploit this SENARIO.

Each SENARIO is identified by an eleven digit ID number so that the rule

$$ID = 10^8 A + i$$

may be used where:

A = Human ID
i = ID number of this case.

The program will first print

39 (SENARIO ID #)

The existence of an ANGLE is specified by a card (a line on the SENARIO AGENDUM SHEET) reading

TYPE		VALUE	COMPONENT
χ_1	χ_2		ANGLE

(here and in what follows, a blank is implied where nothing is written)

χ_1 specifies which expression will be used to evaluate the time necessary for the particle to traverse the angle.

If $\chi_1 = 1$, the time interval is given by:

$$F(E, x, p, \alpha) = \frac{R_0}{c} \frac{E}{\sqrt{E^2 - E_0^2}} \; r(E) \, S(x, p, \alpha)$$

where:

R_0 = Radius (in meters) of machine when E = 100 BEV
c = velocity of light = 3×10^8 m/sec
E = particle energy
E_0 = particle rest energy = 938 MEV

$$r(E) = \left[\frac{E^2 - E_0^2}{1 - E_0^2}\right]^{1/(2k+2)}$$

k = mean field index in this angle

$$S(x, p, \alpha) = 2\pi\alpha + \frac{x}{\nu} \sin 2\pi\alpha\nu + p/\nu \, (1 - \cos 2\pi\alpha\nu)$$
$$+ \frac{x^2}{4\nu^2}\left(2\pi\alpha - \frac{\sin 4\pi\alpha\nu}{2}\right) + \frac{xp}{4\nu^2}(\cos 4\pi\alpha\nu - 1)$$
$$+ \frac{p^2}{4\nu^2}\left(2\pi\alpha + \frac{\sin 4\pi\alpha\nu}{2}\right)$$

x, p = coordinate and momentum of betatron oscillations

α = angle subtended by the portion of the machine in question (in units in which a full circle = 1)

ν = number of betatron oscillations around the machine.

Following at once come 4 cards:

TYPE	VALUE	COMPONENT
1	$R_0 \, 2^{-7}$	
2	$k \, 10^{-3}$	
3	$\nu 10^{-2}$	
4	α	

The identifying digits must be prefixed.

It should be noted here and in what follows that all scaled fractions entered on an agendum must be less than unity.

If $\chi_1 = 2$, an expression for the time identical to the $\chi_1 = 1$ case will be used except

$$S(x,p,\alpha) = 2\pi\alpha$$

The same set of cards as described in the $\chi_1 = 1$ case must follow the ANGLE CARD except that if desired the 3 $\nu\, 10^{-2}$ card may be omitted. It should be noted that if one angle of the whole machine is given time type $\chi_1 = 2$, then all angles of the machine will be of time type 2 even if designated otherwise.

χ_2 gives the type of betatron oscillation transformation which will be used to obtain the $\bar{x}$, $\bar{p}$ at the end of the angle in terms of the x, p at the beginning of the angle. If $\chi_2 = 1$:

$$\bar{x} = x \cos 2\pi\alpha\nu + p \sin 2\pi\alpha\nu$$
$$\bar{p} = -x \sin 2\pi\alpha\nu + p \cos 2\pi\alpha\nu$$

where the same α and ν are used as those given by the cards of the previously discussed time type 1 ($\chi_1 = 1$). No additional cards or entries are needed. If $\chi_2 = 2$:

$$\bar{x} = x \cos 2\pi\alpha'\nu' + p \sin 2\pi\alpha'\nu'$$
$$\bar{p} = -x \sin 2\pi\alpha'\nu' + p \cos 2\pi\alpha'\nu'$$

where α', ν' are two different parameters for which two entries as follows are supplied following the above discussed group of entries specifying the time type.

TYPE	VALUE	COMPONENT
1	$\nu'\, 10^{-2}$	
2	α'	

If $\chi_2 = 3$,

$$\bar{x} = 0$$
$$\bar{p} = 0$$

and of course no entries or cards need be specified.

Upon ingesting an ANGLE the computer will print a line of three columns:

0 χ_1 χ_2

followed by as many two column lines as there are entries under the ANGLE on the SENARIO AGENDUM SHEET. These lines will replicate the identification digit and value of each entry.

The existence of a GAP is specified on the agendum sheet by a line

TYPE		VALUE	COMPONENT
χ_1	χ_2		GAP

It should be noted here that energy is expressed in this program and on all agenda in units in which

$$100 \text{ BEV} = 10^5 \text{MEV} = 1$$

so that for example

$$E_o = 938 \text{ MEV} = .00938$$

At the jth gap on the Nth revolution the particle suffers:

$$E \rightarrow \bar{E} = E + \Delta E$$

$$t \rightarrow \bar{t} = t$$

$$x \rightarrow \bar{x} = \frac{r(E)}{r(\bar{E})}(x + 1) - 1$$

$$p \rightarrow \bar{p} = \frac{r(E)}{r(\bar{E})} p$$

$$\phi_{j,N} = \phi_{j,N-1} + \omega_j \left(\frac{t_{j,N} + t_{j,N-1}}{2}\right)\left[t_{j,N} - t_{j,N-1}\right]$$

$$\Delta E = V_j(t_{j,N}) \sin \phi_{j,N}$$

where

$t_{j,N}$ = time of arrival of the particle at the jth oscillator on the Nth revolution

$\phi_{j,N}$ = phase of particle relative to j^{th} oscillator on N^{th} revolution

(all angles are measured in circles).

Here

$$r(E) = \left(\frac{E^2 - E_o^2}{1 - E_o^2}\right)^{\frac{1}{2k+2}}$$

The k used in this expression will be that pertinent to the angle just before the gap. It is therefore wise to start all SENARIOS with an angle to provide such a value. If k is uniform through all angles of the machine, this is not necessary since the input program which writes the execution program would have provided this value to be available for all subsequently discovered GAPS.

χ_1 gives the voltage type of the gap.

If $\chi_1 = 1$

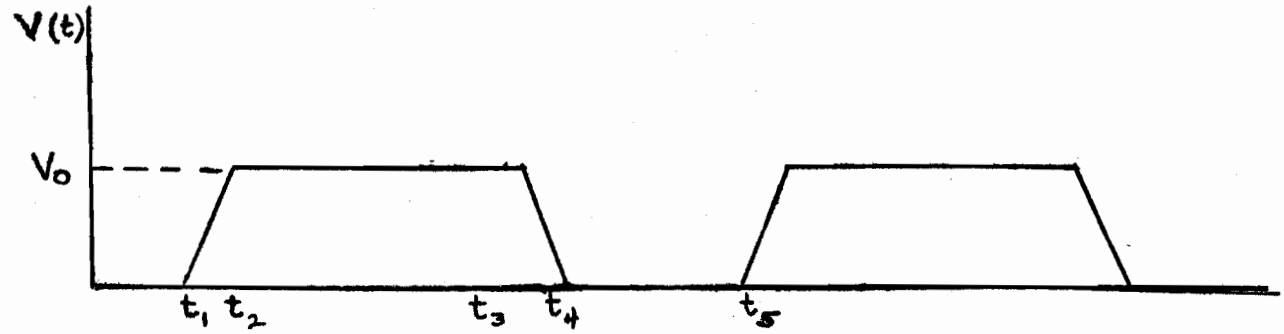
$V(t) = V_o$, a constant

An entry

TYPE	VALUE	COMPONENT
1	V_o 10^4	

must be made just following the GAP entry.

If $\chi_1 = 2$ the voltage has the form



The following identified entries are to be made on the agendum sheet just following the GAP entry.

TYPE	VALUE	COMPONENT
1	t_5	
2	$t_5 - t_4$	
3	$t_4 - t_3$	
4	$t_3 - t_2$	
5	$t_2 - t_1$	
6	$V_o\ 10^4$	

where times are measured in seconds. Note that the time origin t = 0 can be at any place on the above graph. The value t_5 serves to locate the phase of the voltage to the origin once it has been chosen. Each run through the machine can be given an initial time t_o (which need not be zero). However, once chosen, the initial time, the time origin and the time phase of all time varying components must be consistent.

χ_2 gives the frequency dependence of the gap oscillator.

If $\chi_2 = 1$

$$w(t) = w_o\ ,\ \text{a constant.}$$

Two identified entries are made on the agendum sheet just following the above group of voltage type entries:

TYPE	VALUE	COMPONENT
1	$\frac{w_o}{2\pi}\ 2^{-\lambda}$	
2	$\lambda\ 10^{-2}$	

where w is measured in radians/sec and where to retain numerical significance λ should be chosen as large as possible consistent with

$$\frac{w_o}{2\pi}\ 2^{-\lambda} < 1$$

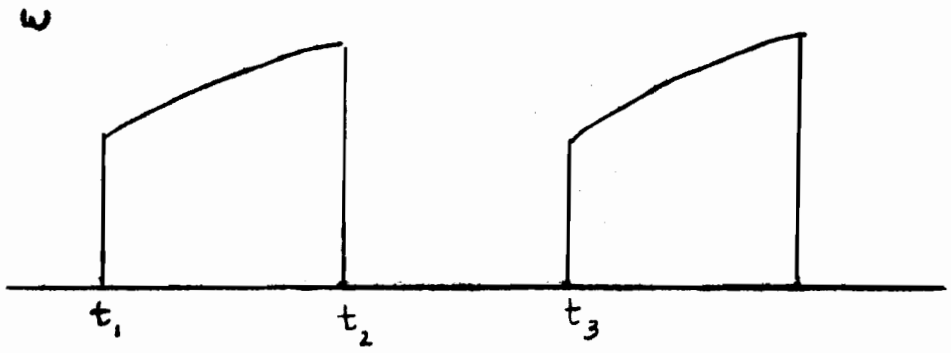
If $\chi_2 = 2$

CONSTANT ENERGY GAIN

w (t) will be used by the machine and parameters should be chosen so as to generate the expression:

$$\frac{\omega(t)}{2\pi} 2^{-\lambda} = \frac{\alpha\{\beta(t-t_1)+\gamma\}^{k/h+2}}{\left[E_0^2 + \{\beta(t-t_1)+\gamma\}^{\frac{2k+2}{k+2}}\right]^{1/2}} \qquad t_1 \leq t \leq t_2$$

$$\frac{\omega}{2\pi} 2^{-\lambda} = 0 \qquad t_1 \leq t \leq t_3$$



Here w is mea ured in radians/sec, t in seconds. The expression must be constructed so that

$$\frac{\omega}{2\pi} 2^{-\lambda} < 1$$

at all times.

To preserve scale and numerical significance the computer will evaluate

$$B \equiv \beta(t-t_1)+\gamma$$

as

$$B = 2^{\mu}(\beta 2^{-\mu})(t-t_1)+\gamma, \quad \mu \geq 0$$

The data are given by the following set of identified entries just following the voltage type entries.

TYPE		VALUE	COMPONENT
	1	t_3	
	2	$t_3 - t_2$	
	3	$t_2 - t_1$	
	4	α	
	5	$\rho 2^{-\mu}$	
	6	γ	
	7	$k\ 10^{-3}$	
	8	$\lambda\ 10^{-2}$	
	9	$\mu\ 10^{-2}$	

The same remarks pertain here with respect to the time origin as were made above in connection with voltage type 2.

After reading in the information pertaining to a GAP the computer will print a line of 3 columns:

$$1 \qquad x_1 \qquad x_2$$

followed by as many two column lines as is necessary to reproduce the identified entries following the GAP.

At present the program limits the number of gaps to twenty.

The third entity which can participate in the constitution of a machine is an energy dissipating FOIL which is called for by an entry

TYPE		VALUE	COMPONENT
X			FOIL

on the agendum sheet. Note that only one parameter which specifies the type of FOIL is necessary. It should be placed in the first column. A FOIL produces an energy loss

$$U = U(R)$$

where

$$R = R_o\, r(E)\,(1 + x)$$

where

$$r(E) = \left(\frac{E^2 - E_o^2}{1 - E_o^2}\right)^{\frac{1}{2k+2}}$$

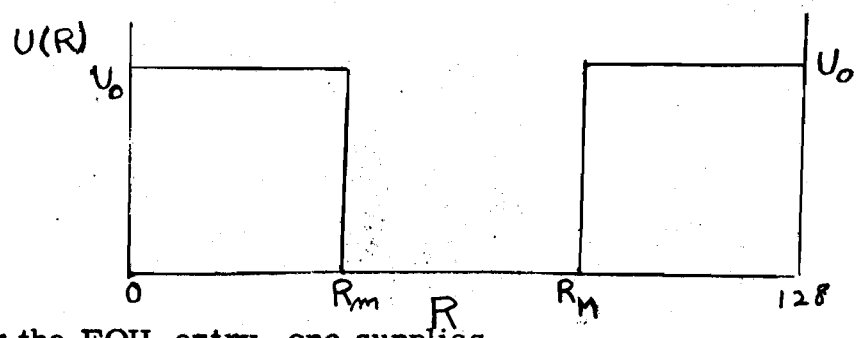
The R_o and k used in these expressions are those pertaining to the last ANGLE before the FOIL. If R_o and k are different for various angles in the machine, the SENARIO should be started with an ANGLE.

At a FOIL

$$E \rightarrow \bar{E} = E - U$$
$$t \rightarrow \bar{t} = t$$
$$x \rightarrow \bar{x} = (1 + x)\frac{r(E)}{r(\bar{E})} - 1$$

$$p \rightarrow \bar{p} = p\,\frac{r(E)}{r(\bar{E})}$$

If $\chi = 1$, the energy loss dependence U (R) of the FOIL is



Following the FOIL entry, one supplies

TYPE	VALUE	COMPONENT
1	$U_o 2^{13}$	
2	$R_m 2^{-7}$	
3	$R_M 2^{-7}$	

where U_o (which can also be negative) has units in which 10^5 MEV = 1, and R, R_m, R_M are measured in meters.

If $\chi = 2$, U (R) has the form

$$U(R) = U_o + U_1 R\,,\quad R < R_s$$
$$U(R) = U_o' + U_1' R\,,\quad R > R_s$$

with

U_o, U_o' in units in which 10^5 MEV = 1
U_1, U_1' in units in which 10^5 MEV/meter = 1
R, R_s in meters

U_o, U_o' U_1, U_1' can be positive, negative, or zero. After the FOIL card one supplies the entries.

TYPE	VALUE	COMPONENT
1	$U_o 2^5$	
2	$U_1 2^{12}$	
3	$R_s 2^{-7}$	
4	$U_o' 2^5$	
5	$U_1' 2^{12}$	

After ingesting the FOIL cards the computer prints a single 3 column line

2 χ 0

followed by as many two column lines as is necessary to replicate the entries pertinent to the foil type in hand.

After the machine has been completely delineated, i.e. "closed", one terminates the SENARIO with a single entry

TYPE	VALUE	COMPONENT
		CURTAIN

During the reading of the SENARIO the computer will check for internal consistency and scaling of the data and may halt rejecting the imperfect and unacceptable SENARIO.

Each SENARIO can be used for a series of many individual runs. Each of these is identified by an 11 digit ID number which should therefore have the form

$$ID = 10^8 A + i$$

where:

A = Human ID

i = Run ID.

The run ID number could if desired embrace the SENARIO ID number by use of some similar rule. This will be left to the discretion and desires of each user.

In this problem a "step" means carrying the particle through one component of the machine, i.e. an ANGLE, a GAP, or a FOIL. Thus the number of steps around a machine is the sum of its number of ANGLES, its number of GAPS, and its number of FOILS.

N_e = Number of steps in problem. For printing the machine has a larger period of $N_{WOP} + N_{WP}$ steps. During N_{WOP} steps no printing will occur, then during N_{WP} steps it can; during N_{WOP} steps it will not, etc. Within the N_{WP} portions, printing will occur every N_P steps. The counters C_e which counts from 0 to N_e, $C_{WOP/WP}$ which counts from 0 to $N_{WOP} + N_{WP}$, and C_P which

counts to N_P can be given initial settings $(C_e)_o$, $(C_{WOP/WP})_o$, and $(C_P)_o$ respectively.

Initial values E_o, t_o, x_o, p_o can be given to E (units 10^5 MEV = 1), t (units seconds), x, and p (dimensionless); and to the initial times and phases of the up to 20 gaps, $t_{j,o}$ (units seconds), $\phi_{j,o}$ (units in circles) where j = 1, 2, 3 . . . , $j_{MAX} \leq 20$.

Overflow limits have been established which can be set if desired. The problem will be stopped if

$$E \leq E_m$$
$$E \geq E_M$$
$$t \geq t_M$$
$$x \geq x_M$$
$$p \geq p_M$$

At the beginning of a series, all parameters are given the value 0 (except E_m, E_M, t_M, x_M, p_M which are given the values shown in parentheses on the TTT AGENDUM SHEET, a sample of which is attached). If any of these automatic values are satisfactory no corresponding entry should be made on the agendum sheet. All values are held from run to run. On subsequent runs of a series only those values which change should be entered on subsequent sheets. All sheets of a series should be securely stapled together. The initial counter settings $(C_e)_o$, $(C_{WOP/WP})_o$, $(C_P)_o$ are <u>not</u> held from run to run, and if initially set different from zero must be so reset on each run of a series.

At the beginning of each run will be printed:

00039	SENARIO ID	RUN ID			
00039	N_e	N_{WOP}	N_{WP}	N_P	
00039	E_m	E_M	t_M	x_M	p_M
	(space)				
00000	ϕ_o	E_o	t_o	x_o	p_o

Subsequent lines of printing will be controlled by the setting of sense switches 4 and 5. If SS5 is down a line

b + i ϕ E t x p

will be printed. If SS4 is down a line

b + i a ϕ E t

will be printed. Here $a = \sqrt{x^2 + p^2}$ and in the index b + i,

i = ordinal number of the line of print
b = 00000 if the print follows an ANGLE
= 10000 if the print follows a GAP
= 20000 if the print follows a FOIL

If overflows occur, the run will terminate and certain standard failure marks will be printed. These consist of a single 5 digit print index without a corresponding line of data. These failure marks and their causes are:

00000	Negative radicand in $\sqrt{x^2 + p^2}$
00001	$t > t_M$
00002	$E < E_m$
00003	$E > E_M$
00004	$x > x_M$
00005	$p > p_M$
00006	Argument negative in log in r(E)
00007	Argument > 0 for exp in r(E)
00008	More than 20 gaps
00009	$E \leq E_o$ in Time Type 1
00010	$-1 < B \leq 0$ in Frequency Type 2
00011	log B > 0 in Frequency Type 2
00013	$2^{13}U > 1$ in FOIL Type 2

If a run endures through N_e steps "END" will be printed.

After any run is terminated by overflow or by arrival at N_e steps, the next run of the series is automatically ingested and begun. However, this program also incorporates the "Search Feature"; as long as runs terminate by overflow the successive runs of a series will be automatically ingested and run. The first run of a series which instead terminates by reaching N_e steps will stop the entire series. Hence, by properly arranging a series of initial conditions, a boundary between two different modes of behavior can be delineated.

TTT (Program 39) AGENDUM SHEET

USE SENARIO NUMBER	

1. Staple a series of runs together with SENARIO AGENDUM sheet first.
2. All values, once set, are held from run to run. Only parameters whose values change need be entered on subsequent sheets of a series. This is not true of $(C_e)_o$, $(C_p)_o$ and $(C_{WOP/WP})_o$, which if set different from zero must be so reset on each run.
3. All quantities are initially set to zero at the beginning of a series. Omit such parameters.
4. The quantities given in parentheses are built into the program but may be altered if desired.

Print a, ϕ , E, t(SS4 DOWN)	
Print ϕ , E, t, x, p (SS5 DOWN)	
Search Feature (SS6 UP)	

INTEGERS

Address	Value	Parameter	Address	Value	Parameter
818		ID Number	801	(0)	$(C_e)_o$
819		N_e	802	(0)	$(C_{WOP/WP})_o$
820		N_{WOP}	803	(0)	$(C_p)_o$
821		N_{WP}			
822		N_P			
FRACTIONS					
825		E_o	831	(.00940)	E_m
826		t_o	832	(1/2)	E_M
827		x_o	833	(1/2)	t_M
828		p_o	834	(1/2)	x_M
725		$c2^{-29}$	835	(1/2)	p_M
681		E_o	682		$1 - E_o^2$
838		ϕ 1,0	858		ϕ 11,0
839		t 1,0	859		t 11,0
840		ϕ 1,0	860		ϕ 12,0
841		t 2,0	861		t 12,0
842		ϕ 3,0	862		ϕ 13,0
843		t 3,0	863		t 13,0
844		ϕ 4,0	864		ϕ 14,0
845		t 4,0	865		t 14,0
846		ϕ 5,0	866		ϕ 15,0
847		t 5,0	867		t 15,0
848		ϕ 6,0	868		ϕ 16,0
849		t 6,0	869		t 16,0
850		ϕ 7,0	870		ϕ 17,0
851		t 7,0	871		t 17,0
852		ϕ 8,0	872		ϕ 18,0
853		t 9,0	873		t 19,0
854		ϕ 9,0	874		ϕ 19,0
855		t 9,0	875		t 19,0
856		ϕ 10,0	876		ϕ 20,0
857		t 10,0	877		t 20,0

TTT (PROGRAM 39) SENARIO AGENDUM SHEET

Staple to front of a series of runs

Page _____ of _____ pages

SENARIO NUMBER

TYPE	VALUE	COMPONENT	TYPE	VALUE	COMPONENT

MEMORANDUM

TO: ALL

February 21, 1957

FROM: J

This memorandum should be regarded as an integral part of the description of TTT (Programme 39) and should be attached thereto in a secure and permanent fashion.

Referring to the description of time type 2 (page 3, top) indicated by the symbol $X_1 = 2$, the user should notice that card 3 is nowhere used in the resultant computation and therefore need not be present, as stated. However, this will require the operator to manually bypass several division hang-ups. In order to continue to subscribe to the "Society for Prevention of Insanity Among Computer Operators" a card 3 should be entered on the Senario even for time type 2. The value on card 3 can be any non-zero fraction, for example, 1/2.

MEMORANDUM March 14, 1957

TO: One and All

FROM: Jim

This memorandum has arisen as a result of consultations between Keith Symon and the author. It should be attached to and become a permanent part of the description of TTT (Programme 39).

The TTT programme may be changed in scale so that particles other than protons can be treated. Considerable thought should be applied to these attempts and the following rules and procedures adhered to:

(1) Select convenient units of energy, time, and distance. These do not appear on the agendum sheet but will be inserted in a special fashion later (see below). They must be kept in mind when writing the Senario and when interpreting the output from a given Senario. All energies E and voltages V, all times t, all distances R, all velocities c, all frequencies w, etc., are to be supplied in these units. The units must be chosen so that all energies, times, distances scaled by 2^{-7}, and in fact every quantity, remain less than 1. If foils appear in the Senario, additional restrictions may have to be applied.

(2) Three additional quantities must be inserted into the programme. These must be placed among the group of fractions pertaining to the first run of any series to be run on this Senario. When this insertion is made on the first run of a series the scaling will be changed for every run of this series. To use this facility, prepare a sheet of paper containing the following three quantities and staple it to the front of such a series just before the sheet pertaining to the first run of that series.

Address	Quantity
681	E_o
682	$1 - E_o^2$
725	$c\ 2^{-29}$

Here E_o is the rest energy of the particle in the chosen units and c is the velocity of light in these units.

The implications of this attempt to change the scale may be far-reaching. The Computer Division will extend all cooperation in an attempt to make this work. However, many hidden and subtle barriers may be encountered.

MEMORANDUM

TO: Everyman

April 4, 1957

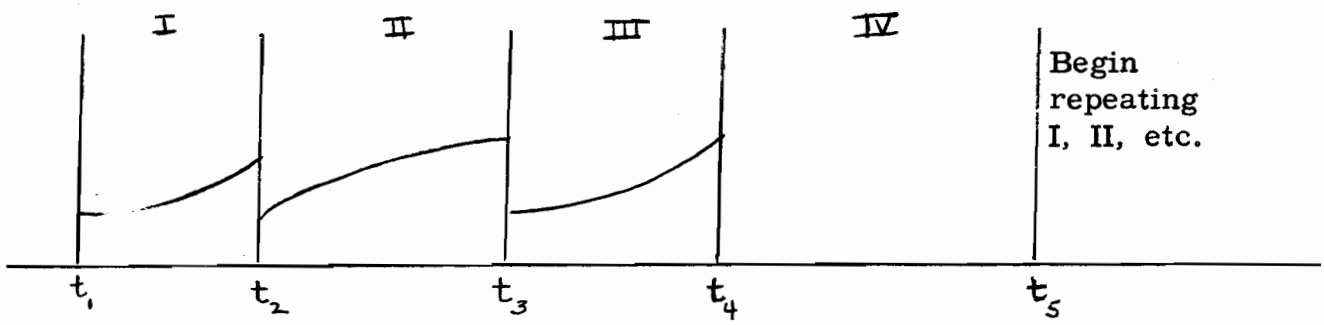
FROM: As usual

This memorandum augments TTT (Programme 39). It should be attached thereto.

A frequency of type 3 ($\chi_2 = 3$) (see page 3 of TTT description) has been provided.

If $\chi_2 = 3$

w (t) will have the form



where:

$$\frac{\omega_I}{2\pi} 2^{-\lambda} = a_I + b_I \left(\frac{t'-t_1}{\tau_I}\right) + c_I \left(\frac{t'-t_1}{\tau_I}\right)^2 + d_I \left(\frac{t'-t_1}{\tau_I}\right)^3$$

$$\frac{\omega_{II}}{2\pi} 2^{-\lambda} = a_{II} + b_{II} \left(\frac{t'-t_2}{\tau_{II}}\right) + c_{II} \left(\frac{t'-t_2}{\tau_{II}}\right)^2 + d_{II} \left(\frac{t'-t_2}{\tau_{II}}\right)^3$$

$$\frac{\omega_{III}}{2\pi} 2^{-\lambda} = a_{III} + b_{III} \left(\frac{t'-t_3}{\tau_{III}}\right) + c_{III} \left(\frac{t'-t_3}{\tau_{III}}\right)^2 + d_{III} \left(\frac{t'-t_3}{\tau_{III}}\right)^3$$

$$\omega_{IV} \equiv 0$$

Here:

$t' = t - t_F < t_5 - t_1$

$t_F = n\,(t_5 - t_1)$, where n is an integer.

The restrictions:

$\tau_I > t_2 - t_1$
$\tau_{II} > t_3 - t_2$
$\tau_{III} > t_4 - t_3$

must be observed.

In the above w is measured in radians/sec, t in seconds. The expressions must be such that

$$\frac{w}{2\pi} 2^{-\lambda} < 1$$

and such that all quantities entered on the SENARIO AGENDUM SHEET must be less than 1.

The data are given by the following set of identified entries just following the voltage type entries on the SENARIO AGENDUM SHEET:

TYPE	VALUE	COMPONENT
1	t_5	
2	$t_5 - t_4$	
3	$t_4 - t_3$	
4	$t_3 - t_2$	
5	$t_2 - t_1$	
6	τ_I	
7	a_I	
8	b_I	
9	c_I	
10	d_I	
11	τ_{II}	
12	a_{II}	
13	b_{II}	
14	c_{II}	
15	d_{II}	
16	τ_{III}	
17	a_{III}	
18	b_{III}	
19	c_{III}	
20	d_{III}	
21	$\lambda 10^{-2}$	

Some of the time differences may be zero; any of the quantities which are not pertinent (i. e. are zero) may be omitted, <u>except</u> that card 21 (λ 10^{-2}) must always be present and must come last. Note that it is required that a single value of λ must satisfactorily scale w_I , w_{II} , and w_{III} .

Note that the time origin t = 0 can be at any place on the above graph. The value of t_5 serves to locate the phase of the frequency variation with respect to the origin once the latter has been chosen. Each run through the machine can be given an initial time t_o (which need not be zero). However, once chosen, the initial time, the time origin, and the time phase of all time varying components must be consistent.

MEMORANDUM

ZU: Al en Menschen

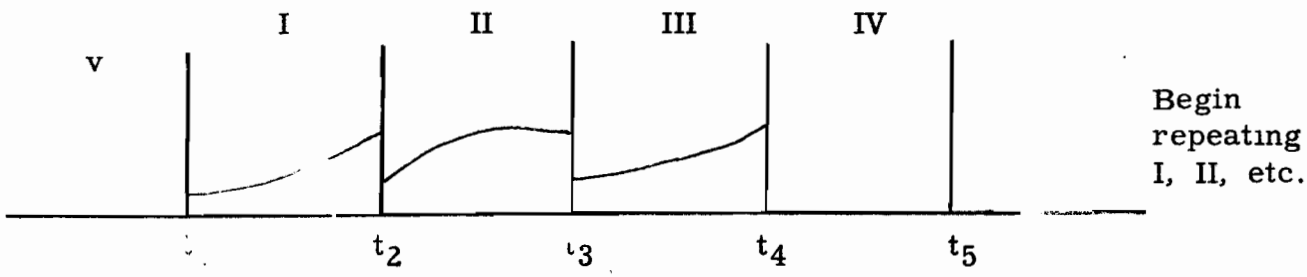
VON: Jess An erson

This pro ramme augment the TT' family (Pro ammes and 119 and should be atta hed to t e description thereof n a erm nent and ecure ashion.

A volta e of typ 3 (γ_1 = , se page 3 of he des iption) ha been provided

If γ_1 - 3

v will hav the form



whe e

$$10^4 V_I = a_I + \left(\frac{t' - t}{\tau_I}\right) + c_I\left(\frac{t' - t_1}{\tau_I}\right)^2 + \ _I\left(\frac{t' \ t_1}{\tau_I}\right)$$

$$10^4 V_{II} = a_{II} + \ _{II}\left(\frac{\ t_2}{\tau_{II}}\right) + c_{II}\left(\frac{t' - t_2}{\tau_{II}}\right) + \left(\frac{t' - \ }{\tau_{II}}\right)^3$$

$$10^4 V_{III} = a_{III} + b_{III}\left(\frac{\ - t_3}{\tau_{III}}\right) + c_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^2 + d_{III}\left(\frac{t \ t_3}{\tau_{III}}\right)^3$$

V_{IV} =

Here

$t' = t \quad t_F < \ - t$

$t_F = n\ (t_5 - t_1$ where n is an integer.

The restrictions

$\tau_I \quad t_2 - t$
$\tau_{II} \quad t_3 - t$
$\tau_{III} \quad t_4 - t_3$ <u>must</u> be observed.

The values must be such that

$$10^4 V < 1$$

and all quantities entered on the SENARIO AGENDUM SHEET are less than 1.

The data are given by the following set of identified entries just following the GAP entry on the SENARIO AGENDUM SHEET:

TYPE	VALUE	COMPONENT
1	t_5	
2	$t_5 - t_4$	
3	$t_4 - t_3$	
4	$t_3 - t_2$	
5	$t_2 - t_1$	
6	τ_I	
7	a_I	
8	b_I	
9	c_I	
10	d_I	
1	τ_{II}	
1	$_{II}$	
13	b_{II}	
14	c_{II}	
15	d_{II}	
16	τ_{III}	
1	a_{III}	
18	b_{III}	
19	c_{III}	
20	d_{III}	

Some of the time differences may be zero; any quantity which is not pertinent (i.e., zero) may be omitted, <u>except</u> that card 20 (d_{III}) must be present and must be last.

Note that the time origin $t = 0$ can be at any place on the above graph. The value of t_5 serves to locate the phase of the voltage variation with respect to the origin once the latter has been chosen. Each run through the machine can be given an initial time t_o (which need not be zero). However, once chosen, the initial time, the time origin, and the time phase of all time varying components must be consistent.

MEMORANDUM

From:
To:

CONCERNING AUGMENTATIONS TO TTT (Program 39)

This memorandum constitutes an intrinsic part of the TTT description and should be attached thereto in such a secure and positive fashion as to guarantee that it will never come asunder leading thereby to confusion and error.

Transformation Type 4

This transformation is specified by ANGLE $\chi_2 = 4$ (see page 3 of TTT description). This transformation type is similar to type 3 in that the betatron oscillations are suppressed

$$\bar{X} = 0$$

$$\bar{P} = 0 .$$

However, time is saved in that the r (E) function (see page 4) at subsequent GAPS is not computed. This function is not needed if betatron oscillations are not being studied. But it should be carefully pointed out that if any one ANGLE of a machine is given $\chi_2 = 4$, then all gaps of the machine will have r (E) suppressed even if other ANGLES are given some other χ_2. Hence if it is desired to suppress betatron oscillations only at certain ANGLES and not at others, the transformation type $\chi_2 = 3$ should be used at the ANGLES to be suppressed.

No additional data cards are needed for transformation type $\chi_2 = 4$.

Time Type 3

If at an ANGLE, $\chi_1 = 3$ be specified, the time function (see page 2)

$$F(E, \alpha) = \frac{\alpha}{f(E)}$$

will be used, where

$$2^{-\sigma} f(E) = a + b\left(\frac{E - E_1}{\epsilon}\right) + c\left(\frac{E - E_1}{\epsilon}\right)^2 + d\left(\frac{E - E_1}{\epsilon}\right)^3 .$$

Note that α measures the angle in units of a circle; σ, a, b, c, d, E_1, and ϵ must be chosen so that the quantity $2^{-\sigma} f(E)$ lies in scale. ϵ must be chosen so that $\epsilon > E - E_1$ for all E to be expected in the problem.

Data cards as follows must be supplied:

TYPE	VALUE	COMPONENT
1	E_1	
2	ϵ	
3	a	
4	b	
5	c	
6	d	
7	$k\ 10^{-3}$	
8	$\sigma 10^{-2}$	
9	α	

The identifying digits must be prefixed; all quantities entered must be less than 1; the 9th card, α , must be present and must be last in the group.

Although the quantity k is not used in the ANGLE portion of the computation, it is present in case betatron oscillations are not to be suppressed (i. e. $\chi_2 \neq 4$) so that a k will be available for the evaluation of r $\overline{(E)}$ at the successive angle. If $\chi_2 = 4$, then the k card may be omitted. Except for the α card, any card may be omitted with the result that the value zero will be automatically substituted.

Note that three time types are now available $\chi_1 = 1, 2, 3$. Any mixture of $\chi_1 = 1$ and $\chi_1 = 3$ may be used with a multi-ANGLE machine. Similarly any mixture of $\chi_1 = 2$ and $\chi_1 = 3$ may be used. But if any ANGLE is marked $\chi_1 = 2$ then all ANGLES marked $\chi_1 = 1$ will also become $\chi_1 = 2$. The $\chi_1 = 3$ ANGLES will be unaffected.

If a FOIL follows an ANGLE the k given by the $\chi_1 = 1, 2,$ or 3 of the ANGLE will be used in evaluating the r (E) necessary in the FOIL routine. If $\chi_1 = 1$ or 2 is used for the ANGLE, the R_o needed by the subsequent FOIL is provided. If a mixture of $\chi_1 = 1$ or 2 and $\chi_1 = 3$ is used for a multi-ANGLE, multi-FOIL machine, the R_o provided by a $\chi_1 = 1$ or 2 ANGLE will persist through subsequent $\chi_1 = 3$ ANGLES until the next $\chi_1 = 1$ or 2 ANGLE is encountered. If no ANGLE is $\chi_1 = 1$ or 2 type but all ANGLES are of $\chi_1 = 3$ type an appropriate $R_o\ 2^{-7}$ should be entered on the agendum sheet at location 779 among the group of fractions.

Extra Printing Provision

If an agendum sheet is clearly inscribed with the graffiti "USE BROWN EXTRA PRINT CARDS" a second line of printing will follow each 5-column type print (if called for). The 4-column type print will be unaffected. The identifying digits on this line will be the same as the corresponding line above.

If printing is called for after a GAP the quantities printed will be:

F: time interval to traverse previous ANGLE
r (E + ΔE): argument is energy after GAP
$\frac{\omega}{2\pi} 2^{-\lambda}$: oscillator frequency of the GAP

If the printing is called for after an ANGLE, the quantities printed will be:

F: time interval to traverse that ANGLE
r (E + ΔE): argument is energy after last previous GAP
$\frac{\omega}{2\pi} 2^{-\lambda}$: oscillator frequency at last GAP

In any case, if χ_2 = 4 type ANGLES are being used, the second quantity printed, r (E + ΔE), will neither be pertinent or meaningful.

MEMORANDUM

TO: JEDER MANN

No. 1 of June 12, 1957

FROM: ME

This memorandum pertains to TTT (Programme 39); it should be attached thereto, become an irrevocable part thereof, and be carefully consulted each time agenda for TTT are prepared.

It has come to my attention that the SENARIO ID NUMBER has been failing to produce itself on the printed output of TTT. The reason for this has been discovered. This particular number must be no more than eight decimal digits since it is read by a different read routine than is usually used to read ID numbers. If this rule will obtain, then it can be guaranteed that the SENARIO ID NUMBER will be printed on each SENARIO print and on each subsequent TTT run.

The above remarks do not apply to the TTT RUN ID NUMBERS which must only conform to the rule of being less than 34 359 738 367.

November 3, 1958

MEMORANDUM

TO: Computer Users

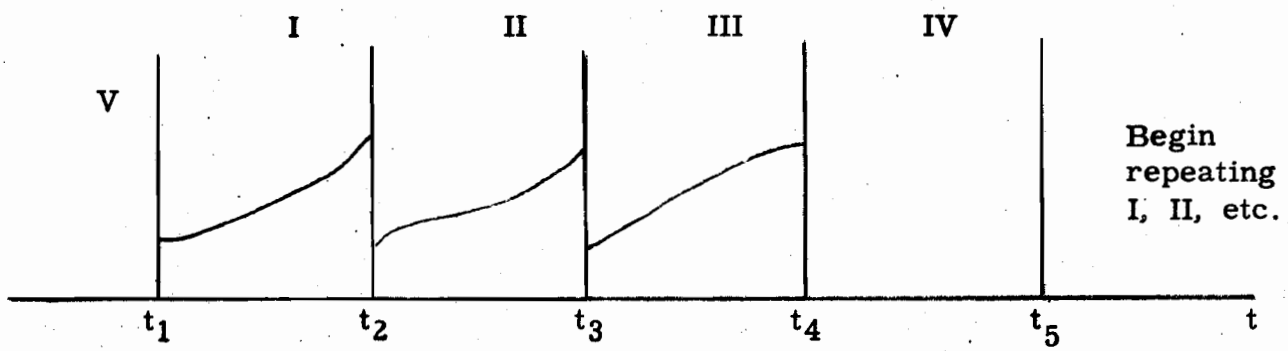
FROM: Jess Anderson

SUBJECT: Computer Program - TTT

The TTT and TTT Scope Programs have been augmented as described below. This memo should be attached securely to and become an integral part of the full write-ups of both programs.

A voltage type 4 ($\chi_1 = 4$, cf. page 3 of the main write-up) has been provided.

If $\chi_1 = 4$, V(t) will have the form



where

$$10^4 V_I = \frac{a_I + b_I\left(\frac{t' - t_1}{\tau_I}\right) + c_I\left(\frac{t' - t_1}{\tau_I}\right)^2 + d_I\left(\frac{t' - t_1}{\tau_I}\right)^3 + e_I\left(\frac{t' - t_1}{\tau_I}\right)^4}{f_I + g_I\left(\frac{t' - t_1}{\tau_I}\right) + h_I\left(\frac{t' - t_1}{\tau_I}\right)^2 + i_I\left(\frac{t' - t_1}{\tau_I}\right)^3 + j_I\left(\frac{t' - t_1}{\tau_I}\right)^4}$$

$$10^4 V_{II} = \frac{a_{II} + b_{II}\left(\frac{t' - t_2}{\tau_{II}}\right) + c_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^2 + d_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^3 + e_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^4}{f_{II} + g_{II}\left(\frac{t' - t_2}{\tau_{II}}\right) + h_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^2 + i_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^3 + j_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^4}$$

$$10^4 V_{III} = \frac{a_{III} + b_{III}\left(\frac{t' - t_3}{\tau_{III}}\right) + c_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^2 + d_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^3 + e_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^4}{f_{III} + g_{III}\left(\frac{t' - t_3}{\tau_{III}}\right) + h_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^2 + i_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^3 + j_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^4}$$

$$10^4 V_{IV} = 0.$$

Here

$$t' = t - t_F < t_5 - t_1$$

$$t_F = n\,(t_5 - t_1),\ n \text{ an integer.}$$

The restrictions

$$\tau_I > t_2 - t_1$$

$$\tau_{II} > t_3 - t_2$$

$$\tau_{III} > t_4 - t_3$$ must be observed.

The values must be such that $10^4\,V < 1$ and all quantities entered on the SENARIO AGENDUM SHEET are less than 1.

The data are given by the following set of identified entries just following the GAP entry on the SENARIO AGENDUM SHEET.

TYPE	VALUE	COMPONENT
1	t_5	
2	$t_5 - t_4$	
3	$t_4 - t_3$	
4	$t_3 - t_2$	
5	$t_2 - t_1$	
6	τ_I	
7	a_I	
8	b_I	
9	c_I	
10	d_I	
11	e_I	
12	f_I	
13	g_I	
14	h_I	
15	i_I	
16	j_I	
17	τ_{II}	
18	a_{II}	
19	b_{II}	
20	c_{II}	
21	d_{II}	
22	e_{II}	
23	f_{II}	
24	g_{II}	
25	h_{II}	
26	i_{II}	
27	j_{II}	

28	τ_{III}
29	a_{III}
30	b_{III}
31	c_{III}
32	d_{III}
33	e_{III}
34	f_{III}
35	g_{III}
36	h_{III}
37	i_{III}
38	j_{III}

Some of the time differences may be zero; any quantity which is not pertinent (i.e., is zero) may be omitted, <u>except</u> that card 38 (j_{III}) must be present and must be last.

Note that the time origin $t = 0$ can be at any place on the above graph. The value of t_5 serves to locate the phase of the voltage variation with respect to the origin once the latter has been chosen.

Each run through the machine can be given an initial time t_o (which need not be zero). However, once chosen, the initial time, the time origin, and the time phase of all time varying components must be consistent.

August 24, 1959

MEMORANDUM

TO: Technical Staff
FROM: G. A. Westlund
SUBJECT: Changes to TTT (program 39)

Certain changes to TTT have been suggested by Robert Stump. The original equation

$$S(x, p, \alpha) = 2\pi\alpha + \frac{x}{\nu} \sin 2\pi\alpha\nu + \frac{p}{\nu} (1 - \cos 2\pi\alpha\nu)$$
$$+ \frac{x^2}{4\nu^2} (2\pi\alpha - \frac{1}{2} \sin 4\pi\alpha\nu) + \frac{xp}{4\nu^2} (\cos 4\pi\alpha\nu - 1)$$
$$+ \frac{p^2}{4\nu^2} (2\pi\alpha + \frac{1}{2} \sin 4\pi\alpha\nu)$$

has been changed to

$$S(x, p, \alpha) = 2\pi\alpha + \frac{x}{\nu} \sin 2\pi\alpha\nu + \frac{p}{\nu} (1 - \cos 2\pi\alpha\nu)$$
$$+ \frac{x^2\nu^2}{4} (2\pi\alpha - \frac{1}{2\nu} \sin 4\pi\alpha\nu) + \frac{xp\nu}{4} (\cos 4\pi\alpha\nu - 1)$$
$$+ \frac{p^2\nu^2}{4} (2\pi\alpha + \frac{1}{2\nu} \sin 4\pi\alpha\nu)$$

The accuracy of the result for S after 100 integration steps has been found to be within 2 parts in one million with this new method.

Since certain scaling problems were introduced by the change, it is now necessary to scale up the entry values of x_o and p_o by ten. This means the user must now enter $10\,x_o$ and $10\,p_o$ instead of x_o and p_o on his agendum sheet.

Since this change is considered to correct the formula for S, this memo should become a permanent part of the original TTT program reports.

October 26, 1959

MEMORANDUM

TO: Computer Users

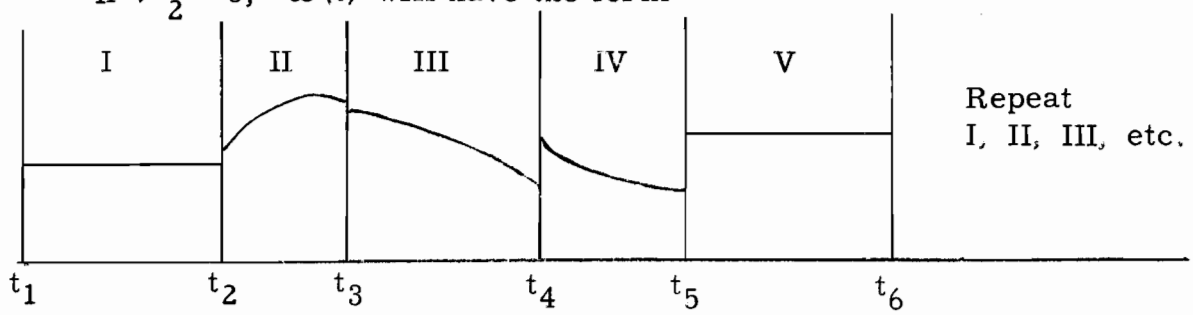
FROM: H. L. Carlson

SUBJECT: Computer Program - TTT (Program No. 39)

This memorandum augments the TTT program and should be a permanent part of the TTT write-up.

A frequency of type 5 ($\chi_2 = 5$) has been provided (see p. 3 of TTT write-up).

If $\chi_2 = 5$, $\omega(t)$ will have the form



where

$$\frac{\omega_I}{2\pi}\, 2^{-\lambda} = a_I$$

$$\frac{\omega_{II}}{2\pi}\, 2^{-\lambda} = \frac{a_{II} + b_{II}\left(\frac{t' - t_2}{\tau_{II}}\right) + c_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^2 + d_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^3 + e_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^4}{f_{II} + g_{II}\left(\frac{t' - t_2}{\tau_{II}}\right) + h_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^2 + i_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^3 + j_{II}\left(\frac{t' - t_2}{\tau_{II}}\right)^4}$$

$$\frac{\omega_{III}}{2\pi}\, 2^{-\lambda} = \frac{a_{III} + b_{III}\left(\frac{t' - t_3}{\tau_{III}}\right) + c_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^2 + d_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^3 + e_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^4}{f_{III} + g_{III}\left(\frac{t' - t_3}{\tau_{III}}\right) + h_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^2 + i_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^3 + j_{III}\left(\frac{t' - t_3}{\tau_{III}}\right)^4}$$

$$\frac{\omega_{IV}}{2\pi}\, 2^{-\lambda} = \frac{a_{IV} + b_{IV}\left(\frac{t' - t_4}{\tau_{IV}}\right) + c_{IV}\left(\frac{t' - t_4}{\tau_{IV}}\right)^2 + d_{IV}\left(\frac{t' - t_4}{\tau_{IV}}\right)^3 + e_{IV}\left(\frac{t' - t_4}{\tau_{IV}}\right)^4}{f_{IV} + g_{IV}\left(\frac{t' - t_4}{\tau_{IV}}\right) + h_{IV}\left(\frac{t' - t_4}{\tau_{IV}}\right)^2 + i_{IV}\left(\frac{t' - t_4}{\tau_{IV}}\right)^3 + j_{IV}\left(\frac{t' - t_4}{\tau_{IV}}\right)^4}$$

$$\frac{\omega_V}{2\pi}\, 2^{-\lambda} = a_V$$

$$t' = t - t_F < t_6 - t_1$$

$$t_F = n\,(t_6 - t_1), \text{ where } n \text{ is an integer.}$$

The following restrictions <u>must</u> be observed.

$$\tau_{II} > t_3 - t_2 ,$$
$$\tau_{III} > t_4 - t_3 ,$$
$$\tau_{IV} > t_5 - t_4 ,$$

and

$$\frac{\omega}{2\pi}\, 2^{-\lambda} < 1 ,$$ where ω is in radians/sec and t in seconds.

Also, all quantities on the SENARIO AGENDUM SHEET must be less than 1.

The data for this TTT augmentation should be entered on the SENARIO AGENDUM SHEET just following the voltage-type entries and should have the form as shown on page 4 of this write-up.

Some of the time differences may be zero; any of the quantities which are zero may be omitted, except that card 42 ($\lambda \cdot 10^{-2}$) must always be present and must come last. Note that this single value of λ must properly scale all of the ω's.

The time origin $t = 0$ can be at any place on the graph (page 1). The value of t_6 serves to locate the phase of the frequency variation with respect to the origin once the latter has been chosen. Each run through the machine can be given an initial time, t_o (not necessarily zero). However, once chosen, the initial time, the time origin, and the time phase of all time varying components must be consistent.

TTT (χ_2 = 5 Modification)

TYPE	VALUE	COMPONENT
1	t_6	
2	$t_6 - t_5$	
3	$t_5 - t_4$	
4	$t_4 - t_3$	
5	$t_3 - t_2$	
6	$t_2 - t_1$	
7	a_1	
8	τ_{II}	
9	a_{II}	
10	b_{II}	
11	c_{II}	
12	d_{II}	
13	e_{II}	
14	f_{II}	
15	g_{II}	
16	h_{II}	
17	i_{II}	
18	j_{II}	
19	τ_{III}	
20	a_{III}	
21	b_{III}	
22	c_{III}	
23	d_{III}	
24	e_{III}	
25	f_{III}	
26	g_{III}	
27	h_{III}	
28	i_{III}	
29	j_{III}	
30	τ_{IV}	
31	a_{IV}	
32	b_{IV}	
33	c_{IV}	
34	d_{IV}	
35	e_{IV}	
36	f_{IV}	
37	g_{IV}	
38	h_{IV}	
39	i_{IV}	
40	j_{IV}	
41	a_V	
42	$\lambda \cdot 10^{-2}$	