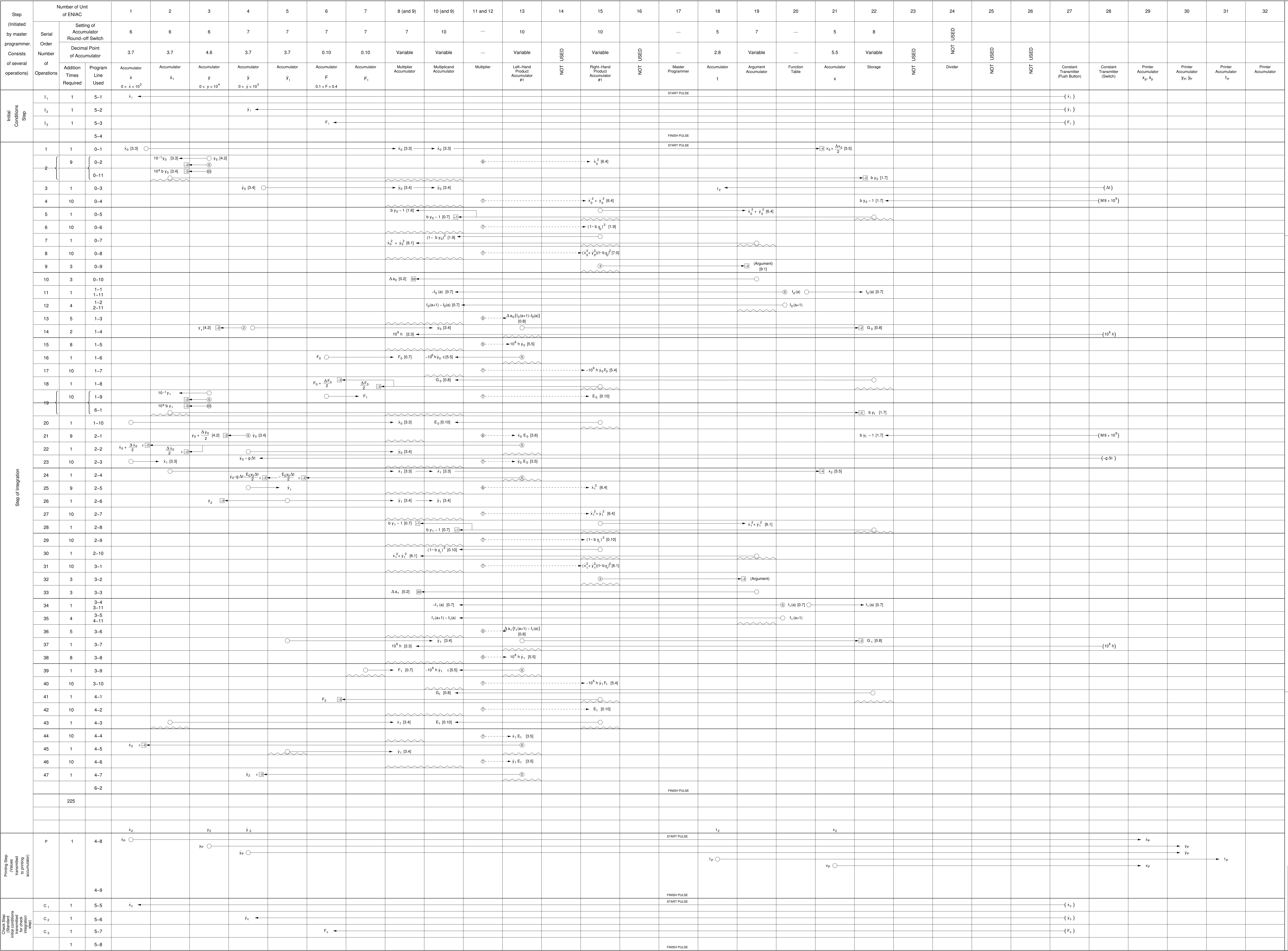

CODE

○	Transmit from add output to accumulator indicated.
Ⓢ	Transmit from subtract output to accumulator indicated.
ⓝ	Transmit from add output n times to accumulator indicated.
Sn	Transmit from subtract output n times to accumulator indicated.
$\boxed{n}$	Indicates that incoming number is shifted n places to to the left before being placed in accumulator. (A negative number indocates a shift to the right.)
[n.p]	Indicates number of digits before and after decimal point respectively.
⋀⋀⋀	Clear contents of accumulator to zero.
◇n	Indicates the number of multiplier digits used in multiplication.
f(a)	Function table transmits the value of the function corresponding to the first two places of the argument, i.e. corresponding to the 4th and 5th places in the argument accumulator.
f(a+1)	Function table transmits the value of the function corresponding to the first two places of hhe argument plus 1.
$\boxed{2d}$	Indicates a special adaptor which deletes all but the 6th & 7th places of the argument and shifts them five places to the left.
◇- - - -	Indicates multiplication.
c.	Indicates correction pulse must be put in

DIFFERENCE EQUATIONS

(HEUN METHOD)

NOTATION:

Values at beginning of integration step:

$$t_0 \quad x_0 \quad \dot{x}_0 \quad y_0 \quad \dot{y}_0 \quad F_0 \quad G_0 \quad E_0$$

Intermediate values of variables:

$$x_1 \quad \dot{x}_1 \quad y_1 \quad \dot{y}_1 \quad F_1 \quad G_1 \quad E_1$$

Values at end of integration steps:

$$t_2 \quad x_2 \quad \dot{x}_2 \quad y_2 \quad \dot{y}_2 \quad F_2$$

VALUES OF CONSTANTS:	RANGE OF VARIABLES	
$\frac{\Delta t}{2} = 0.01$ seconds	$0 < x < 10^5$	meters
$b = 9.85 \times 10^{-6} \frac{1}{\text{meters}}$	$0 < y < 10^4$	meters
$h = 95.736 \times 10^{-6} \frac{1}{\text{meters}}$	$0 < \dot{x} < 10^3$	$\frac{\text{meters}}{\text{second}}$
$H_0 = 1$	$0 < \dot{y} < 10^3$	$\frac{\text{meters}}{\text{second}}$
$c = 2.5$ to 5.0	$0 < (x^2 + y^2) < \frac{1}{3} 10^6$	
$F_0 = \frac{1}{c}$	$0.1 < F < 0.4$	

THE EQUATIONS:

$$t_2 = t_0 + 2\left(\frac{\Delta t}{2}\right)$$

$$\frac{\Delta \dot{y}_0}{2} = -(E_0 \dot{y}_0 + g)\frac{\Delta t}{2} \qquad \dot{y}_1 = \dot{y}_0 + 2\left(\frac{\Delta \dot{y}_0}{2}\right)$$

$$\frac{\Delta \dot{y}_1}{2} = -(E_1 \dot{y}_1 + g)\frac{\Delta t}{2} \qquad \dot{y}_2 = \dot{y}_0 + \frac{\Delta \dot{y}_0}{2} + \frac{\Delta \dot{y}_1}{2}$$

$$\frac{\Delta \dot{x}_0}{2} = -(E_0 \dot{x}_0)\frac{\Delta t}{2} \qquad \dot{x}_1 = \dot{x}_0 + 2\left(\frac{\Delta \dot{x}_0}{2}\right)$$

$$\frac{\Delta \dot{x}_1}{2} = -(E_1 \dot{x}_1)\frac{\Delta t}{2} \qquad \dot{x}_2 = \dot{x}_0 + \frac{\Delta \dot{x}_0}{2} + \frac{\Delta \dot{x}_1}{2}$$

$$\frac{\Delta F_0}{2} = -(h F_0 \dot{y}_0)\frac{\Delta t}{2} \qquad F_1 = F_0 + 2\left(\frac{\Delta F_0}{2}\right)$$

$$\frac{\Delta F_1}{2} = -(h F_1 \dot{y}_1)\frac{\Delta t}{2} \qquad F_2 = F_0 + \frac{\Delta F_0}{2} + \frac{\Delta F_1}{2}$$

$$\frac{\Delta y_0}{2} = \dot{y}_0 \frac{\Delta t}{2} \qquad y_1 = y_0 + 2\left(\frac{\Delta y_0}{2}\right)$$

$$\frac{\Delta y_1}{2} = \dot{y}_1 \frac{\Delta t}{2} \qquad y_2 = y_0 + \frac{\Delta y_0}{2} + \frac{\Delta y_1}{2}$$

$$\frac{\Delta x_0}{2} = \dot{x}_0 \frac{\Delta t}{2} \qquad x_2 = x_0 + \frac{\Delta x_0}{2} + \frac{\Delta x_1}{2}$$

$$\frac{\Delta x_1}{2} = \dot{x}_1 \frac{\Delta t}{2} \qquad t_2 = t_0 + \Delta t$$

The range of the argument of G is extended by a factor of 3 to make full use of the range of the E.N.I.A.C. function table. Hence:

$$G_0 = G\left[\,3(\dot{x}_0^2 + \dot{y}_0^2)(1 - b\,y_0)^2\,\right] \qquad E_0 = F_0 G_0$$

$$G_1 = G\left[\,3(\dot{x}_1^2 + \dot{y}_1^2)(1 - b\,y_1)^2\,\right]$$

Linear interpolation is performed to get the value for G. Hence:

$$G = f(a) + \Delta a\,[\,f(a+1) - f(a)\,]$$

where a is the first two places of the argument, and Δ a, the third and fourth places.

MOORE SCHOOL OF ELECTRICAL ENGINEERING
UNIVERSITY OF PENNSYLVANIA

SETUP OF EXTERIOR BALLISTIC EQUATIONS

Drawn by	Checked by	Approved by	
RAB January 1944			PX–1–81