

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Memorandum

TO : Mr. Jenke, JB-3
Through: ~~Mr. Kampmeier, R-ASTR-BV~~
9-11-10-66

FROM : Chief, Guidance and Control Systems
Analysis Branch, R-ASTR-NG

DATE: November 10, 1966
In reply refer to:
R-ASTR-NG-156-66
ECSmith/vjd/876-4595

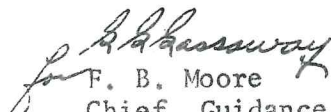
SUBJECT: Saturn V/501 open loop transient response study

1. Purpose: This memorandum presents the results of the open loop transient response study of the Saturn V/501 flight control computers. The results are provided for information purposes in comparison with the pre-launch tests by JB.
2. Results: The results of these tests are shown in the enclosed Figures 2 through 27 for computer number 503. These curves are representative of the flight control computer number 504.
3. Test Arrangement:
 - a. The test arrangement for measuring the transient response in actuator motion (β) is shown in the enclosed Figure 1a. This arrangement consisted of the flight control computer, simulated valves and actuators, and an operational amplifier for isolation purposes.
 - b. The test arrangement for measuring the transient response in the output of the control computer (i_v) is shown in the enclosed Figure 1b. This arrangement consisted of the control computer operating into dummy loads, and an operational amplifier for isolation purposes.
4. Test Procedure: The actuator motion (β) and computer output (i_v) were recorded in response to a step input to the (ψ) and (ϕ) channels, respectively. Responses were obtained for each control gain for the inputs listed in the enclosed Table I. The table also includes the corresponding calculated steady-state outputs. The measured output values monitored on blockhouse recorders should be within $\pm 20\%$ of the calculated steady-state values for i_v and β . This $\pm 20\%$ includes $\pm 10\%$ for a_0 and a_1 gains, and $\pm 10\%$ for the method of measurement and the measuring equipment.

3 Enc:
a/s


S. M. Seltzer

Approval:


F. B. Moore
Chief, Guidance and Control Division
MSFC - Form 488 (August 1960)

Received copy

SAFETY

FORM NO. 100-100

CLASSIFICATION

REPORT NO.

cc:

- JB-3, Mr. Whiteside
- JB-3, Mr. Terry
- JB-33, Mr. Eli (5)
- R-ASTR-N, Mr. Moore
- R-ASTR-N, Mr. Gassaway
- R-ASTR-NG, Dr. Seltzer
- R-ASTR-NG, Mr. Brooks
- R-ASTR-NGA, Mr. Drawe
- R-ASTR-NGA, Mr. Kennel
- R-ASTR-NGA, Mr. Schultz
- R-ASTR-NGA, Mr. Roberts
- R-ASTR-NGD, Mr. Chubb
- R-ASTR-NGD, Mr. Brown
- R-ASTR-NGD, Mr. Jones
- R-ASTR-NGI, Mr. Blanton
- R-ASTR-NGI, Mr. Scott (10)
- R-ASTR-NGI, Mr. Nicaise
- R-ASTR-NGI, Mr. E. C. Smith
- R-ASTR-NF, Mr. Bridges (2)
- ~~R-ASTR-NG, Record file/Branch file~~
- R-ASTR-X, Reference file

CENTERING GUIDE LINES

REPORT NO.

LIMIT OF TYPING

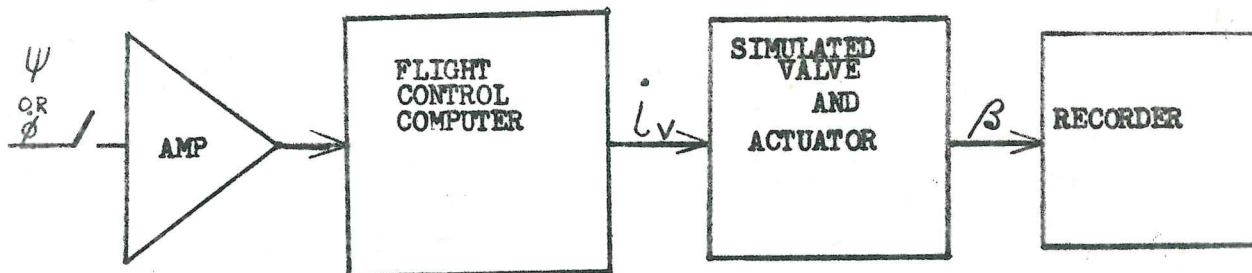
CLASSIFICATION

FOR EMERGENCY USE ONLY

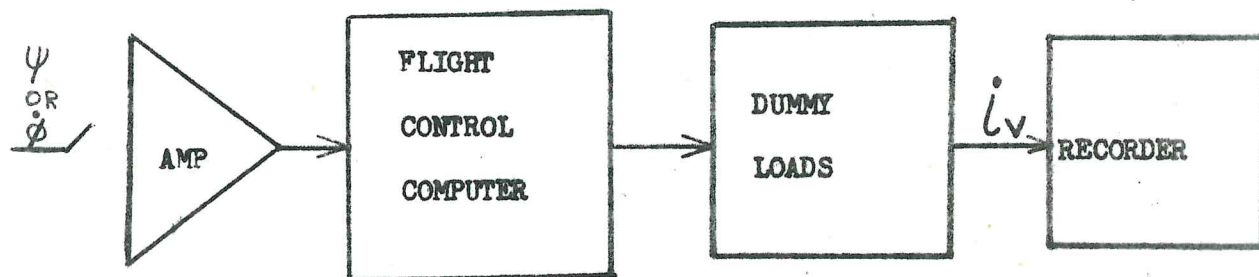
FIGURE 1

TEST ARRANGEMENT FOR OPEN LOOP TRANSIENT
RESPONSE STUDY

S-IC, S-II, & S-IVB STAGES



A. β ACTUATOR VERSUS STEP INPUT IN
 ψ OR $\dot{\phi}$ CHANNEL.



B. i_v VERSUS STEP INPUT IN
 ψ OR $\dot{\phi}$ CHANNEL.

TABLE I
INPUT AND OUTPUT SIGNALS FOR
CONTROL SYSTEM TRANSIENT RESPONSES

A. β RESPONSE

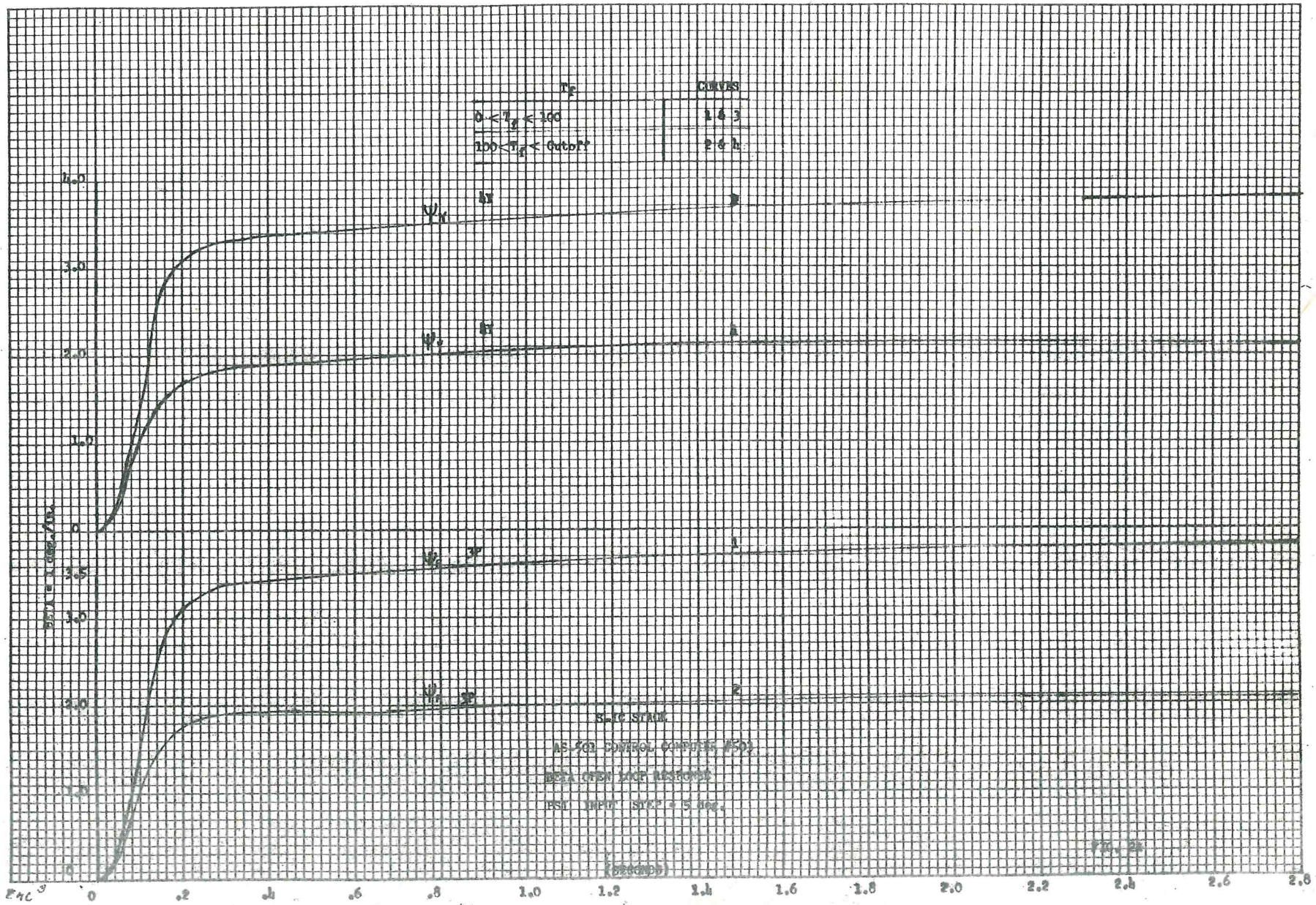
1. S-IC STAGE	INPUT	GAINS	STEADY-STATE OUTPUT CALCULATED	FIGURE NO.	
				P	Y
	$\psi=5^\circ$ (P&Y) $0 < T_f < 100$	0.82	$\beta = 4.10^\circ$	2	2
	$\psi=5^\circ$ (P&Y) $100 < T_f < \text{cutoff}$	0.45	$\beta = 2.25^\circ$	2	2
	$\psi=10^\circ$ (P) S-IC Burn	0.245	$\beta = 1.732^\circ$	3	3
	$\dot{\phi}=5^\circ/\text{s}$ (P&Y) $0 < T_f < 100$	0.657	$\beta = 2.63^\circ$	4	5
	$\dot{\phi}=5^\circ/\text{s}$ (P&Y) $100 < T_f < \text{cutoff}$	0.438	$\beta = 1.752^\circ$	4	5
	$\dot{\phi}=10^\circ/\text{s}$ (R) S-IC Burn	0.15	$\beta = 1.061^\circ$	3	3
2. S-II STAGE					
	$\psi=5^\circ$ (P&Y) Ignition $< T_f < 60$	1.12	$\beta = 5.60^\circ$	6	7
	$\psi=5^\circ$ (P&Y) $60 < T_f < 190$	0.65	$\beta = 3.25^\circ$	6	7
	$\psi=5^\circ$ (P&Y) $190 < T_f < \text{cutoff}$	0.44	$\beta = 2.20^\circ$	6	7
	$\psi=10^\circ$ (P) S-II Burn	0.25	$\beta = 1.77^\circ$	8	8
	$\dot{\phi}=4^\circ/\text{s}$ (P&Y) Ignition $< T_f < 60$	1.89	$\beta = 7.56^\circ$	9	10
	$\dot{\phi}=4^\circ/\text{s}$ (P&Y) $60 < T_f < 190$	1.10	$\beta = 4.40^\circ$	9	10
	$\dot{\phi}=4^\circ/\text{s}$ (P&Y) $190 < T_f < \text{cutoff}$	0.74	$\beta = 2.96^\circ$	9	10
	$\dot{\phi}=10^\circ/\text{s}$ (P) S-II Burn	0.20	$\beta = 1.414^\circ$	8	8
3. S-IVB STAGE					
	$\psi=5^\circ$ (P&Y) 1st S-IVB Burn	0.809	$\beta = 4.045^\circ$	11	12
	$\psi=5^\circ$ (P&Y) 2nd S-IVB Burn	0.809	$\beta = 4.045^\circ$	11	12
	$\dot{\phi}=4^\circ/\text{s}$ (P&Y) 1st S-IVB Burn	0.970	$\beta = 3.88^\circ$	11	12
	$\dot{\phi}=4^\circ/\text{s}$ (P&Y) 2nd S-IVB Burn	0.970	$\beta = 3.88^\circ$	11	12
	Ignition $< T_f < 263.2$				
	$\dot{\phi}=4^\circ/\text{s}$ (P&Y) 2nd S-IVB Burn	0.698	$\beta = 2.79^\circ$	11	12
	$263.2 < T_f < \text{cutoff}$				

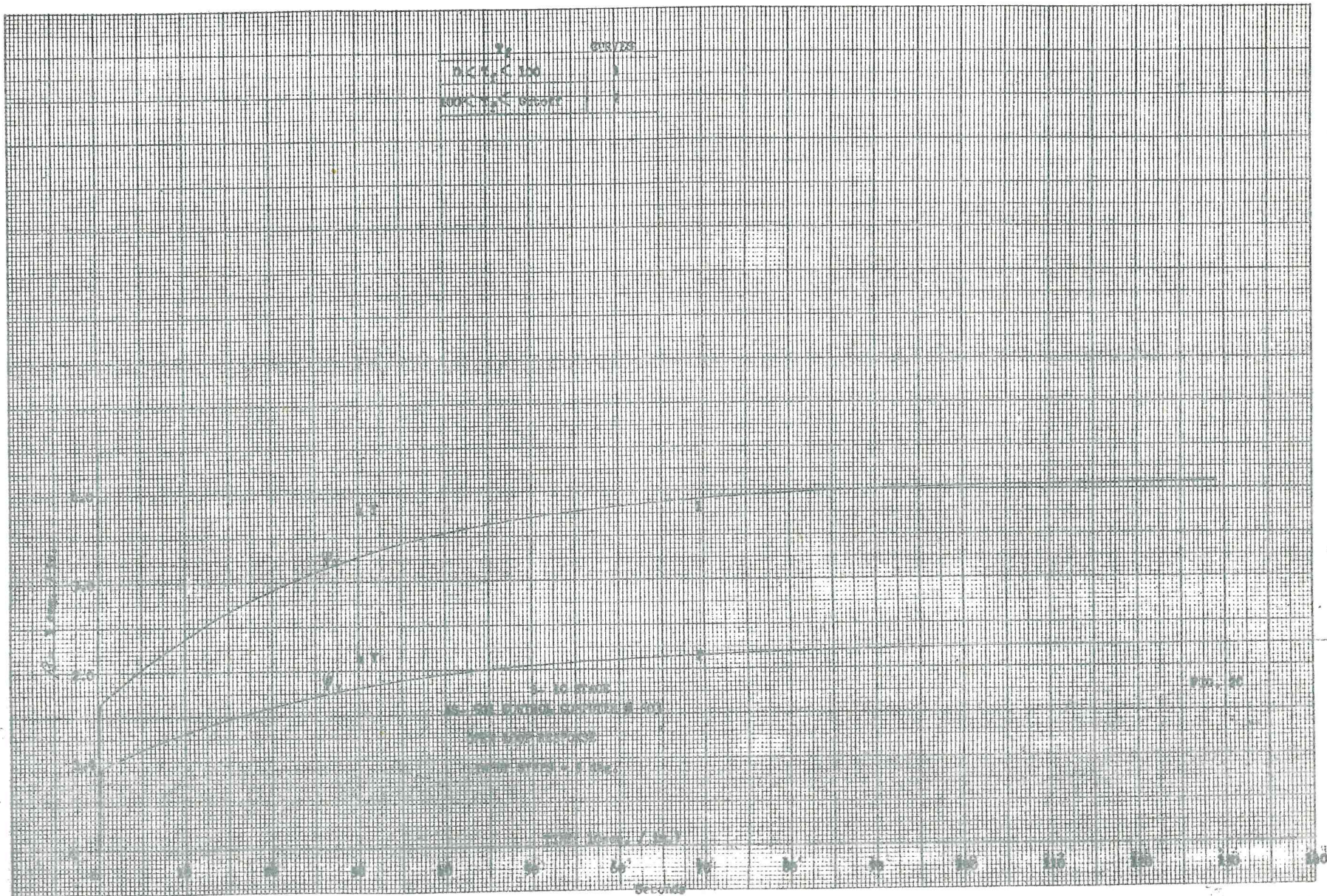
Same as Figures 11 and 12 except redundant channel is used 13 14

TABLE I (CONT)

B. i_v RESPONSES

1. S-IC STAGE	INPUT	GAINS	STEADY-STATE OUTPUT CALCULATED	FIGURE NO.		
				X	Y	
1. S-IC STAGE	$\dot{\phi}=5^\circ$ (P&Y) $0 < T_f < 100$	0.82	$i_v = 39.69$ ma	15	15	
	$\dot{\phi}=5^\circ$ (P&Y) $100 < T_f < \text{cutoff}$	0.45	$i_v = 21.78$ ma	15	15	
	$\dot{\phi}=10^\circ/s$ (R) S-IC Burn	0.245	$i_v = 16.77$ ma	16	16	
	$\dot{\phi}=5^\circ/s$ (P&Y) $0 < T_f < 100$	0.657	$i_v = 31.80$ ma	17	18	
	$\dot{\phi}=5^\circ/s$ (P&Y) $100 < T_f < \text{cutoff}$	0.438	$i_v = 21.20$ ma	17	18	
	$\dot{\phi}=10^\circ/s$ (R) S-IC Burn	0.15	$i_v = 10.27$ ma	16	16	
	2. S-II STAGE	$\dot{\phi}=5^\circ$ (P&Y) Ignition $< T_f < 60$	1.12	$i_v = 35.17$ ma	19	20
		$\dot{\phi}=5^\circ$ (P&Y) $60 < T_f < 190$	0.65	$i_v = 20.40$ ma	19	20
		$\dot{\phi}=5^\circ$ (P&Y) $190 < T_f < \text{cutoff}$	0.44	$i_v = 13.82$ ma	19	20
		$\dot{\phi}=10^\circ$ (R) S-II Burn	0.25	$i_v = 11.10$ ma	21	21
$\dot{\phi}=4^\circ/s$ (P&Y) Ignition $< T_f < 60$		1.89	$i_v = 47.48$ ma	22	23	
$\dot{\phi}=4^\circ/s$ (P&Y) $60 < T_f < 190$		1.10	$i_v = 27.63$ ma	22	23	
$\dot{\phi}=4^\circ/s$ (P&Y) $190 < T_f < \text{cutoff}$		0.74	$i_v = 18.59$ ma	22	23	
$\dot{\phi}=10^\circ/s$ (R) S-II Burn		0.20	$i_v = 8.88$ ma	21	21	
3. S-IVB STAGE		$\dot{\phi}=5^\circ$ (P&Y) 1st S-IVB Burn	0.809	$i_v = 27.02$ ma	24	25
		$\dot{\phi}=5^\circ$ (P&Y) 2nd S-IVB Burn	0.809	$i_v = 27.02$ ma	24	25
	$\dot{\phi}=4^\circ/s$ (P&Y) 1st S-IVB Burn	0.970	$i_v = 25.92$ ma	24	25	
	$\dot{\phi}=4^\circ/s$ (P&Y) 2nd S-IVB Burn	0.970	$i_v = 25.92$ ma	24	25	
	Ignition $< T_f < 263.2$					
	$\dot{\phi}=4^\circ/s$ (P&Y) 2nd S-IVB Burn	0.698	$i_v = 18.65$ ma	24	25	
	$263.2 < T_f < \text{cutoff}$					
	Same as Figures 24 and 25 except redundant channel is used			26	27	

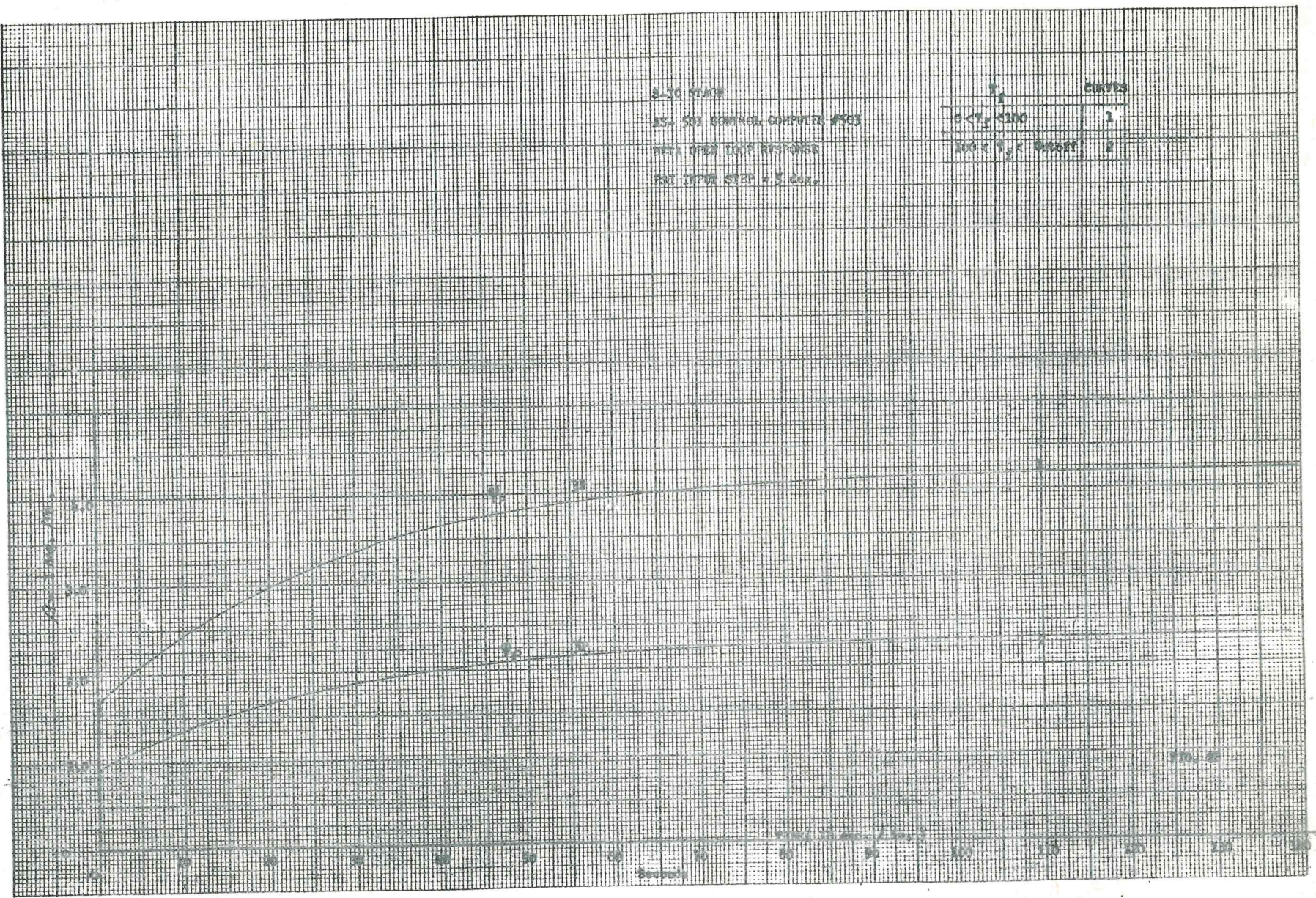


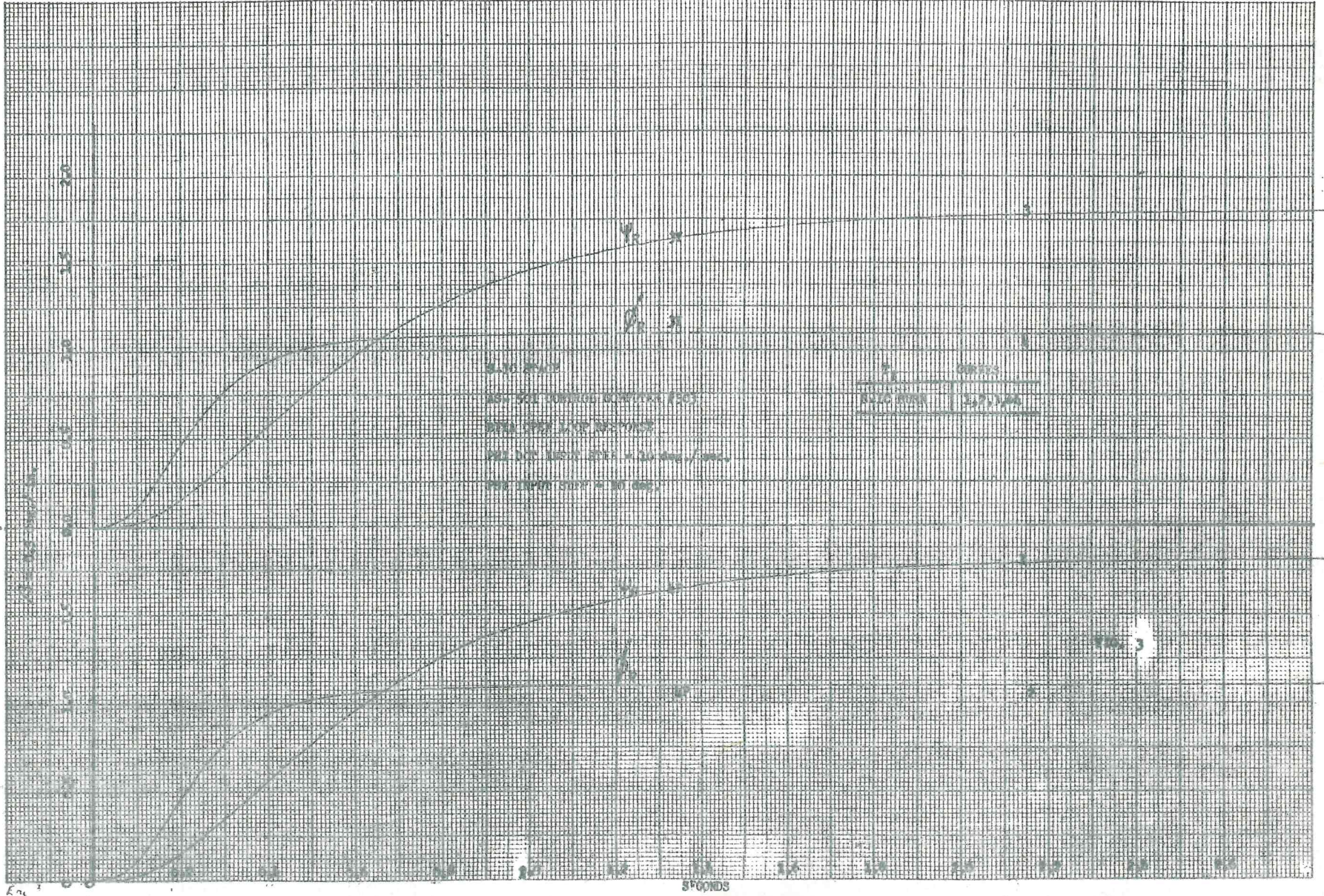


276

8-10 STATE
 AS-501 CONTROL COMPUTER #503
 BEST OPEN LOOP RESPONSE
 ROT INPUT STEP = 5 deg.

TIME	CURVES
0 CT, 1100	1
100 CT, 0400	2





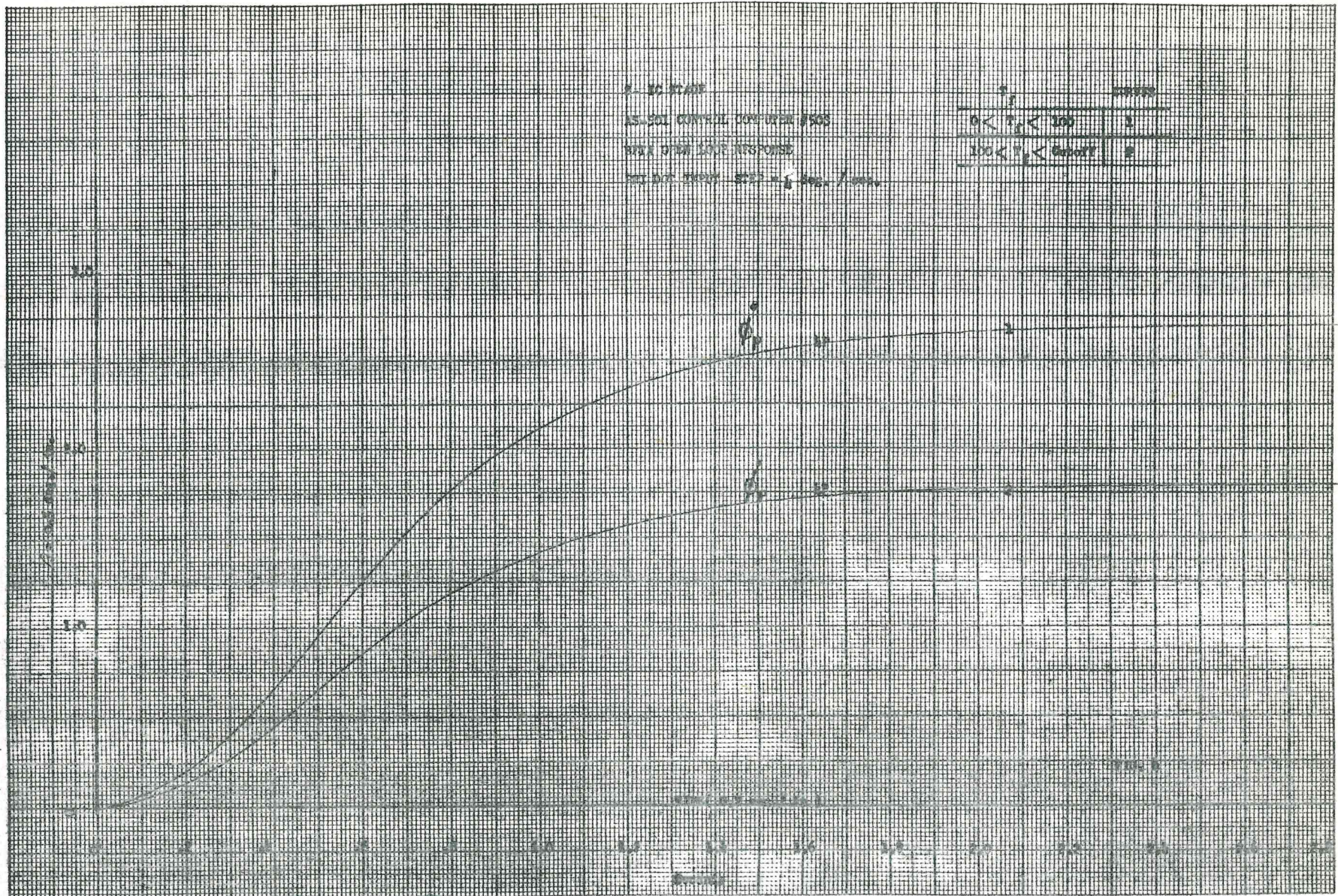
1. 10. 1957

AS. 201 CONTROL COMPUTER #505

WPA OVER 100 RESPONSE

WPA OVER 100 RESPONSE - 100% / 100%

γ_1	WPA
$0 < \gamma_1 < 100$	1
$100 < \gamma_1 < \infty$	2



S. NO. 2740

AS-504 CONTROL COMPUTER / 503

OPEN LOOP RESPONSE

PERIODIC INPUT STEP = $1 \text{ sec} / \text{sec}$

τ	PERIOD
$0 < \tau < 100$	1
$100 < \tau < \infty$	2

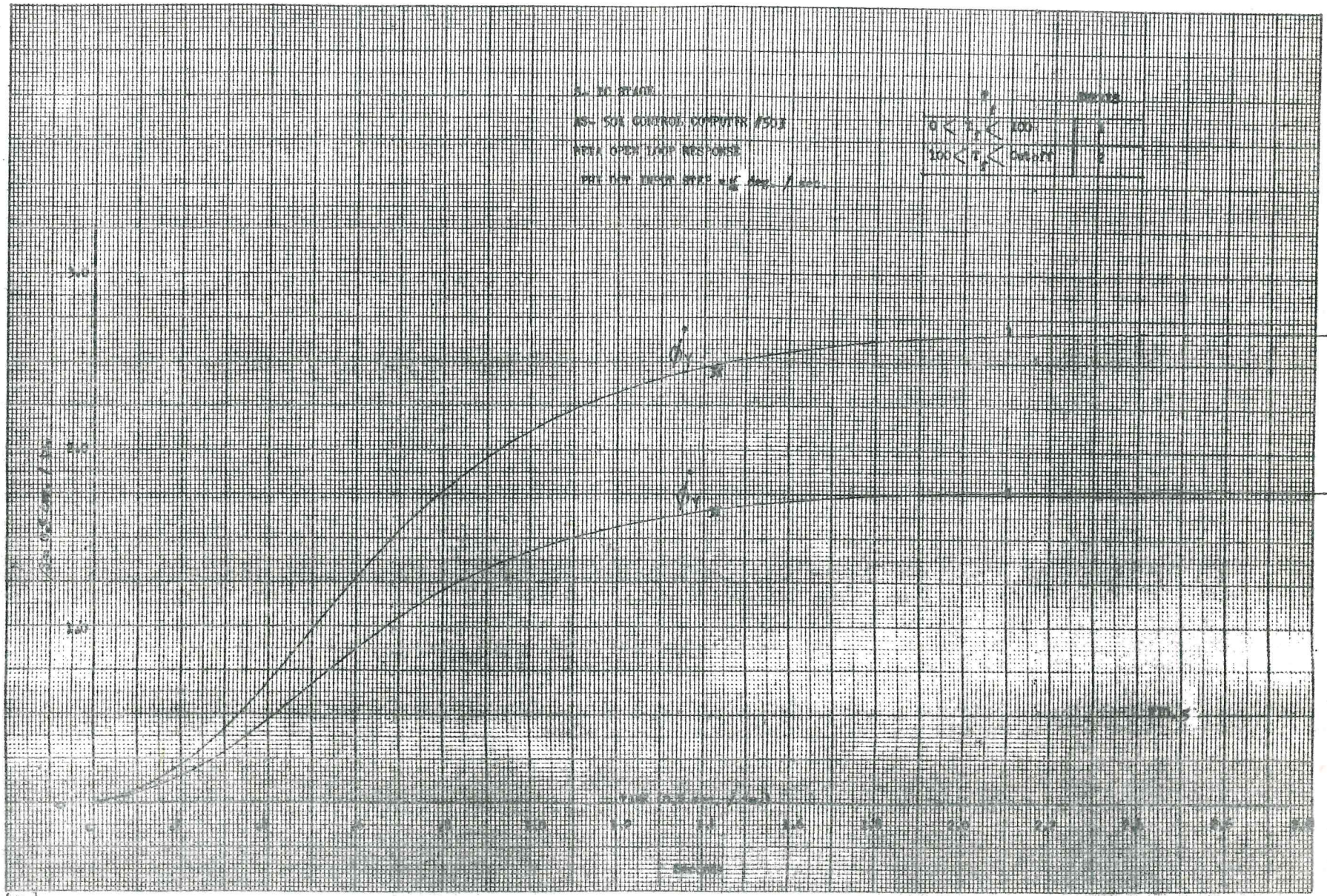


Fig. 3

T_f	CURVES
IGNITION < T_f < 60	1
60 < T_f < 190	2
190 < T_f < Cutoff	3

$\beta = 1 \text{ deg/n.}$

6

5

4

3

2

1

0

.2

.4

.6

.8

1.0

1.2

1.4

1.6

1.8

TIME (Seconds)

ψ_P LP 1

ψ_P LP 2

ψ_P LP 3

S-II STAGE
AS-501 CONTROL COMPUTER #503
 β OPEN LOOP RESPONSE
 ψ INPUT STEP = 5 deg.

FIG. 6

T_f	CURVES
IGNITION < T_f < 60	1
60 < T_f < 190	2
190 < T_f < Cutoff	3

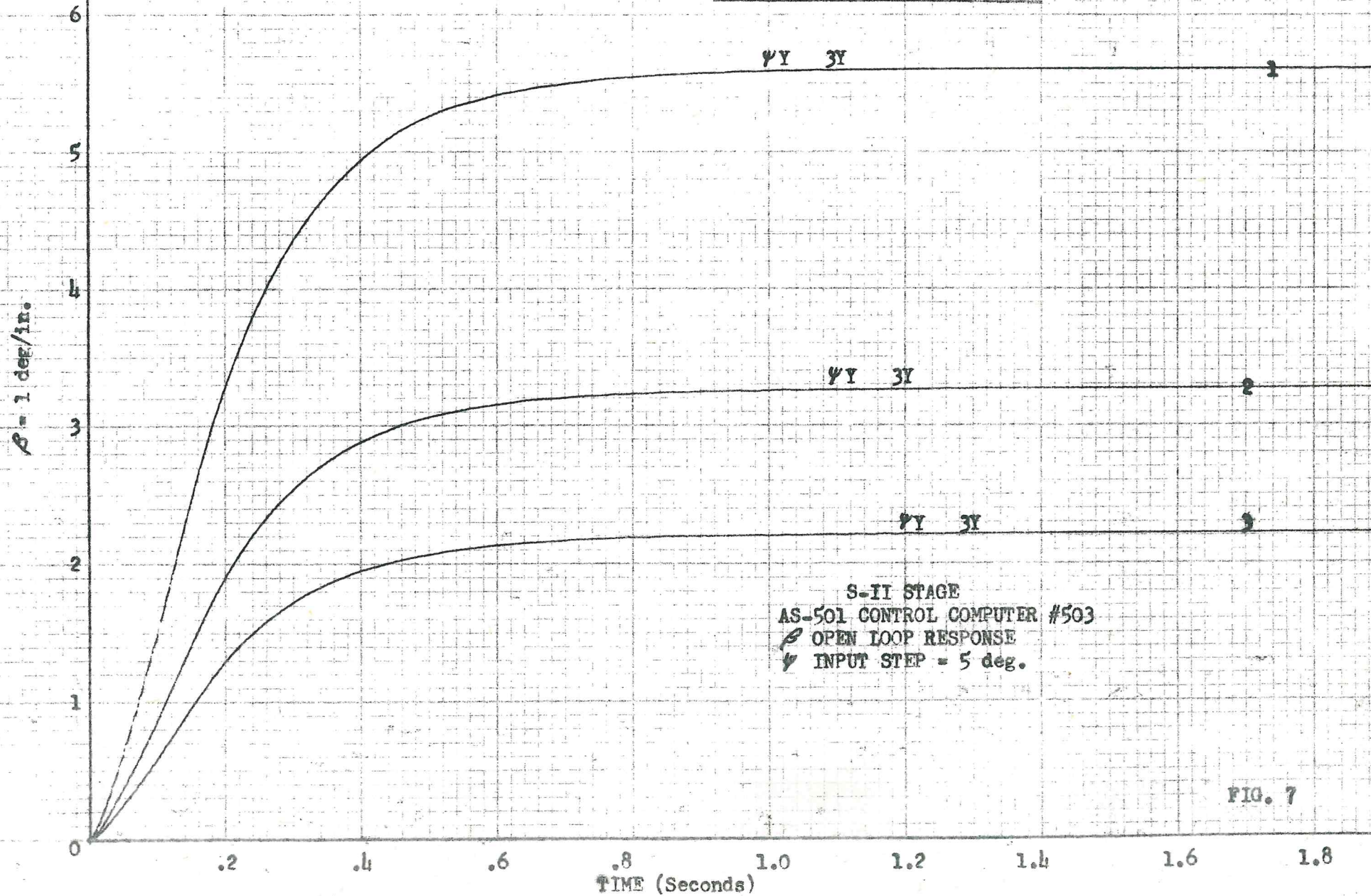


FIG. 7

S-II STAGE
 AS-501 CONTROL COMPUTER #503
 β OPEN LOOP RESPONSE
 ϕ INPUT STEP = 10 deg/sec
 ψ INPUT STEP = 10 deg.

T_f	CURVES
S - II BURN	1,2,3,&4

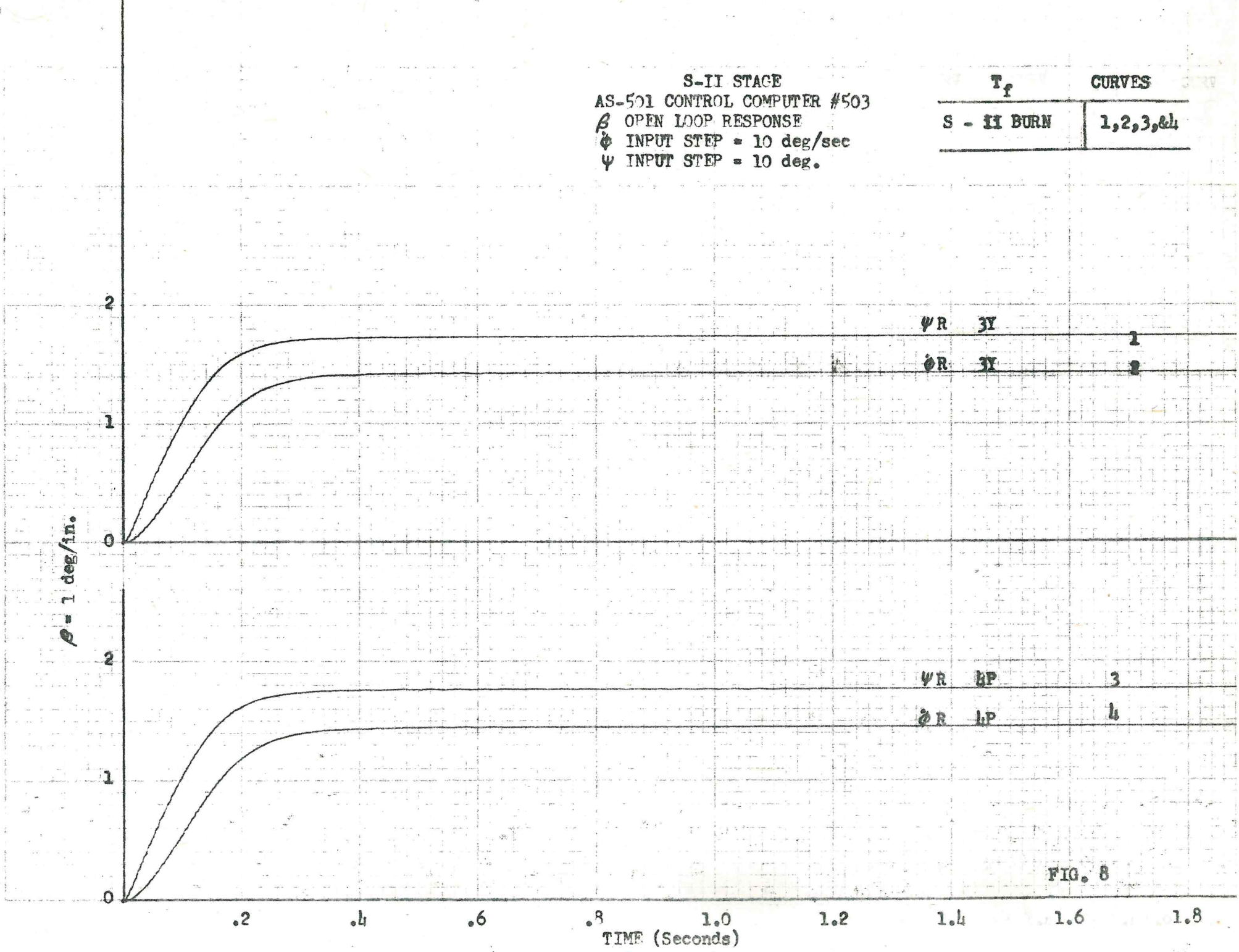


FIG. 8

S-II STAGE
 AS-501 CONTROL COMPUTER #503
 β OPEN LOOP RESPONSE
 $\dot{\phi}$ INPUT STEP = 4 deg/sec

T_f	CURVES
IGNITION < T_f < 60	1
60 < T_f < 190	2
190 < T_f < Cutoff	3

$\beta = 2 \text{ deg/in.}$

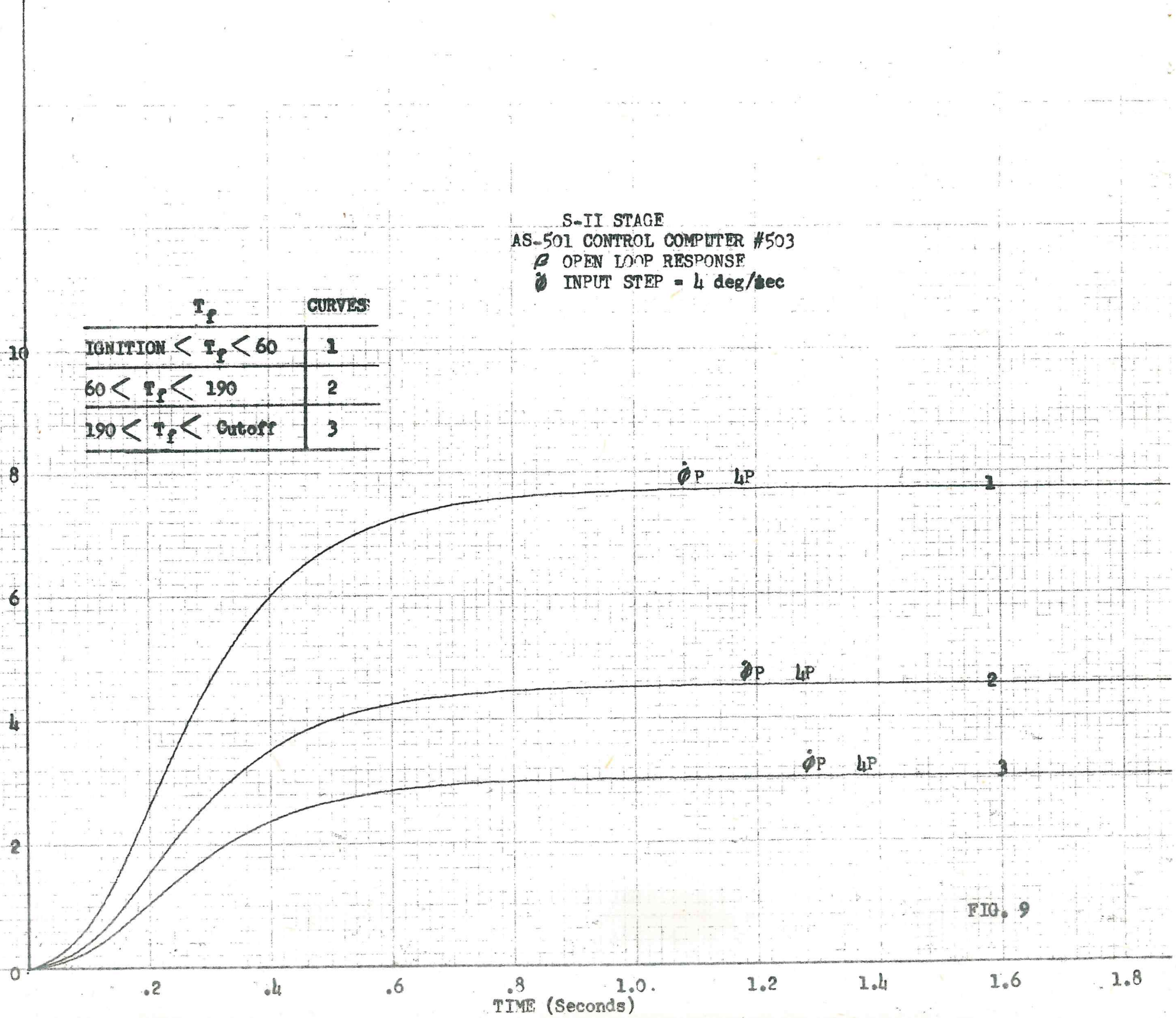


FIG. 9

T_f	CURVES
IGNITION < T_f < 60	1
60 < T_f < 190	2
190 < T_f < Cutoff	3

S-II STAGE

AS-501 CONTROL COMPUTER #503

β OPEN LOOP RESPONSE

$\dot{\theta}$ INPUT STEP = 4 deg/sec

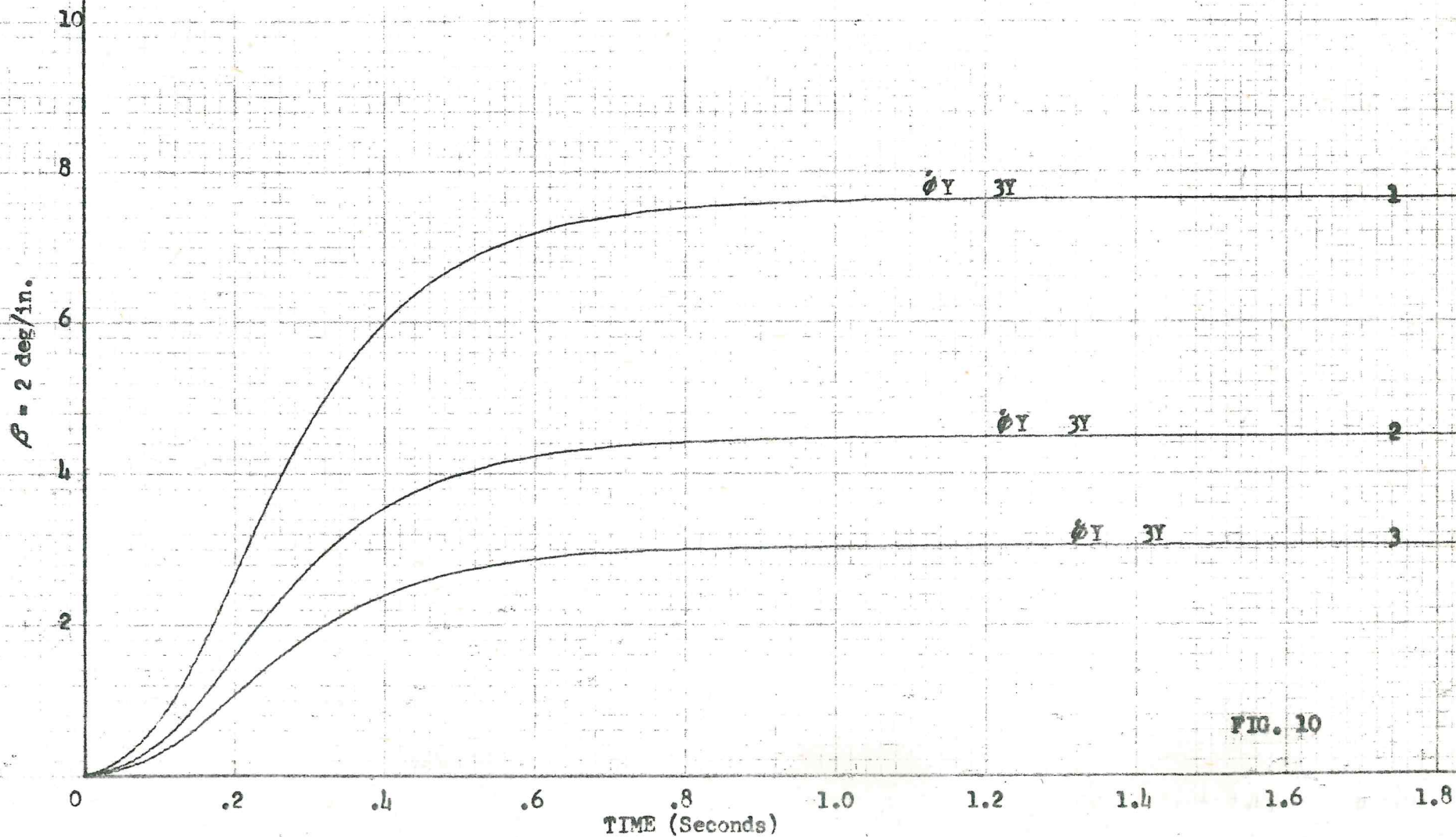
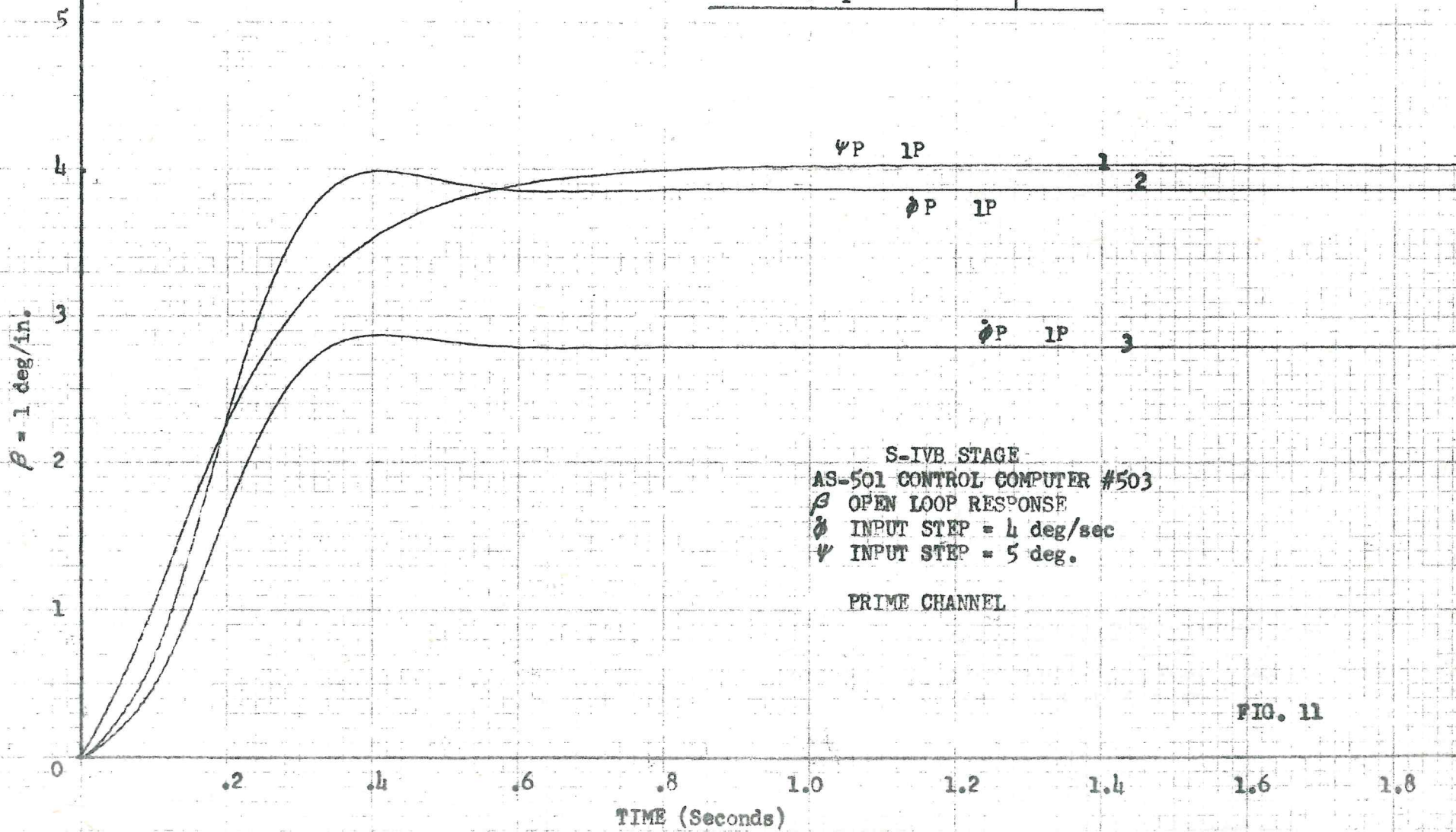


FIG. 10

T_f	CURVES
1 ST & 2 ND BURN	1
2 ND BURN	
IGNITION $< T_f < 263.2$	2
$263.2 < T_f < \text{Cutoff}$	3



$\beta = 1 \text{ deg/in.}$

5
4
3
2
1
0

.2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8

TIME (Seconds)

T_f	CURVES
1 ST & 2 ND BURN	1
2 ND BURN	
IGNITION $< T_f < 263.2$	2
$263.2 < T_f < \text{Cutoff}$	3

ψ Y IY 1
 $\dot{\theta}$ Y IY 2

$\dot{\theta}$ Y IY 3

S-IVB STAGE
AS-501 CONTROL COMPUTER #503
 β OPEN LOOP RESPONSE
 $\dot{\theta}$ INPUT STEP = 4 deg/sec
 ψ INPUT STEP = 5 deg.

PRIME CHANNEL

FIG. 12

Line 3

T_f	CURVES
1 ST & 2 ND BURN	1
2 ND BURN	
IGNITION < T_f < 263.2	2
263.2 < T_f < Cutoff	3

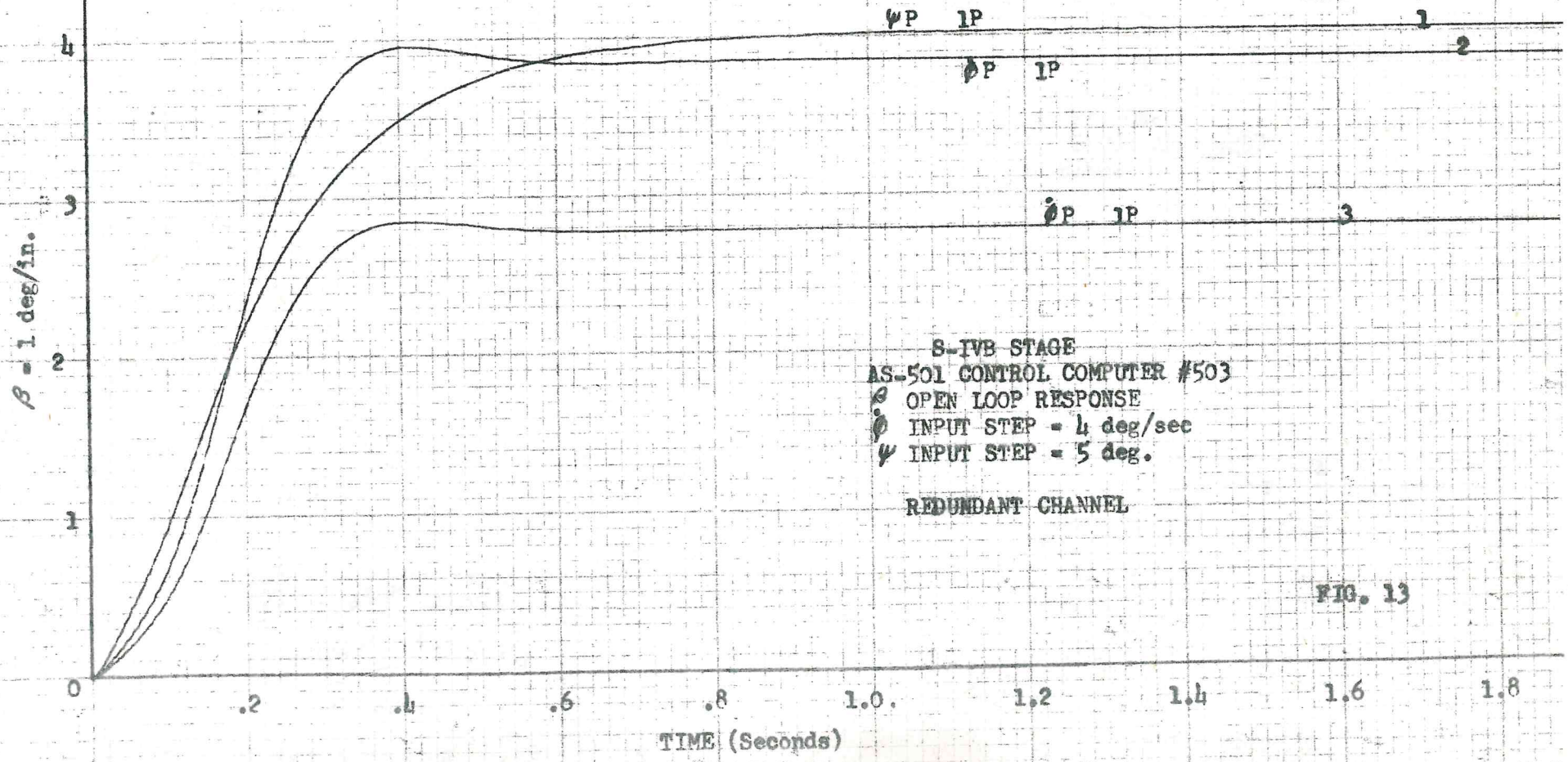


FIG. 13

T_f	CURVES
1 ST & 2 ND BURN	1
2 ND BURN	
IGNITION < T_f < 263.2	2
263.2 < T_f < Cutoff	3

$\beta = 1 \text{ deg/in.}$

5

4

3

2

1

0

1 ST & 2 ND BURN

2 ND BURN

IGNITION < T_f < 263.2

263.2 < T_f < Cutoff

1

2

3

ψY 1Y

ϕY 1Y

ϕY 1Y

1

2

3

S-IVB STAGE
 AS-501 CONTROL COMPUTER #503
 β OPEN LOOP RESPONSE
 ϕ INPUT STEP = 4 deg/sec
 ψ INPUT STEP = 5 deg.

REDUNDANT CHANNEL

FIG. 14

TIME (Seconds)

.2

.4

.6

.8

1.0

1.2

1.4

1.6

1.8

5- TC STAGES

6E - 101 CONTROL COMPARTMENT

7- OPERATOR STATION

TEST POINTS SHOWN - 2 sec.

F_1	CIRCUITS
$0 < F_1 < 100$	1 & 2
$100 < F_1 < \text{Cutoff}$	3 & 4

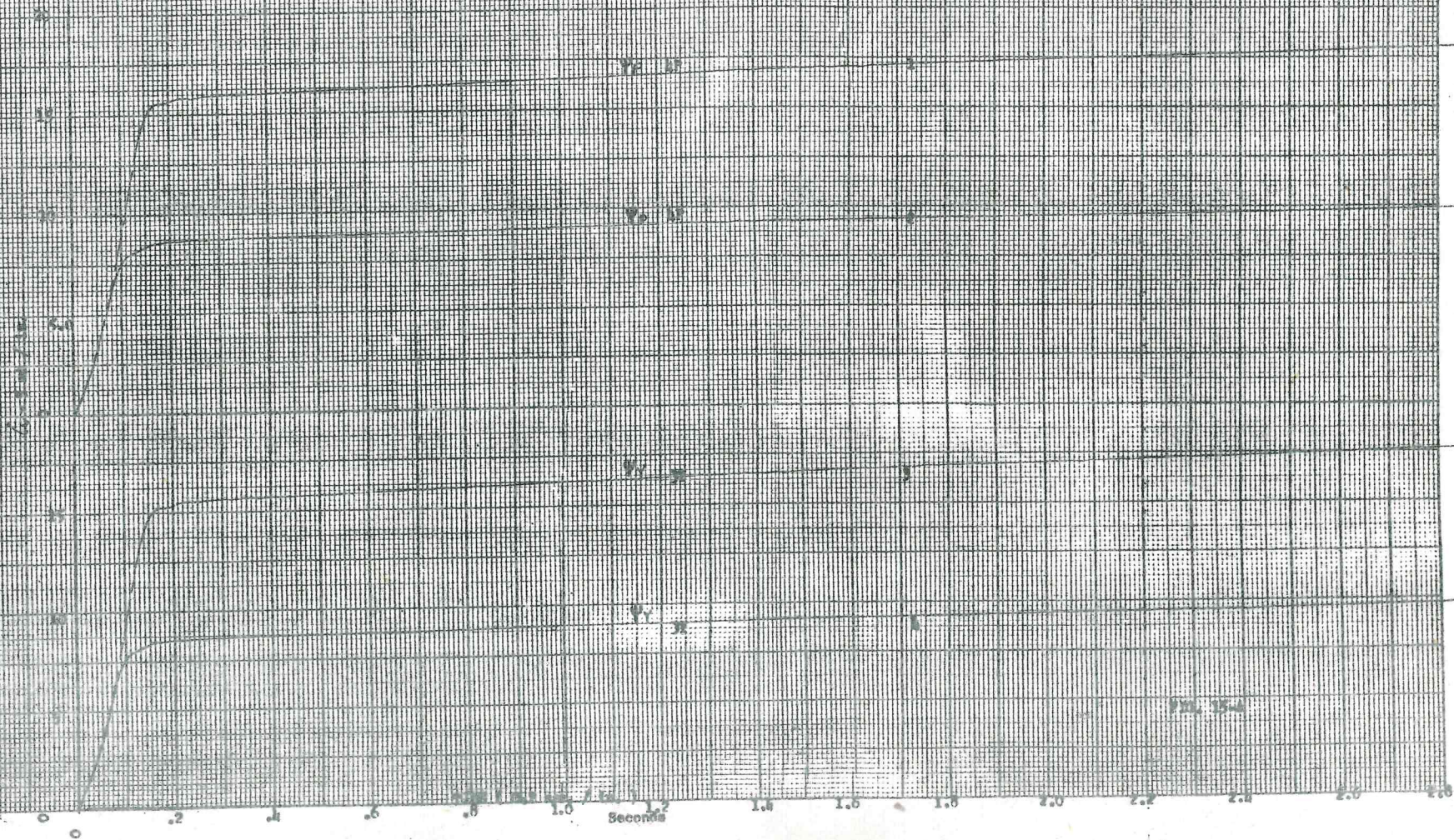


FIG. 5-4

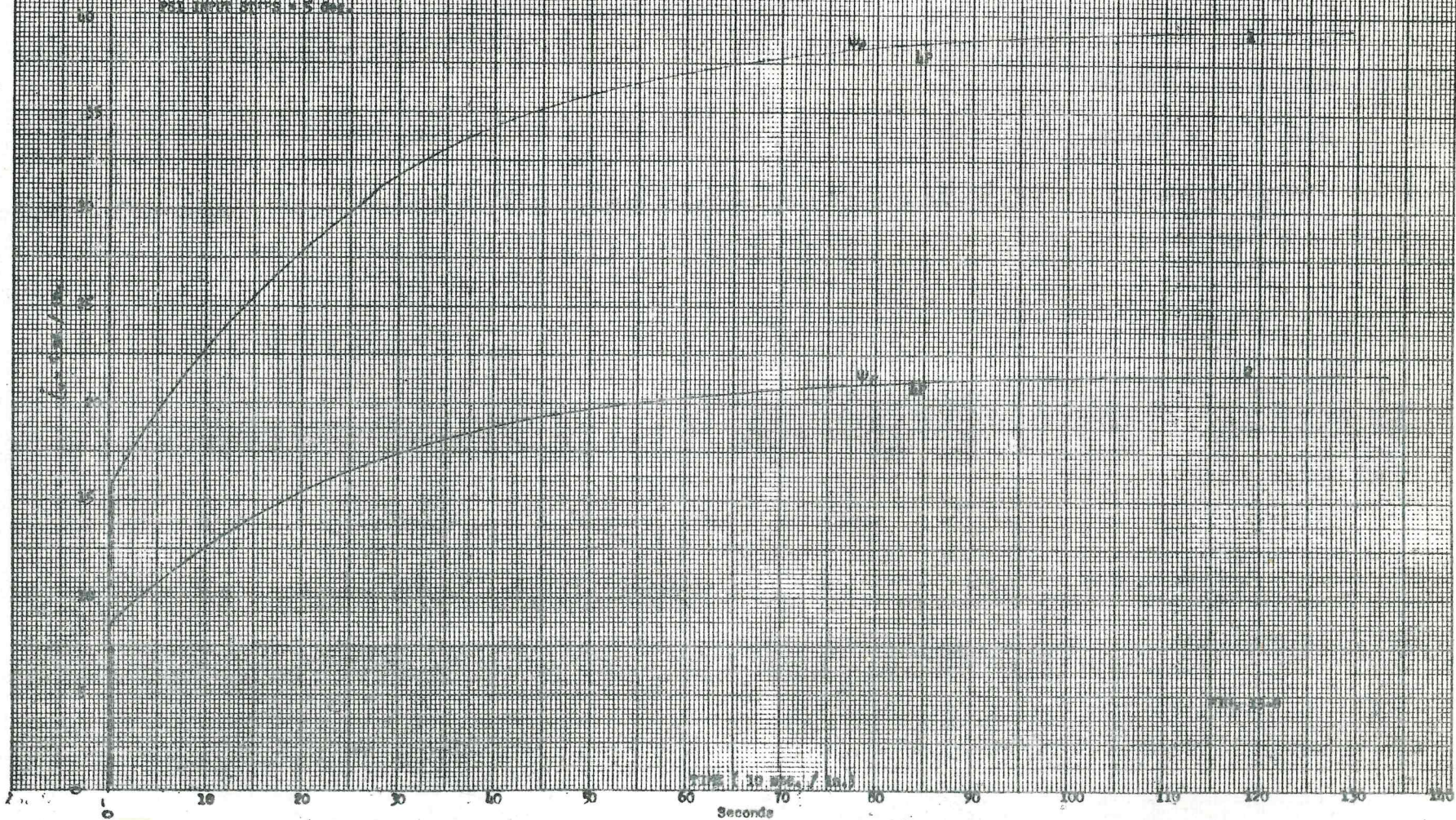
8- TO STAGE

AS - 501 CONTROL COMPUTER 7 503

5₁ OPEN LOOP RESPONSE

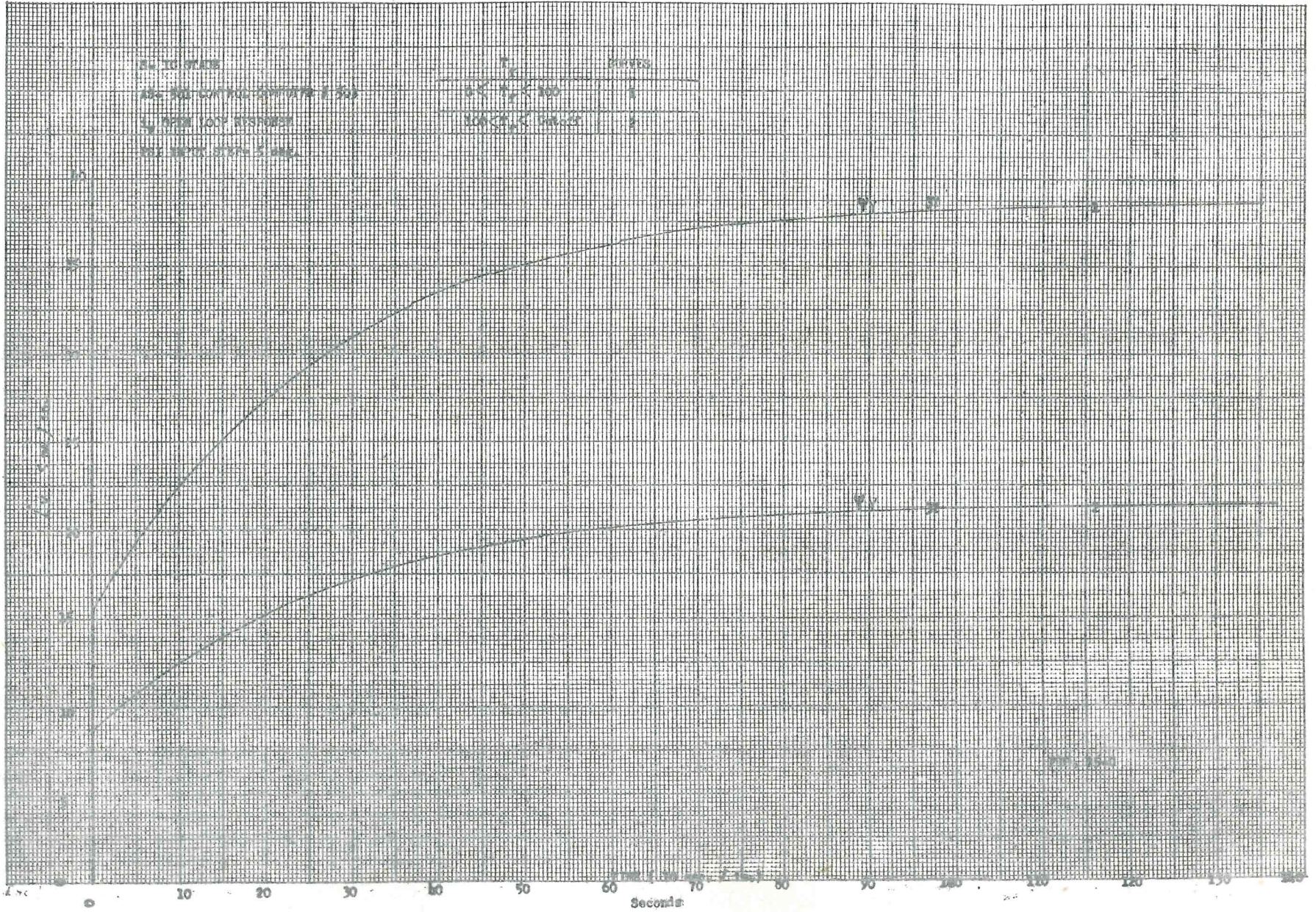
PSI INPUT STEPS = 5 deg.

T_d	CURVES
$0 < T_d < 100$	1
$100 < T_d < \infty$	2



1. 100%
 2. 100%
 3. 100%
 4. 100%

Time	Value
0	0
10	100
20	200
30	300
40	400
50	500
60	600
70	700
80	800
90	900
100	1000



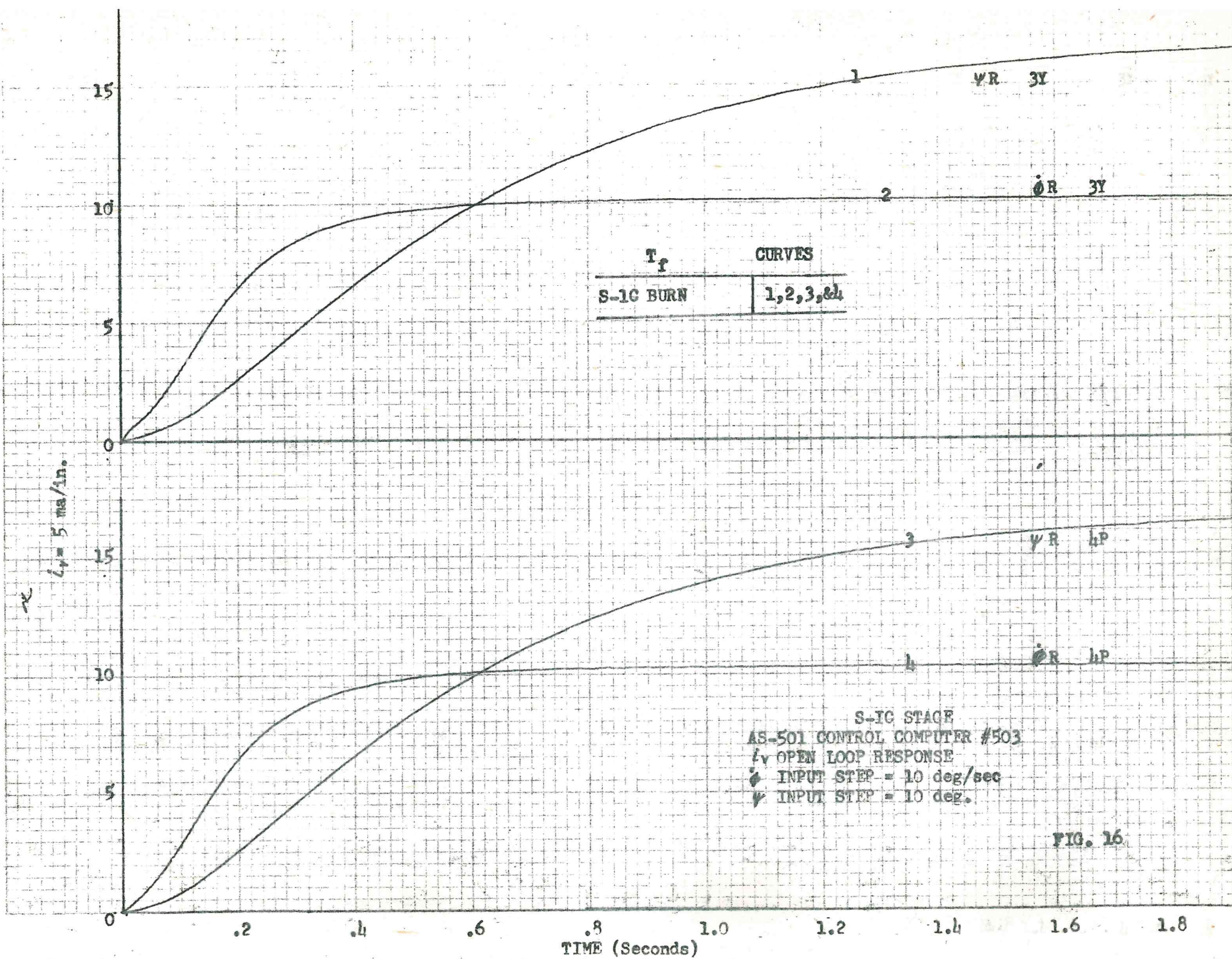
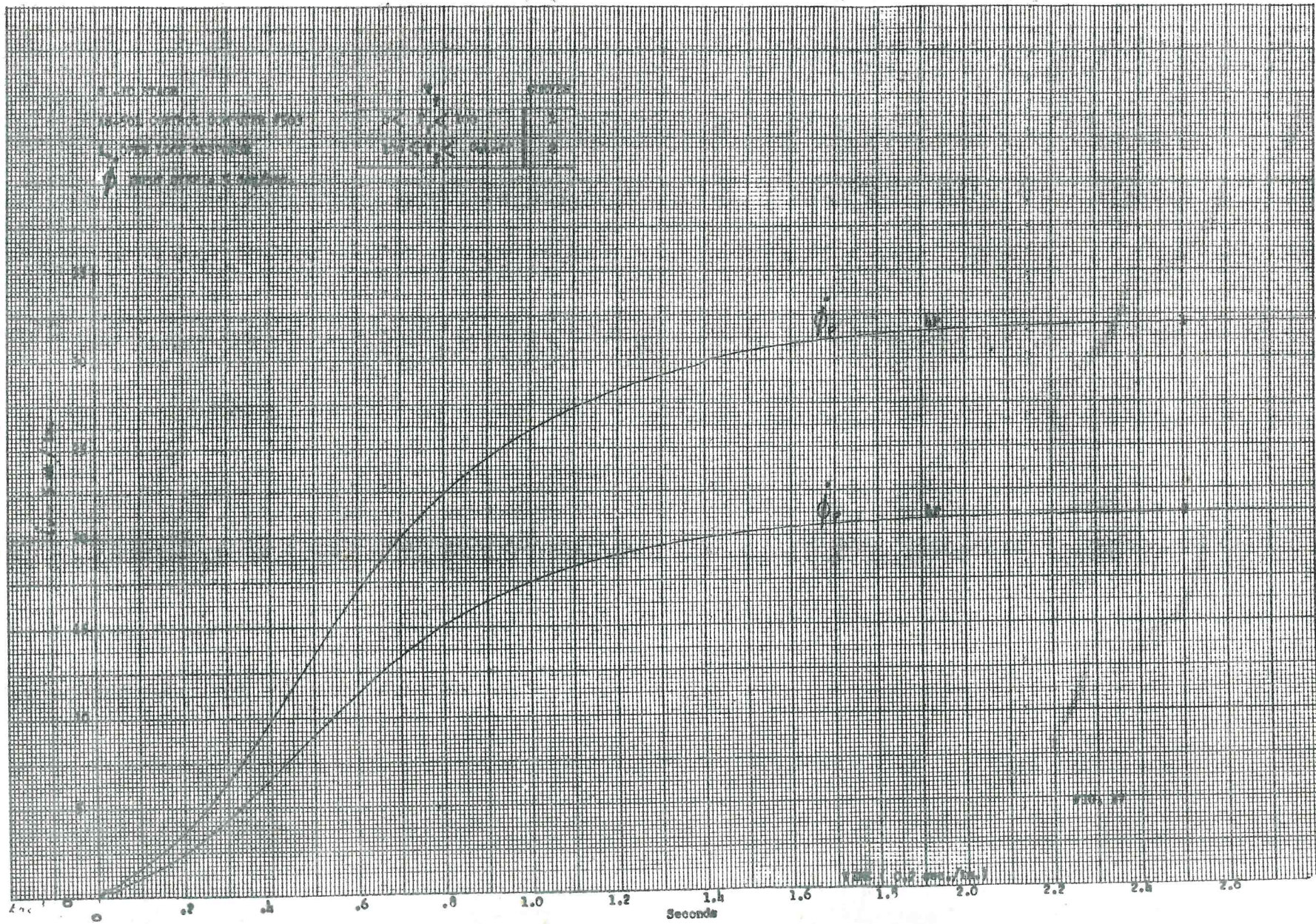
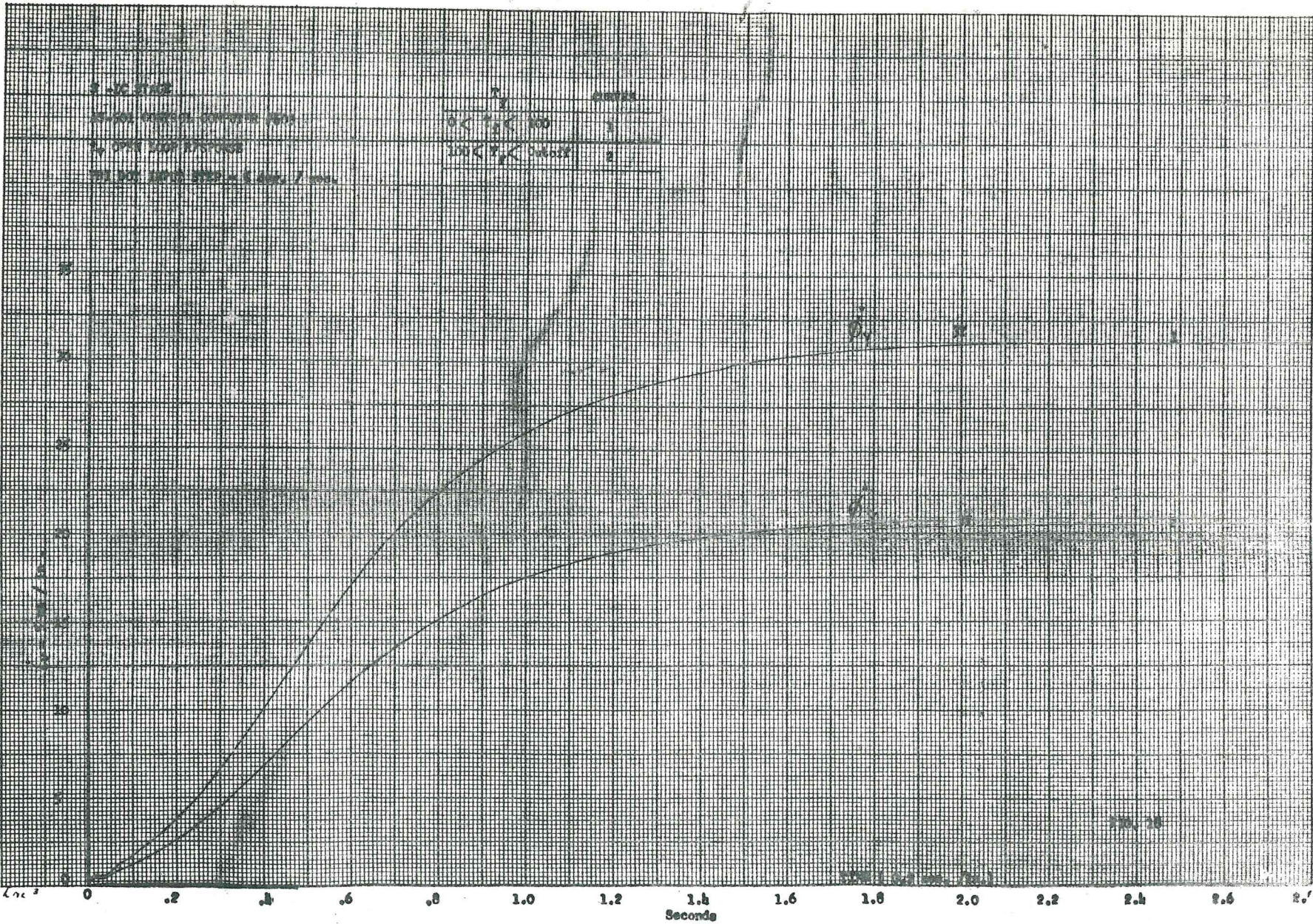


FIG. 16





T_f	CURVES
IGNITION < T_f < 60	1
60 < T_f < 190	2
190 < T_f < Cutoff	3

S-II STAGE
 AS-501 CONTROL COMPUTER #503
 i_v OPEN LOOP RESPONSE
 ψ INPUT STEP = 5 deg.

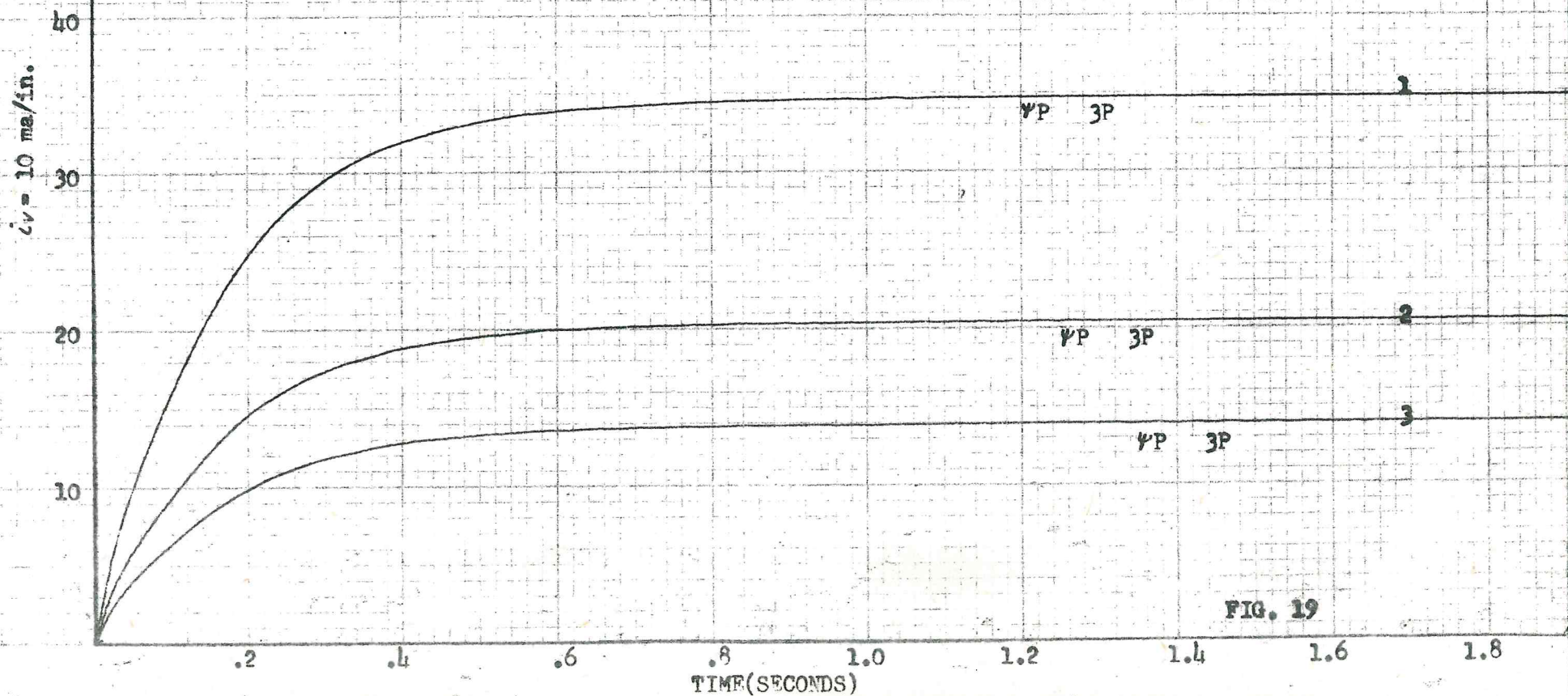


FIG. 19

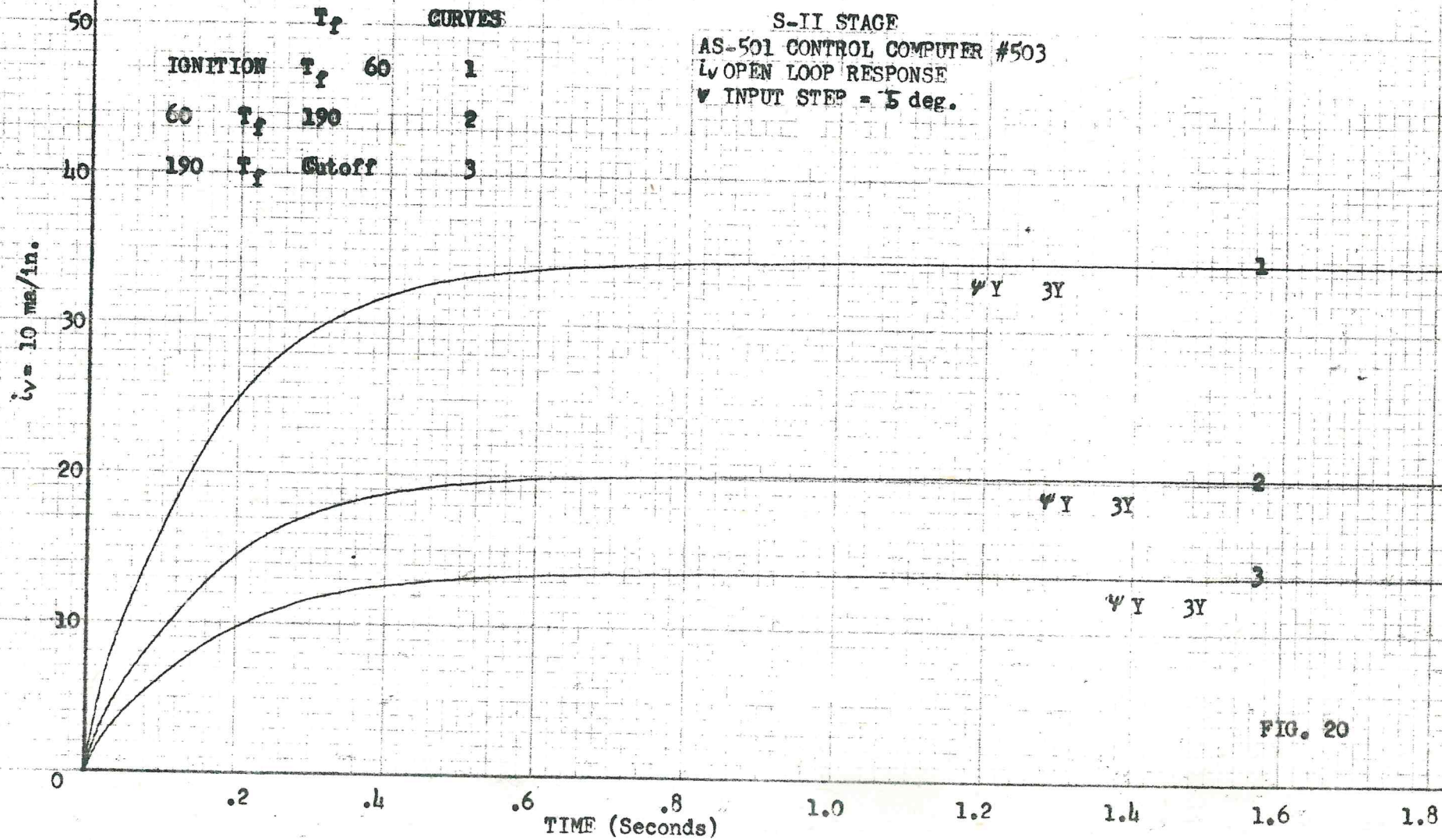


FIG. 20

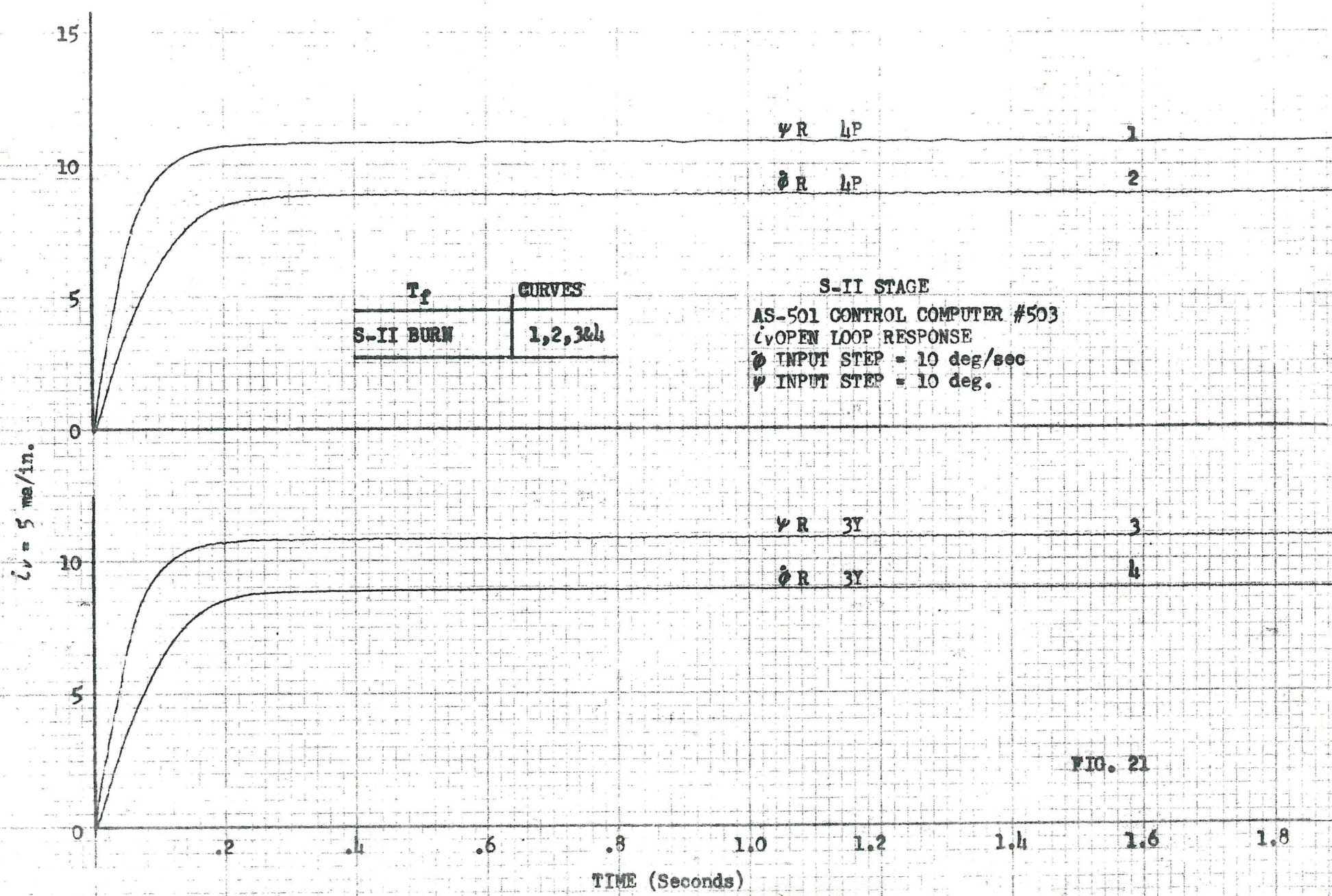


FIG. 21

T_f	CURVES
IGNITION < T_f < 60	1
60 < T_f < 190	2
190 < T_f < Cutoff	3

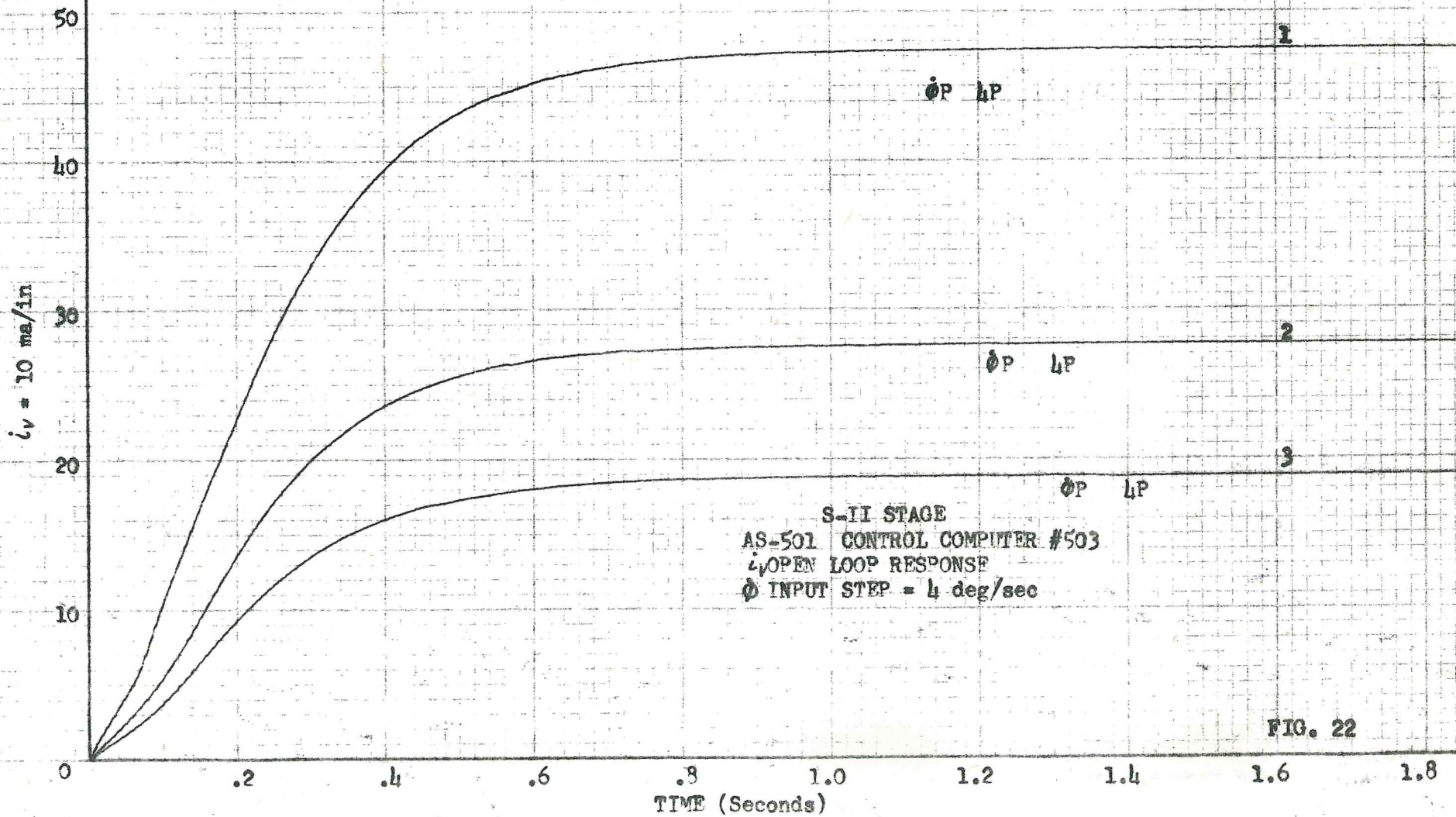


FIG. 22

T_f	CURVES
IGNITION < T_f < 60	1
60 < T_f < 190	2
190 < T_f < Cutoff	3

S-II STAGE
 AS-501 CONTROL COMPUTER #503
 L_v OPEN LOOP RESPONSE
 $\dot{\phi}$ INPUT STEP = 4 deg/sec

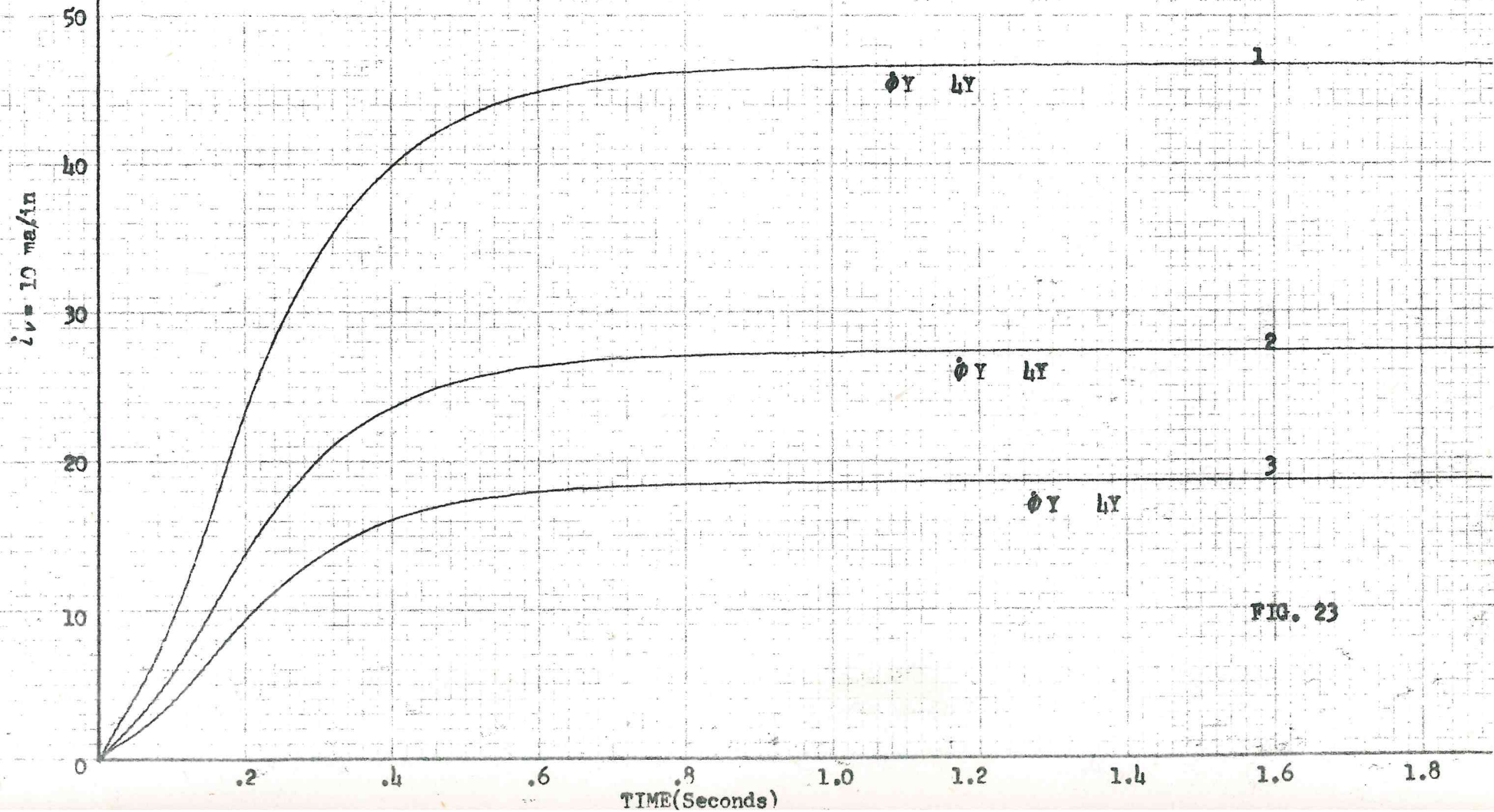
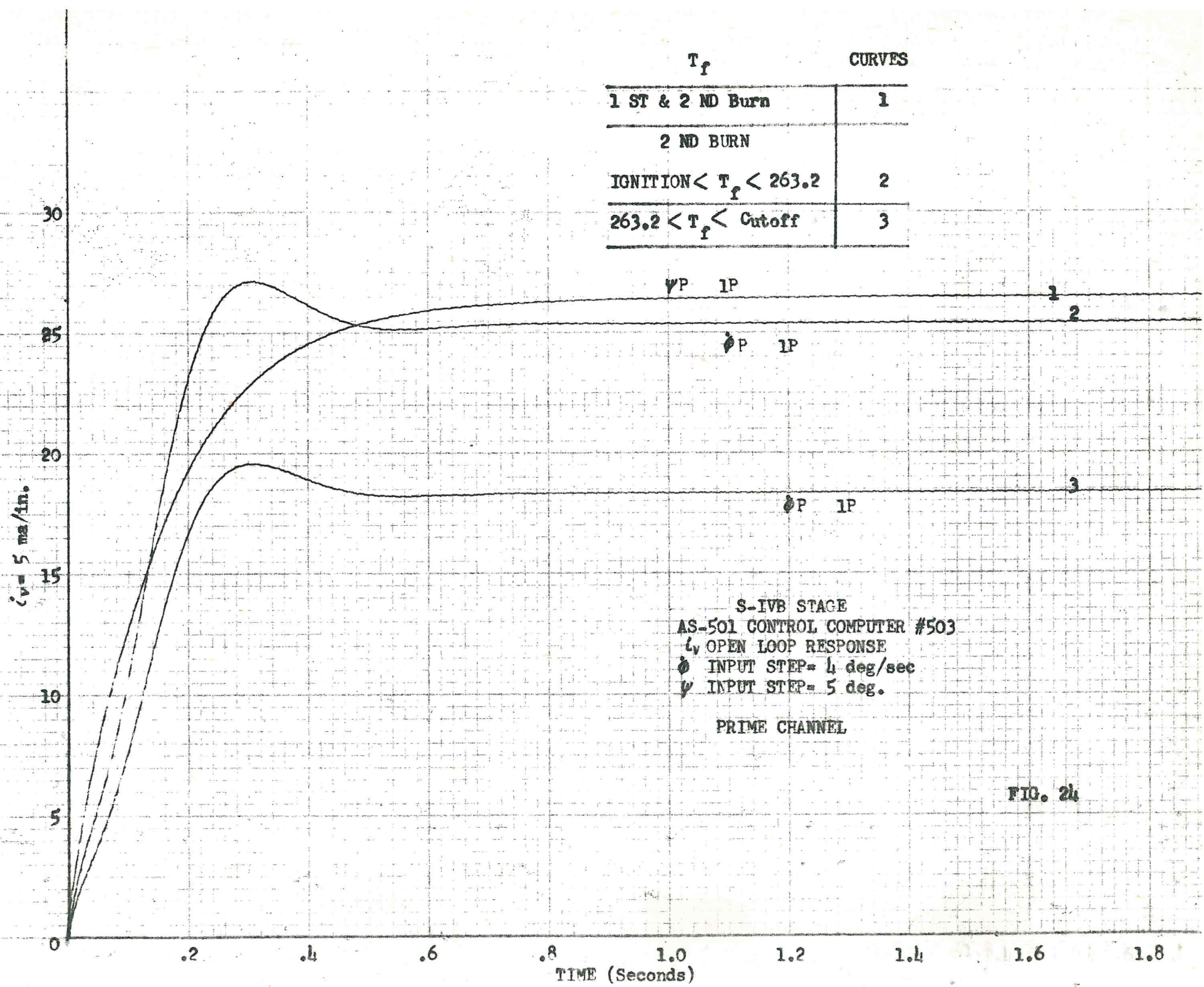


FIG. 23



8 21/27

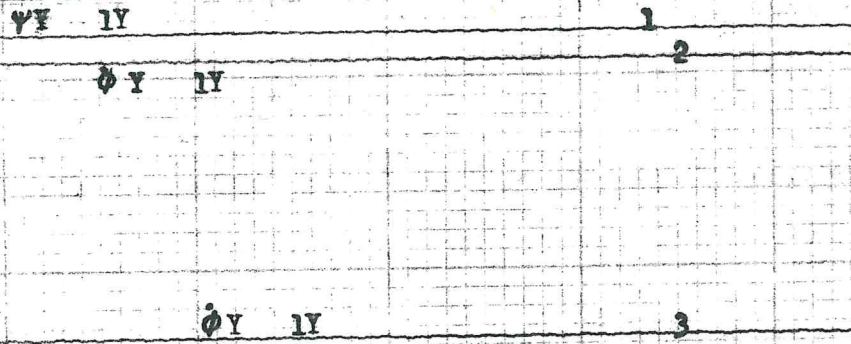
T_f	CURVES
1 ST & 2 ND BURN	1
2 ND BURN	
IGNITION $< T_f < 263.2$	2
$263.2 < T_f < \text{Cutoff}$	3

$i_y = 5 \text{ ma/in.}$

30
25
20
15
10
5
0

0 .2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8

TIME (Seconds)



S-IVB STAGE
 AS-501 CONTROL COMPUTER #503
 i_y OPEN LOOP RESPONSE
 ϕ STEP INPUT = 4 deg/sec
 ψ STEP INPUT = 5 deg.

PRIME CHANNEL

FIG. 25

T_f	CURVES
1 ST & 2 ND BURN	1
2 ND BURN	
IGNITION < T_f < 263.2	2
263.2 < T_f < Cutoff	3

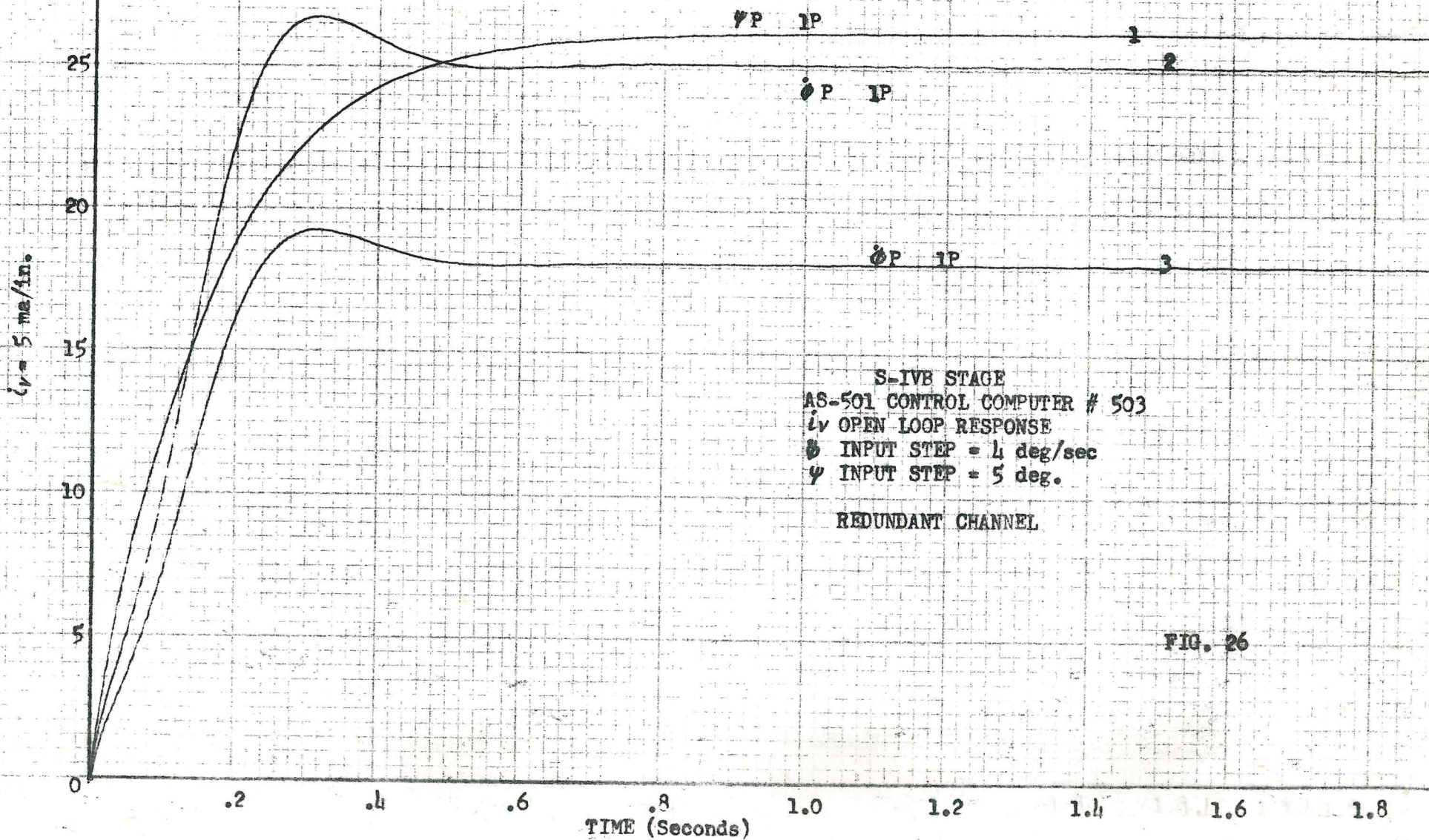


FIG. 26

$i_y = 5 \text{ ma/in.}$

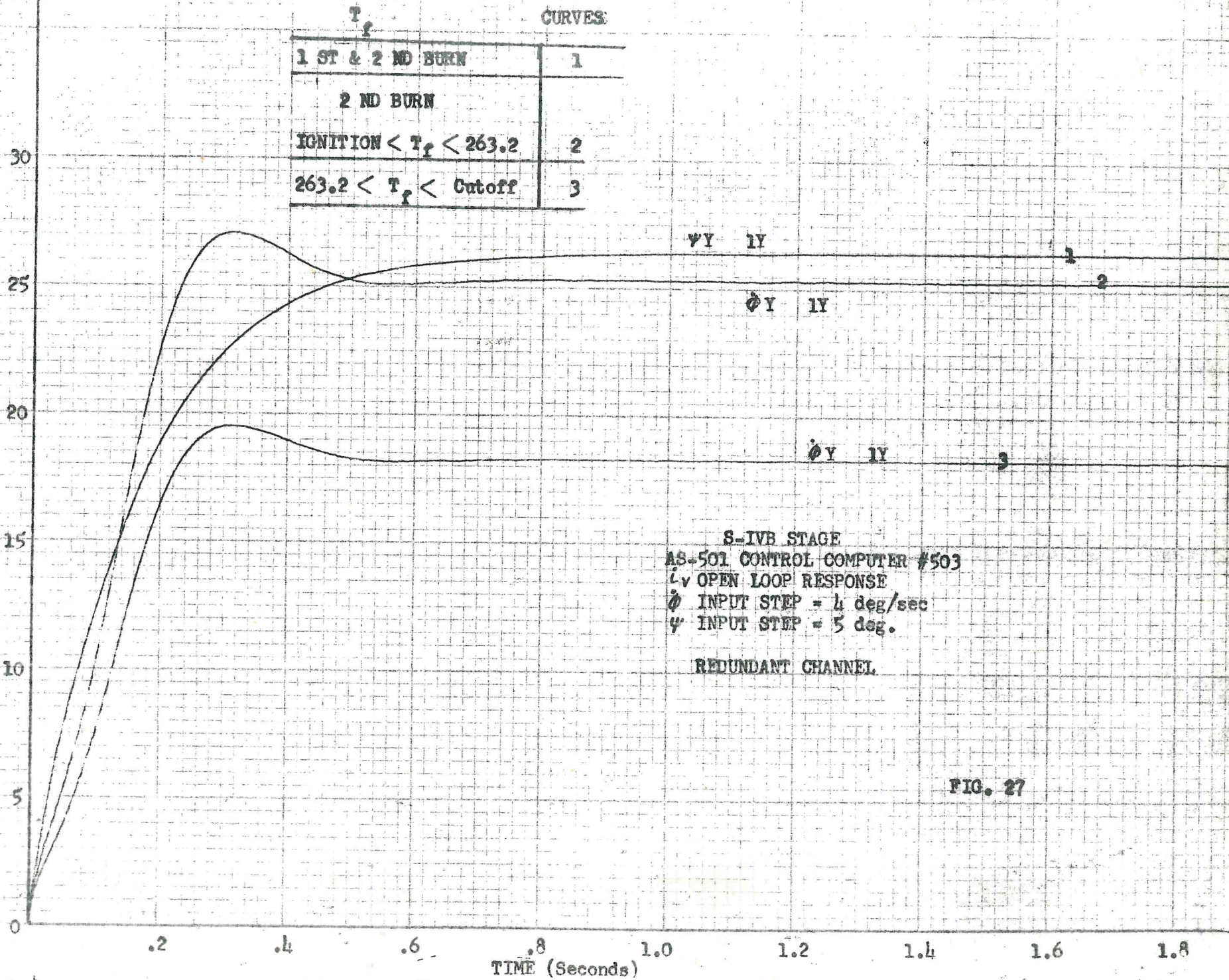


FIG. 27