2S3 Conf-790645--2

GAS INJECTION IN EBT-S FOR ASSESSMENT OF PARTICLE LOADING EFFECTS OF NEUTRAL BEAM INJECTION*

K. H. CARPENTER AND J. C. GLOWIENKA
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

EXPERIMENTS HAVE BEGUN TO EXAMINE THE PHYSICS OF NEUTRAL BEAM INJECTION ON EBT-S. PRELIMINARY EXPERIMENTS HAVE BEEN LIMITED TO A CALIBRATED GAS PUFFING EXPERIMENT WHICH SIMULATES THE EFFECTS OF A PULSED BEAM WITH ZERO ENERGY. THESE EXPERIMENTS BEGIN TO ADDRESS SOME OF THE COMPATIBILITY PROBLEMS THAT EXIST FOR FUTURE BEAM HEATING EXPERIMENTS ON EBT DEVICES. IN PARTICULAR, NEUTRAL BEAMS ARE TO BE A SIGNIFICANT PART OF THE PLANNED EBT-II EXPERIMENT[1] WHICH IS DESIGNED TO DEMONSTRATE STEADY-STATE, REACTOR-LIKE CONDITIONS WITH BOTH ELECTRON CYCLOTRON HEATING AND NEUTRAL BEAM HEATING.

AS MIGHT BE EXPECTED WITH A STEADY-STATE EXPERIMENT, EFFECTIVE PARTICLE CONTROL IS NECESSARY TO PREVENT THE VACUUM SYSTEM FROM BEING SWAMPED AND HENCE THE BACKGROUND PRESSURE FROM RISING. THIS IS PARTICULARLY CRITICAL FOR AN EBT DEVICE BECAUSE OVERALL MHD STABILITY, AS ESTABLISHED BY THE HIGH BETA HOT ELECTRON ANNULI, IS DETERMINED BY OPERATING WITHIN A RANGE OF NEUTRAL PRESSURE EQUILIBRIA.

OUTSIDE THAT RANGE, AT HIGH PRESSURES, THERE IS INSUFFICIENT ENERGY IN THE RINGS TO ESTABLISH A STABLE MINIMUM AVERAGE B CONFIGURATION. AT LOW PRESSURE, THERE IS INSUFFICIENT COLD PLASMA, WHOSE SOURCE IS THE NEUTRAL BACKGROUND REFLUXING FROM THE WALLS, TO STABILIZE THE RINGS.

THE ZERO ENERGY BEAM SIMULATES A GAS LOADING THAT ORIGINATES FROM TRAPPED, NON-HEATING PARTICLES, BEAM SCRAPE-OFF, AND BACKSTREAMING FROM THE BEAM LINE AND THE BEAM DUMP. FLOW RATES ARE IN THE RANGE OF 0.01 TO 0.4 TORR LITERS/SEC AND ARE TO BE CONTRASTED WITH A STEADY STATE PUMPING CAPACITY OF 0.015 TORR LITERS/SEC AT THE LOW PRESSURE END (3×10^{-6} TORR) OF PRESENT STABLE EXPERIMENTS. THE EFFECTS ON THE PLASMA EQUILIBRIUM (PRESSURE, RING STABILITY, MICROWAVE REFLECTED POWER, ETC.) AS OBSERVED WITH THE LIMITED SET OF FAST DIAGNOSTICS AVAILABLE WILL BE DISCUSSED.

*RESEARCH SPONSORED BY THE OFFICE OF FUSION ENERGY, U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. W-7405-ENG-26 WITH UNION CARBIDE CORPORATION.

[1]R. A. DANDL ET AL., THE EBT-II CONCEPTUAL DESIGN STUDY, ORNL/TM-5955 (1978).

NEUTRAL BEAMS LOOK ATTRACTIVE FOR AUXILLARY HEATING ON AN EBT DEVICE

BUT ARE THEY COMPATIBLE?

POTENTIAL PROBLEMS

1. MICROWAVE ISOLATION

2. PARTICLE HANDLING

THIS PAPER ADDRESSES #2.

EBT IS A STEADY-STATE DEVICE WITH DISTINCT MODES OF OPERATION THAT APPEAR TO BE DEFINED BY THE BACKGROUND NEUTRAL PRESSURE EQUILIBRIUM

FUSION RELEVANT "T-MODE" $10^{-6} \leq P \leq 10^{-5}$ TORR

- EXPERIMENTALLY, WE MOVE FROM ONE MODE TO ANOTHER BY MAKING SLOW (SECONDS) CHANGES IN GAS FEED (AND HENCE PRESSURE)

- MASSIVE HEATING BEAMS COULD PRESENT A PROBLEM WITH A STEADY-STATE EBT BECAUSE THE BEAMS ARE AN ADDITIONAL SOURCE OF COLD GAS THROUGH BACKSTREAMING AND COLD GAS EVOLUTION FROM SCRAPEOFF.

THIS COLD GAS

1) PROVIDES NO HEATING
2) CAN CHANGE PRESSURE EQUILIBRIUM
3) CAN DESTROY STABLE EQUILIBRIUM BY QUENCHING RINGS

NEUTRAL BEAMS LOOK ATTRACTIVE FOR AUXILLARY HEATING ON AN EBT DEVICE

BUT ARE THEY COMPATIBLE?

POTENTIAL PROBLEMS

1. MICROWAVE ISOLATION

2. PARTICLE HANDLING

THIS PAPER ADDRESSES #2.

EBT IS A STEADY-STATE DEVICE WITH DISTINCT MODES OF OPERATION THAT APPEAR TO BE DEFINED BY THE BACKGROUND NEUTRAL PRESSURE EQUILIBRIUM

FUSION RELEVANT "T-MODE" $10^{-6} \leq P \leq 10^{-5}$ TORR

- EXPERIMENTALLY, WE MOVE FROM ONE MODE TO ANOTHER BY MAKING SLOW (SECONDS) CHANGES IN GAS FEED (AND HENCE PRESSURE)

- MASSIVE HEATING BEAMS COULD PRESENT A PROBLEM WITH A STEADY-STATE EBT BECAUSE THE BEAMS ARE AN ADDITIONAL SOURCE OF COLD GAS THROUGH BACKSTREAMING AND COLD GAS EVOLUTION FROM SCRAPEOFF.

THIS COLD GAS

1) PROVIDES NO HEATING
2) CAN CHANGE PRESSURE EQUILIBRIUM
3) CAN DESTROY STABLE EQUILIBRIUM BY QUENCHING RINGS

ADDRESS PROBLEMS ON EBT-S

- DETERMINE NET PUMPING SPEED
- SIMULATE COLD GAS LOADING WITH CALIBRATED GAS PUFF

POINT OF INFORMATION – A SIGNIFICANT ION HEATING EXPERIMENT ON EBT-S

$$n = 3 \times 10^{12}$$

$$T_e = 400 \text{ eV}$$

$$T_i = 100 \text{ eV}$$

$$V = 4 \times 10^5 \text{ cm}^3$$

TO DOUBLE POWER TO IONS REQUIRES

50 kW

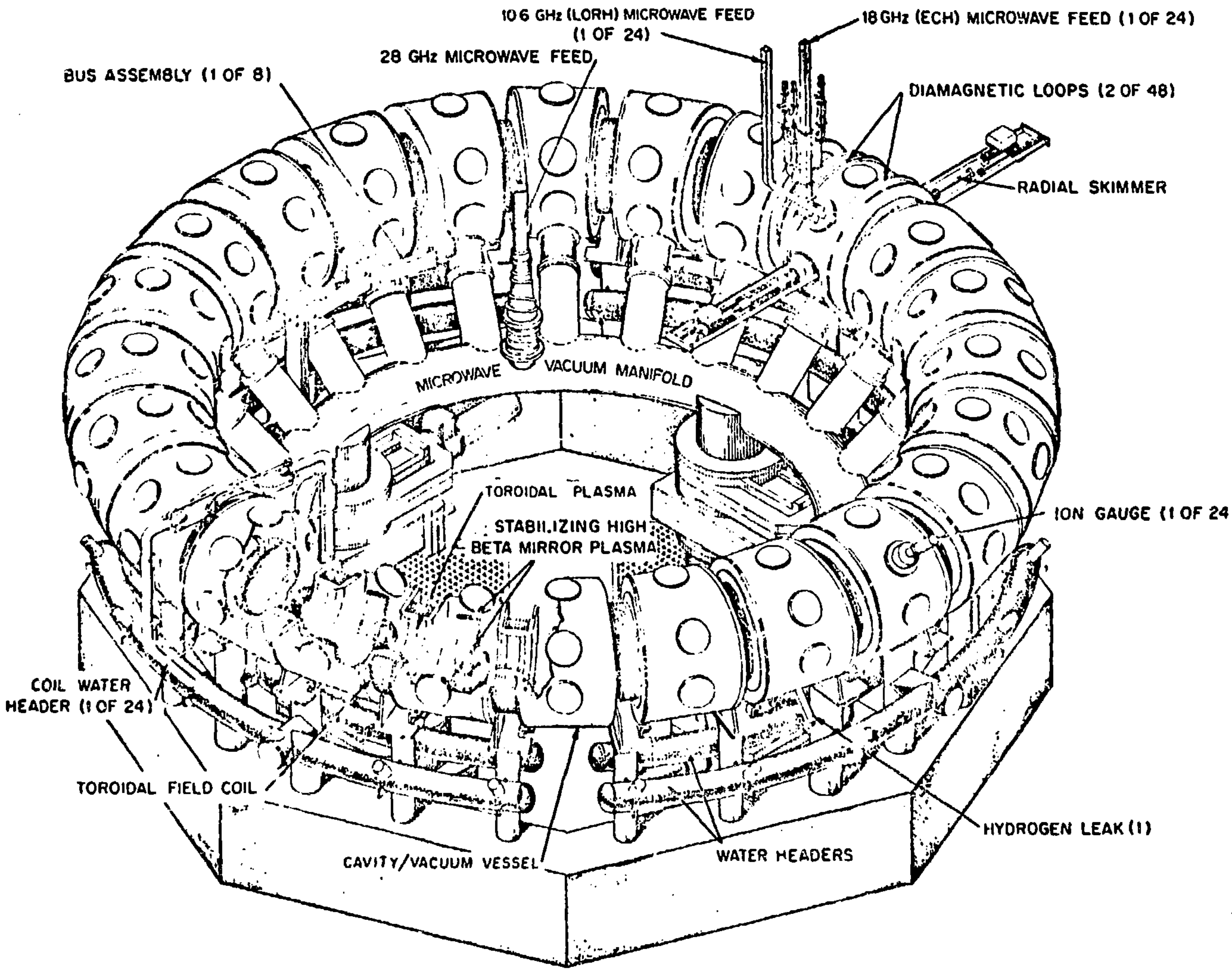
@ 5 kV

@ 10 A

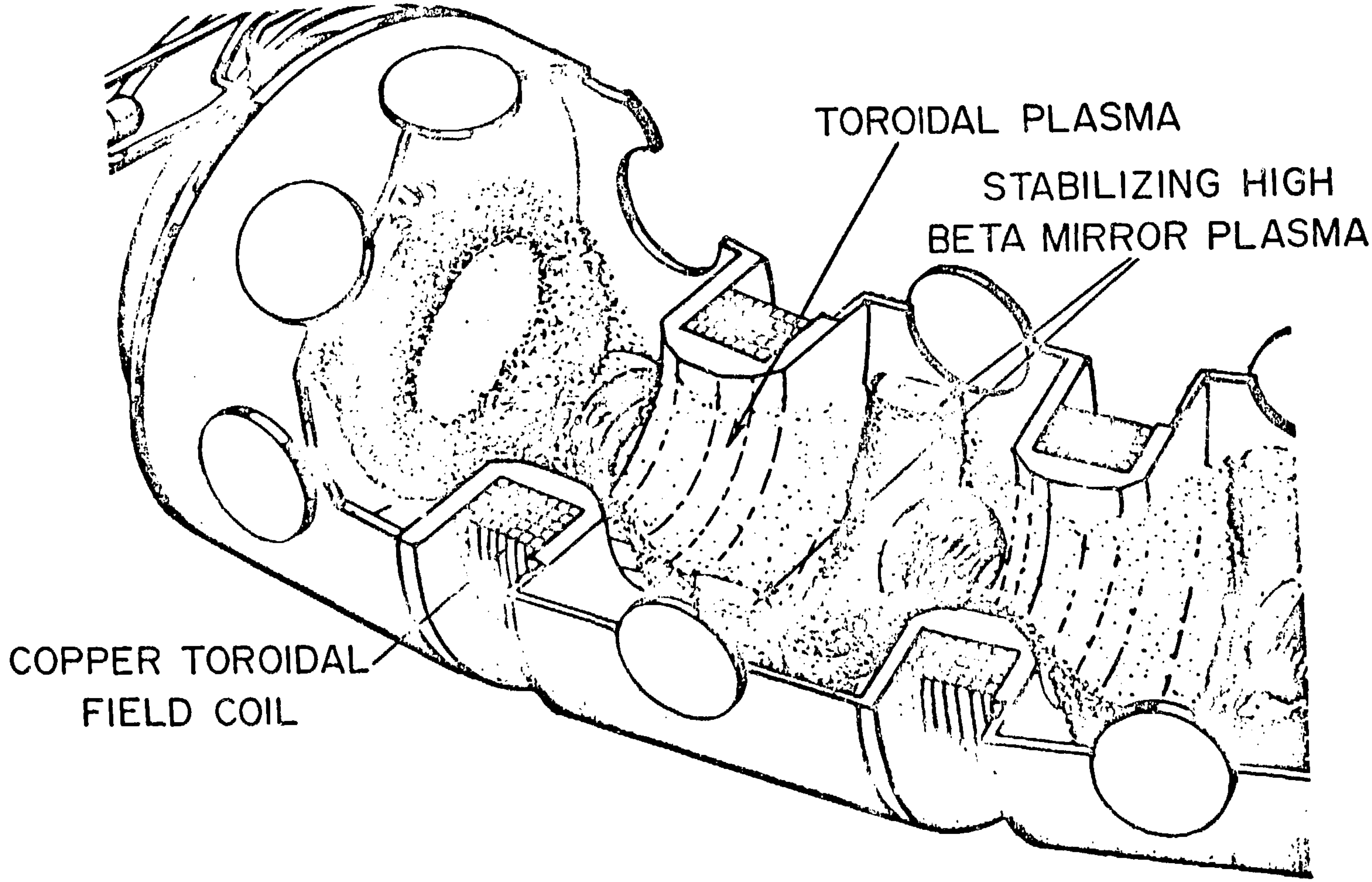
WITH 5 kV, 10% TRAPPED

OF THAT 25% HEAT, 100% CHARGE EXCHANGE AND BECOME PART OF THE GAS LOAD

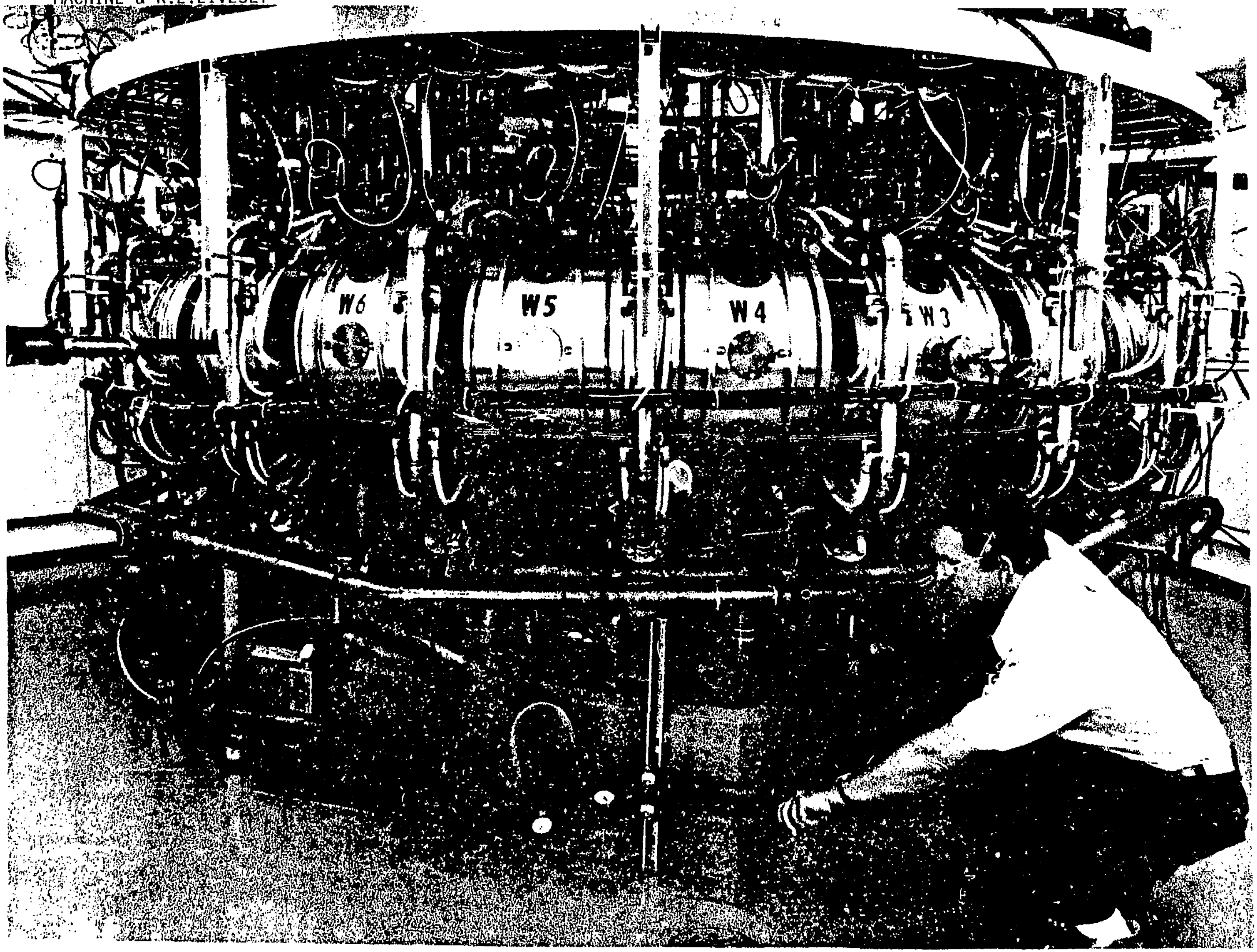
ORNL DWG 73-5045R5C



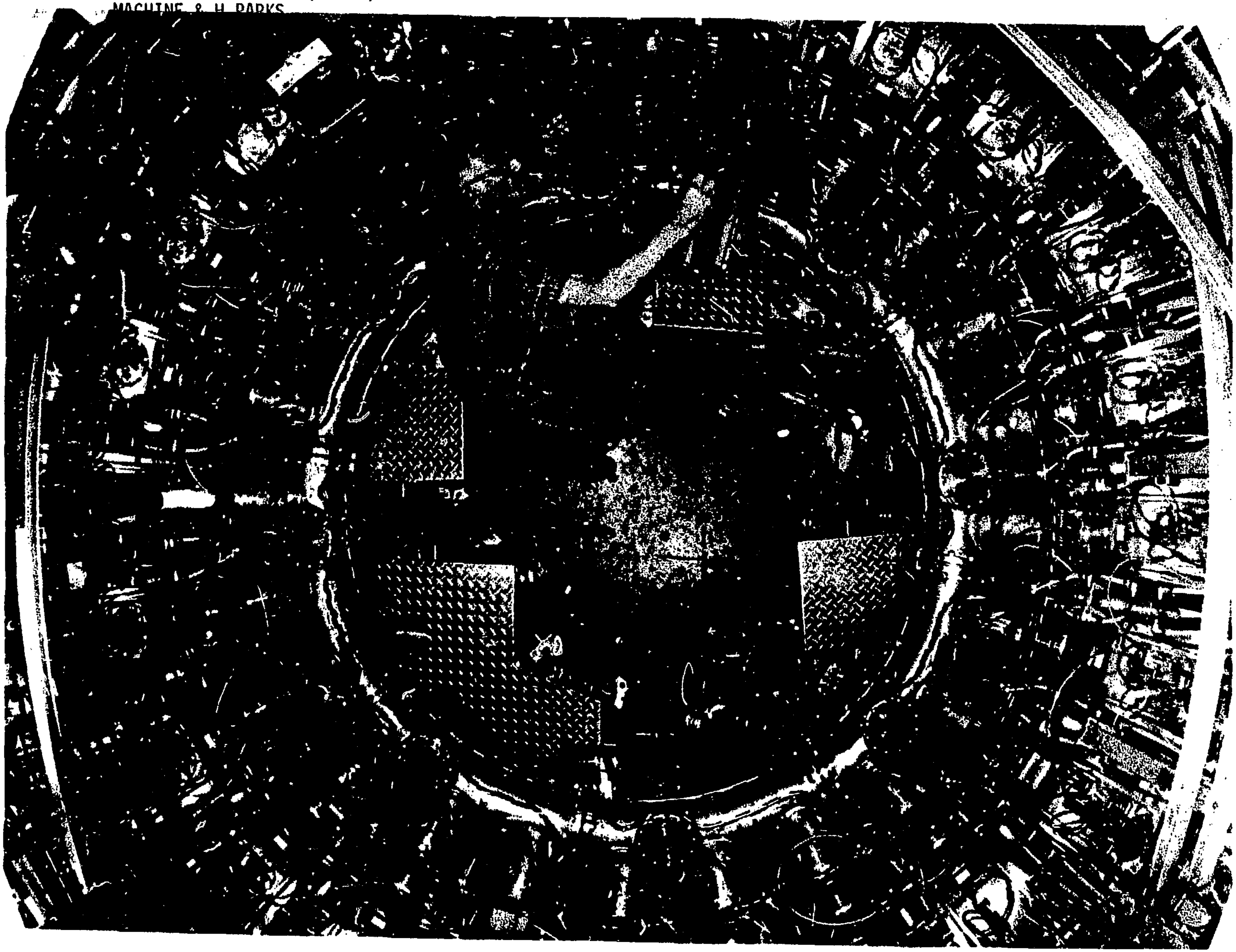
Elmo Bumpy Torus.

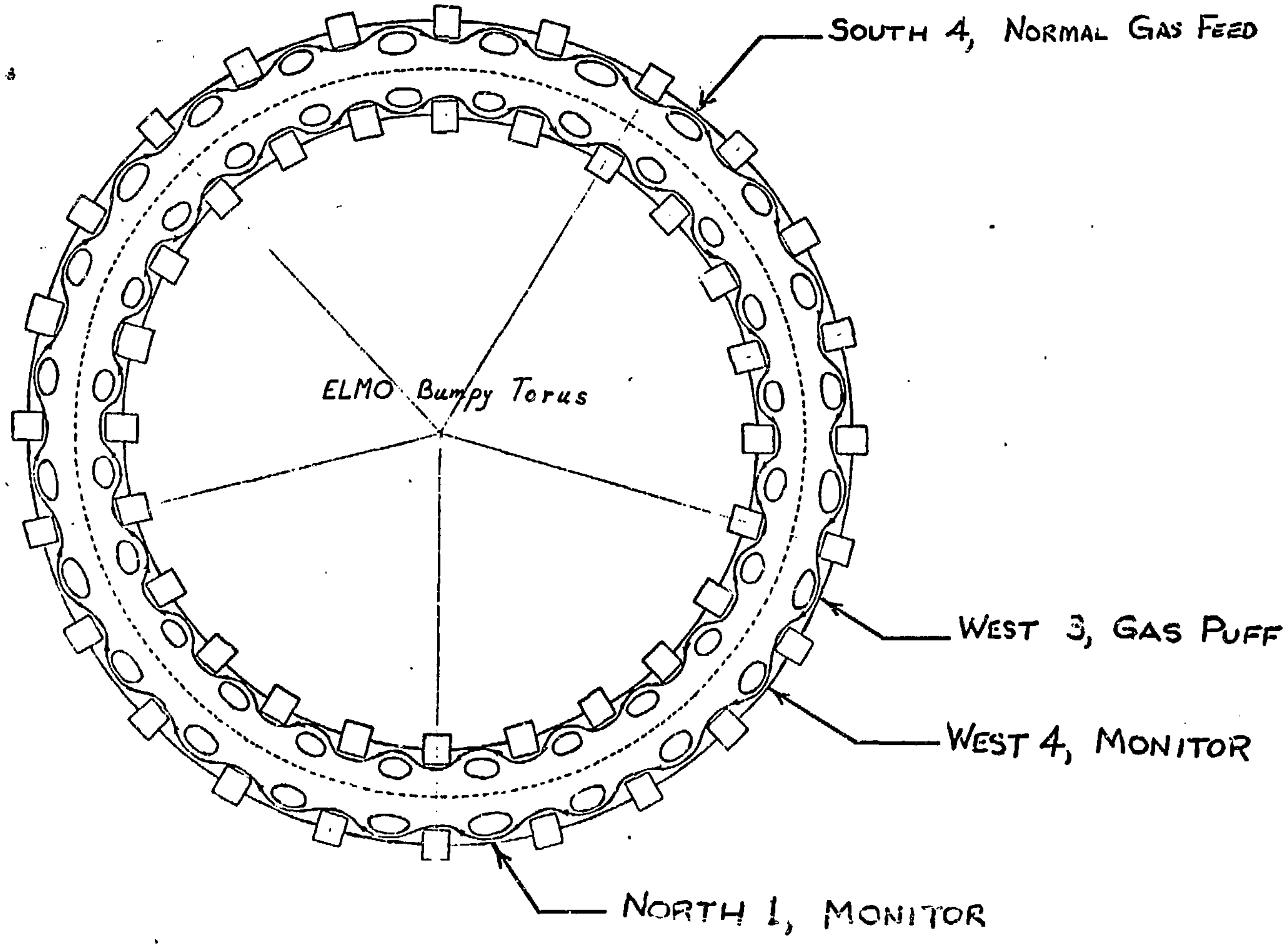

TOROIDAL PLASMA
STABILIZING HIGH
BETA MIRROR PLASMA
COPPER TOROIDAL
FIELD COIL

EBT-PHOTOS #14
ORO PHOTO 78-24[illegible] (COLOR)
MACHINE & R.L.LIVESEY



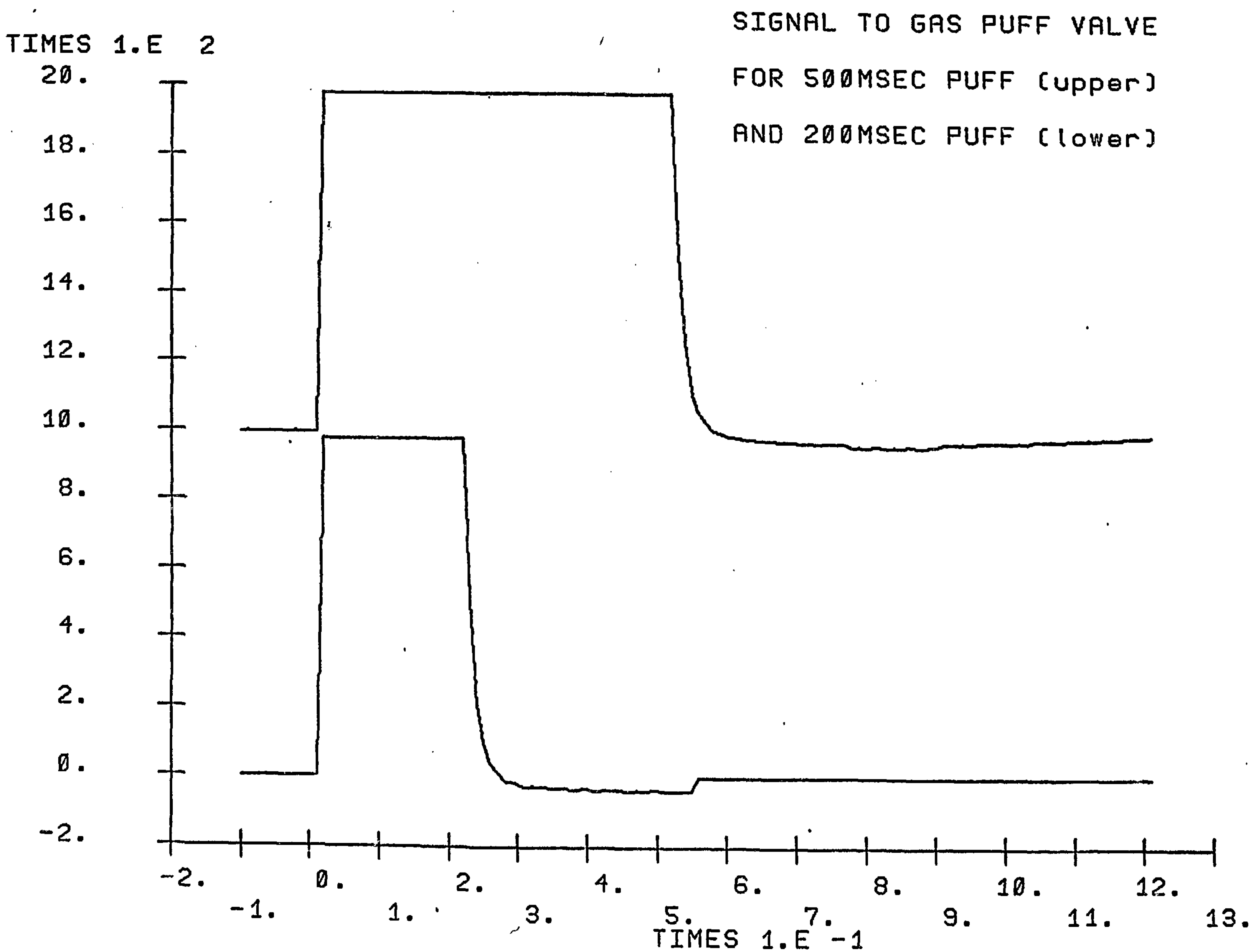
EBT-PHOTOS #16
ORO PHOTO 78-250-1 (COLOR)
MACHINE & H PARKS

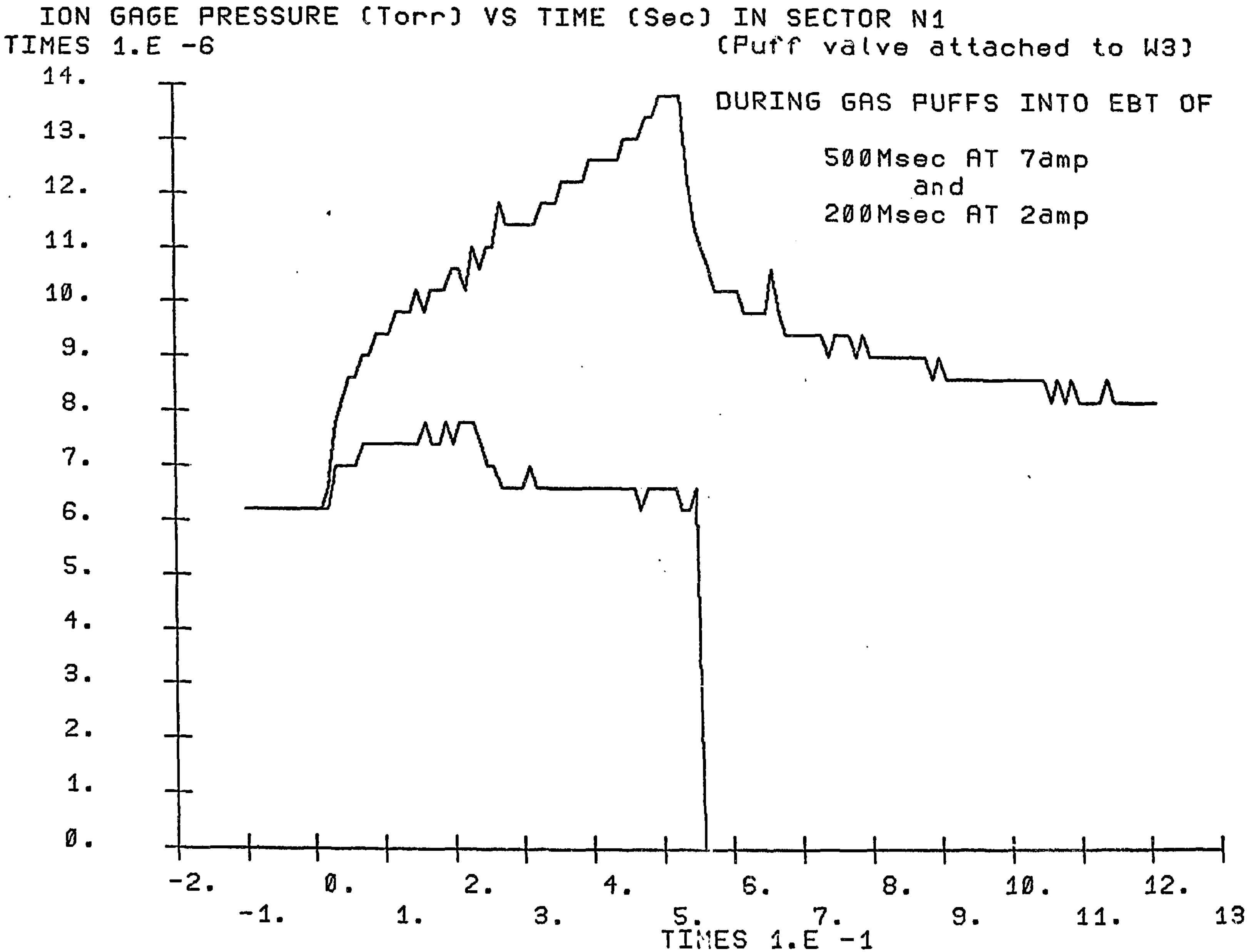


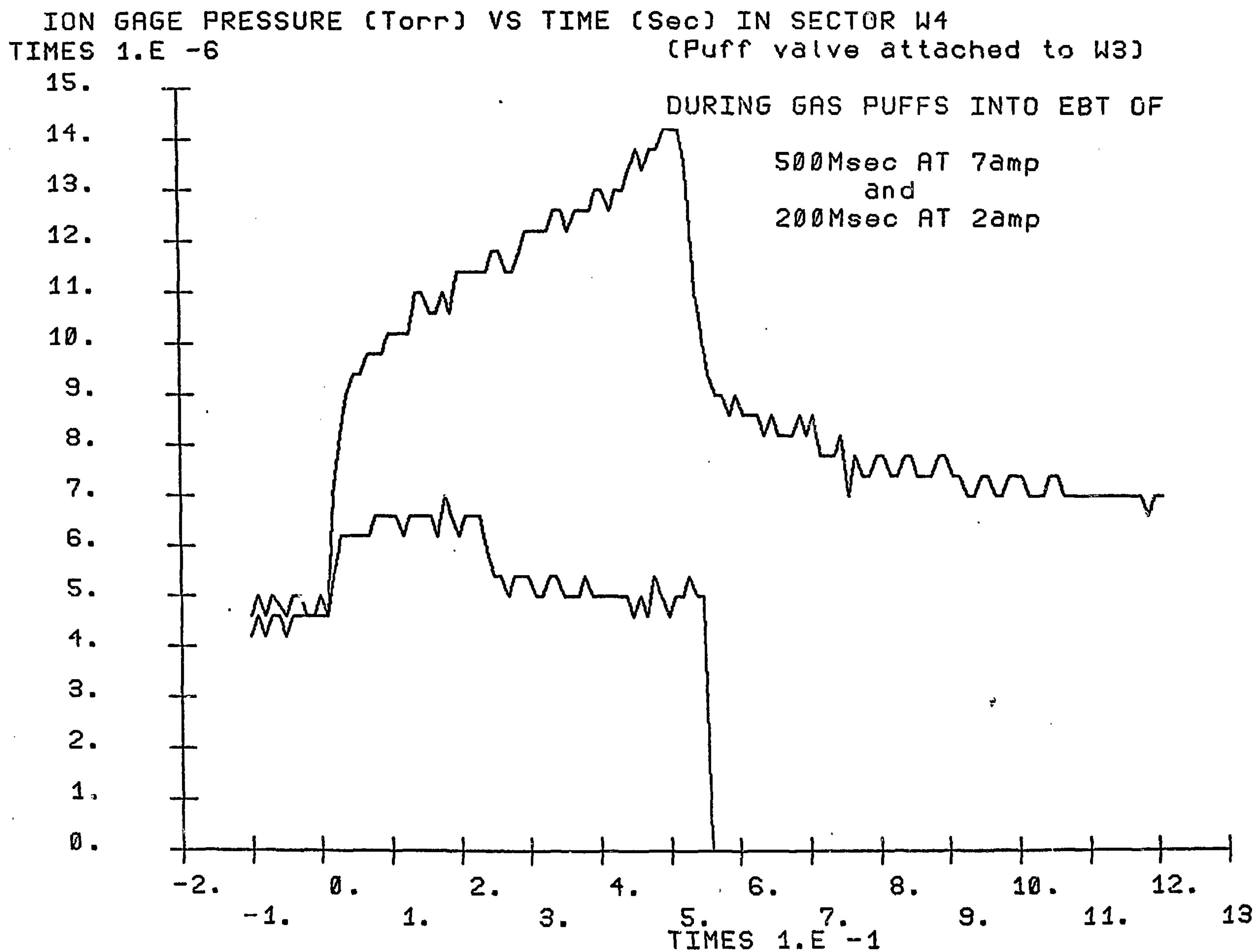

SOUTH 4, NORMAL GAS FEED
ELMO Bumpy Torus
WEST 3, GAS PUFF
WEST 4, MONITOR
NORTH 1, MONITOR

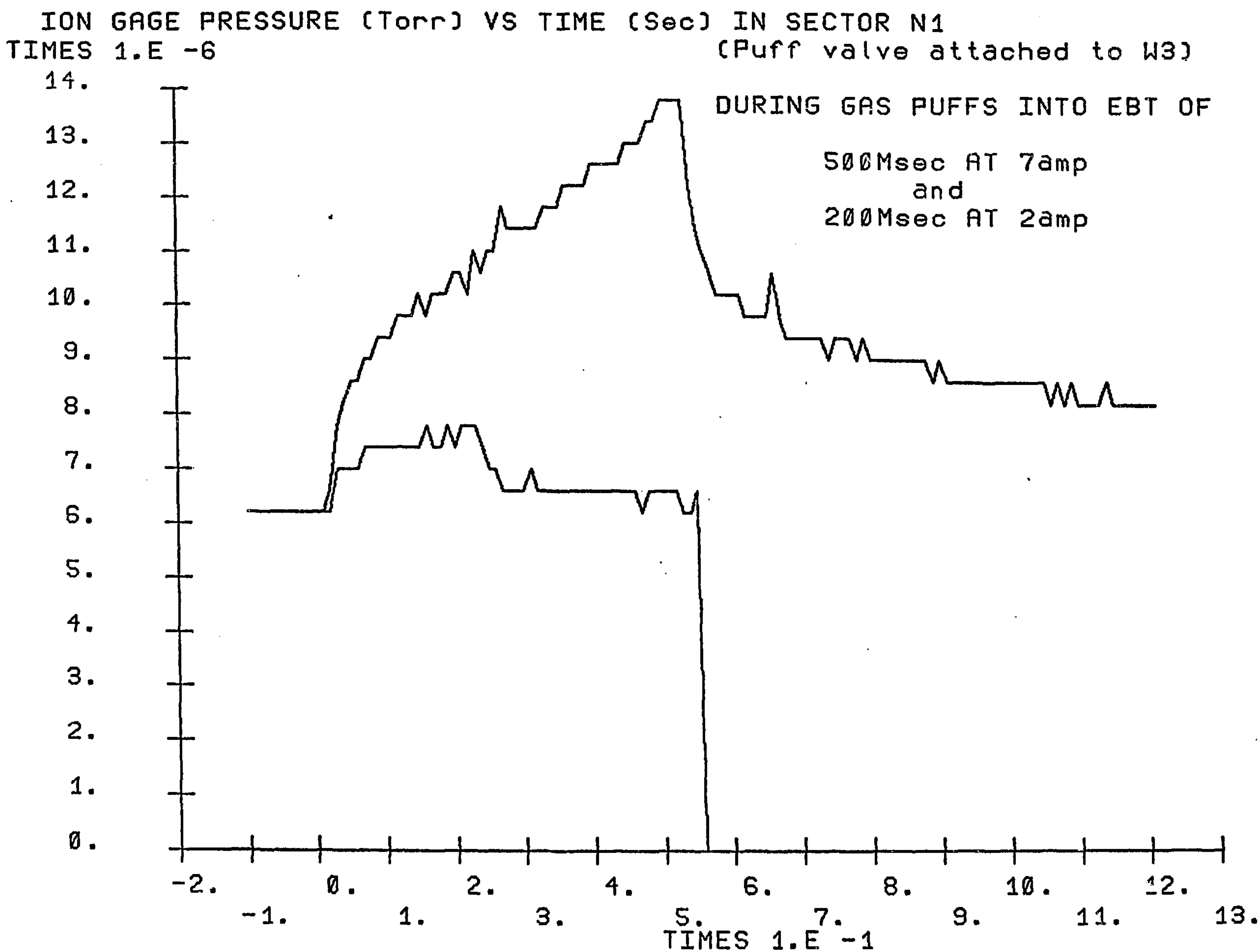
PUFF EXPERIMENT

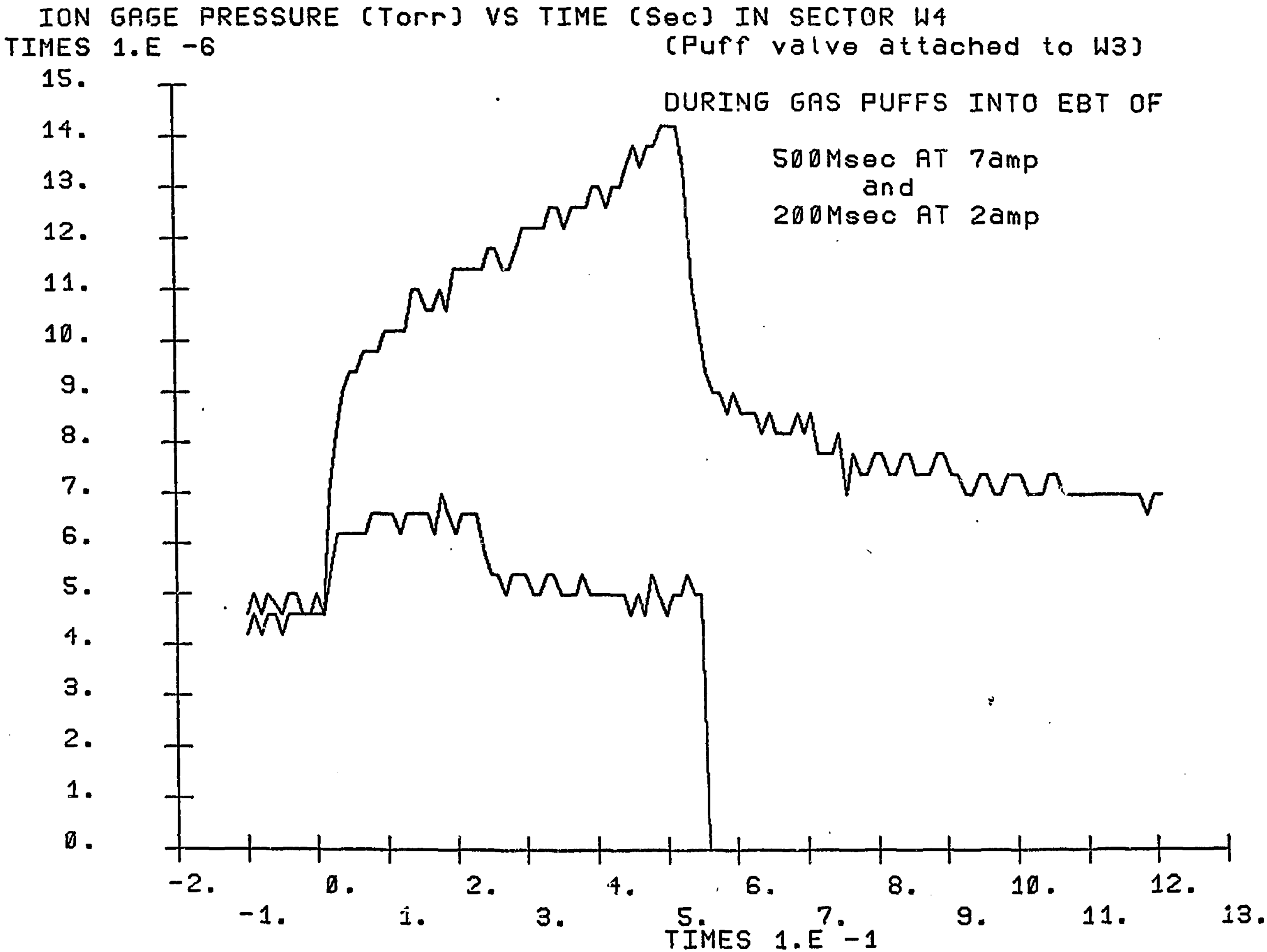
PULSE NO.	P_B(TORR)	Δt(ms)	FLUENCE	
1	21	100	0.075 TORR ℓ/SEC	0.38A
2	22	200	0.081	0.4
3	22	500	0.081	0.4
4	30	500	0.15	0.77
5	30	200	0.15	0.77
6	50	200	0.43	2.1
7	70	500	0.43	2.1
8	70	500	0.83	4.2
9	70	200	0.83	4.2
10	90	200	1.4	7.0
11	91	500	1.4	7.0


SIGNAL TO GAS PUFF VALVE
FOR 500MSEC PUFF (upper)
AND 200MSEC PUFF (lower)
TIMES 1.E 2
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0.
-2.
-2.
-1.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
TIMES 1.E -1

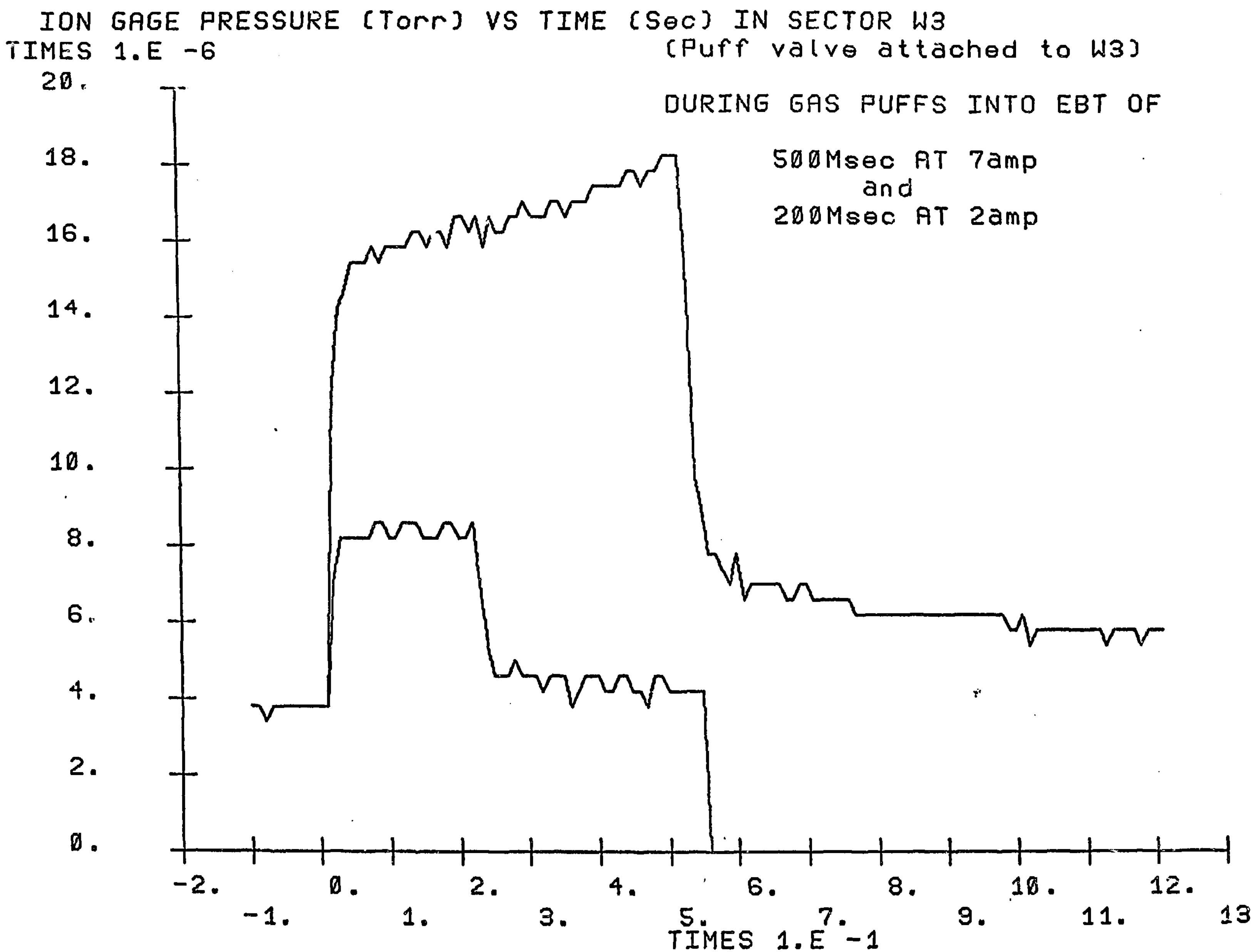

ION GAGE PRESSURE (Torr) VS TIME (Sec) IN SECTOR N1
TIMES 1.E -6
(Puff valve attached to W3)
DURING GAS PUFFS INTO EBT OF
500Msec AT 7amp
and
200Msec AT 2amp
14.
13.
12.
11.
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
0.
-2.
0.
2.
4.
6.
8.
10.
12.
-1.
1.
3.
5.
7.
9.
11.
13.
TIMES 1.E -1


ION GAGE PRESSURE (Torr) VS TIME (Sec) IN SECTOR W4
TIMES 1.E -6
(Puff valve attached to W3)
DURING GAS PUFFS INTO EBT OF
500Msec AT 7amp
and
200Msec AT 2amp
15.
14.
13.
12.
11.
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
0.
-2.
0.
2.
4.
6.
8.
10.
12.
-1.
1.
3.
5.
7.
9.
11.
13.
TIMES 1.E -1

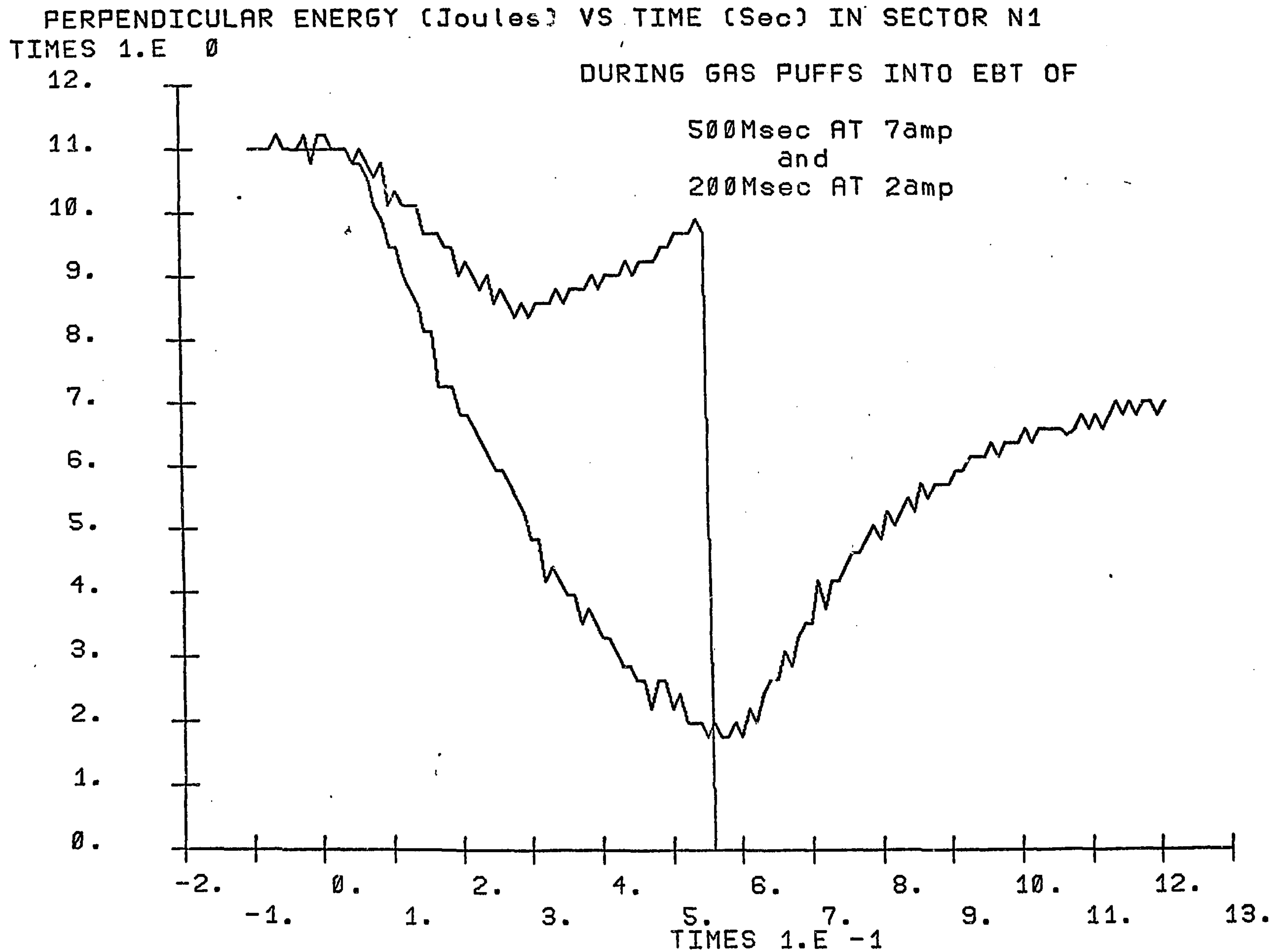

ION GAGE PRESSURE (Torr) VS TIME (Sec) IN SECTOR N1
TIMES 1.E -6
(Puff valve attached to W3)
DURING GAS PUFFS INTO EBT OF
500Msec AT 7amp
and
200Msec AT 2amp
14.
13.
12.
11.
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
0.
-2.
-1.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
TIMES 1.E -1



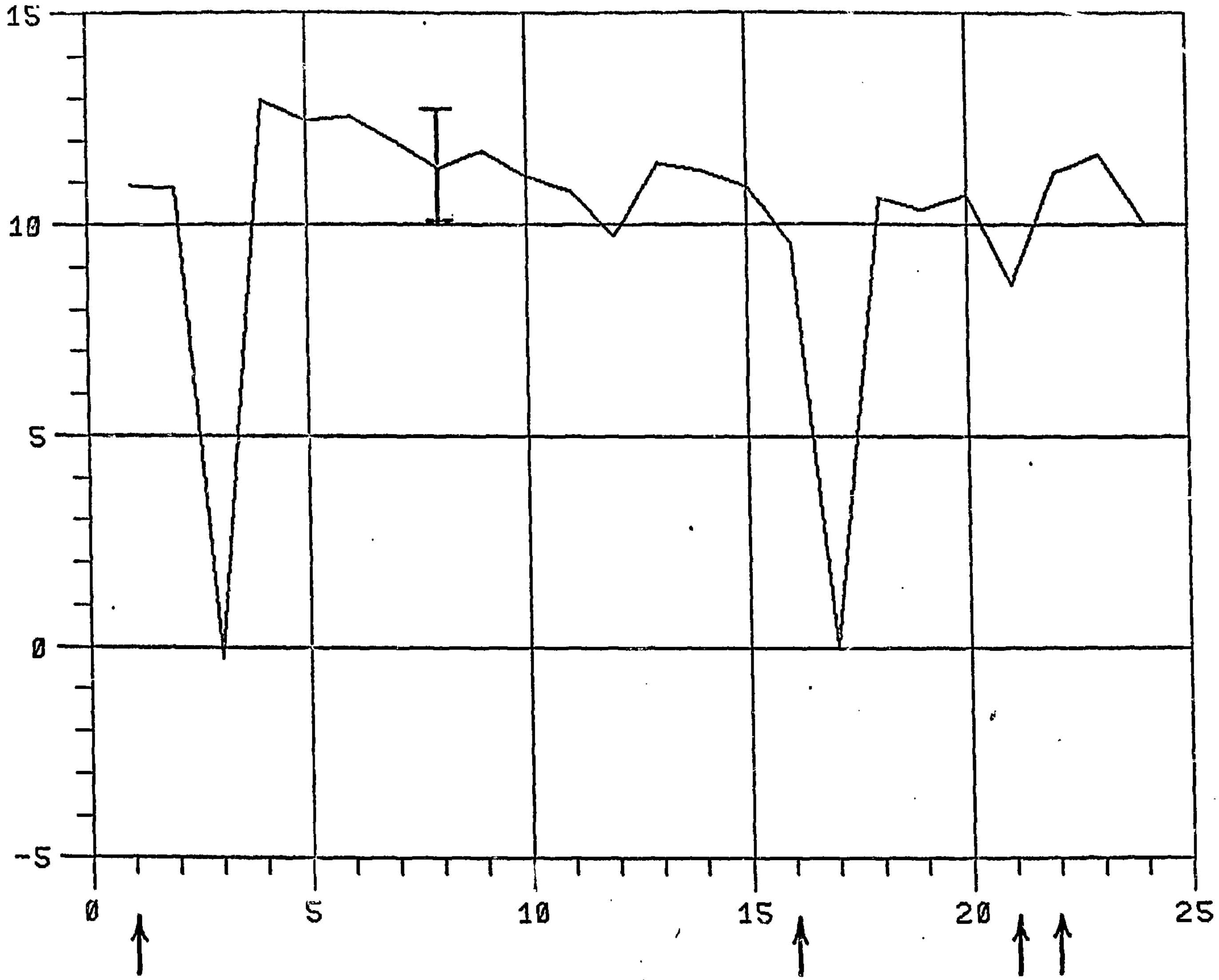
ION GAGE PRESSURE (Torr) VS TIME (Sec) IN SECTOR W4
TIMES 1.E -6
(Puff valve attached to W3)
DURING GAS PUFFS INTO EBT OF
500Msec AT 7amp
and
200Msec AT 2amp
15.
14.
13.
12.
11.
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
0.
-2.
-1.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
TIMES 1.E -1



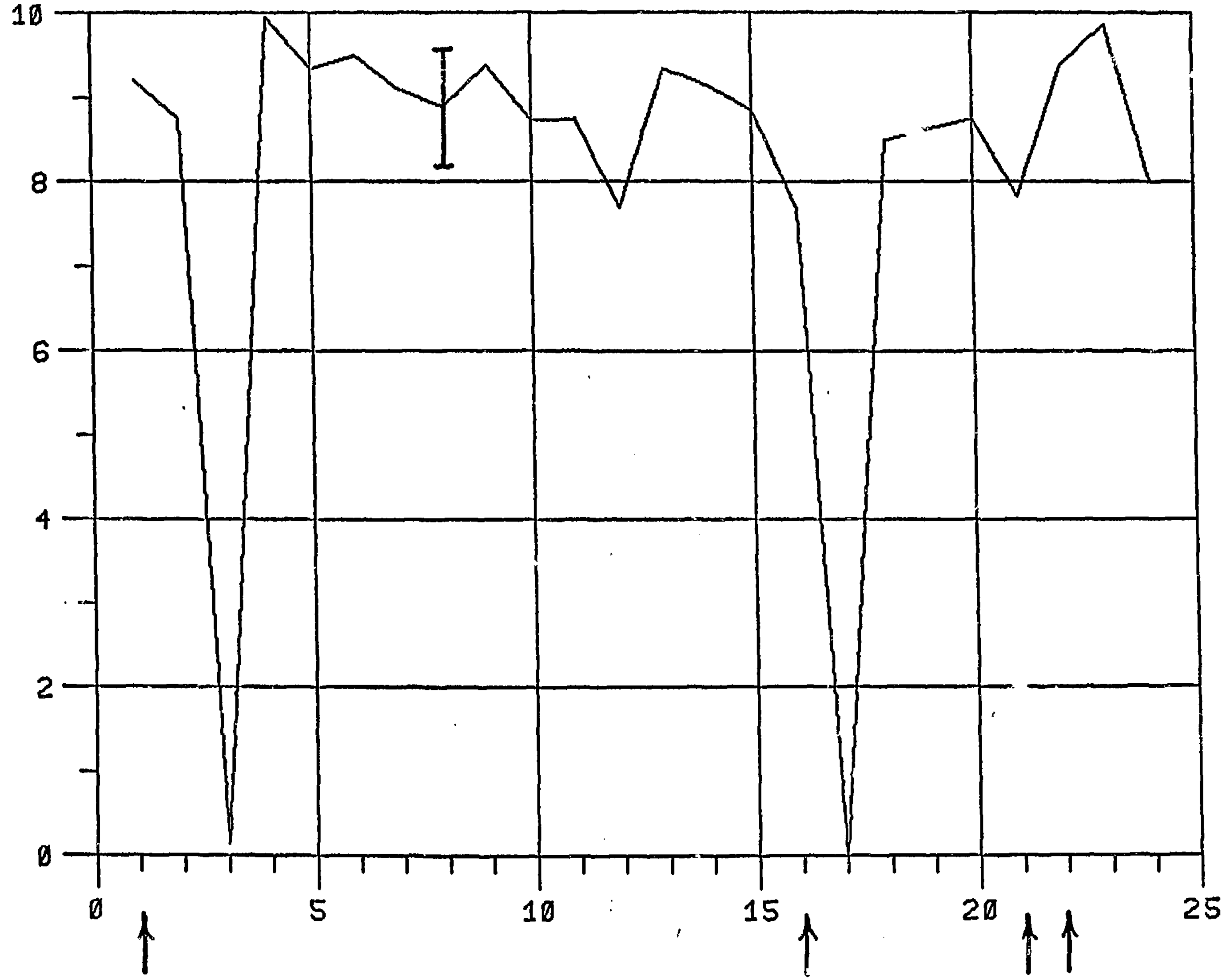
ION GAGE PRESSURE (Torr) VS TIME (Sec) IN SECTOR W3
TIMES 1.E -6
(Puff valve attached to W3)
DURING GAS PUFFS INTO EBT OF
500Msec AT 7amp
and
200Msec AT 2amp
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0.
-2.
-1.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
TIMES 1.E -1


PERPENDICULAR ENERGY (Joules) VS TIME (Sec) IN SECTOR N1
TIMES 1.E 0
DURING GAS PUFFS INTO EBT OF
500Msec AT 7amp
and
200Msec AT 2amp
12.
11.
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
0.
-2.
-1.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
TIMES 1.E -1

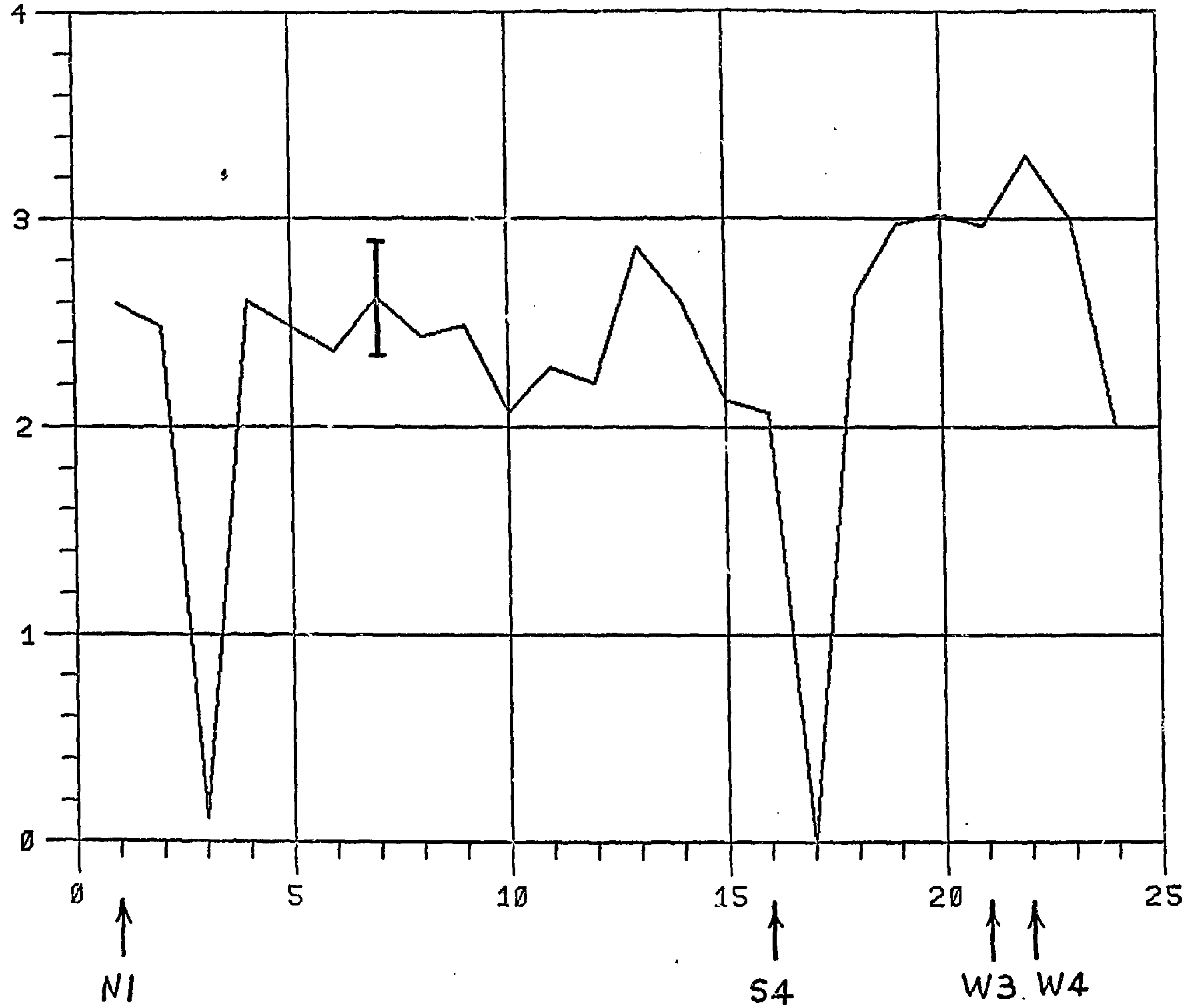
PERPENDICULAR ENERGY (in Joules) VS SECTOR (1=N1, 24=W6)
FOR BASE CONDITIONS FOR GAS PUFFING EXPERIMENTS ON EBT



DECREASE IN PERPENDICULAR ENERGY (in Joules) VS. SECTOR (1=N1, 24=W6)
ON 500 MSEC GAS PUFF INTO EBT AT 7 amp PARTICLE INFLUX



DECREASE IN PERPENDICULAR ENERGY (in Joules) VS. SECTOR (1=N1, 24=W6)
ON 200 MSEC GAS PUFF INTO EBT AT 2 amp PARTICLE INFLUX



CONCLUSIONS

EBT PLASMA CAN WITHSTAND GAS PUFF

- PLASMA REMAINS MHD STABLE
- PRESSURE EQUILIBRIUM REQUIRES MINUTES
- MICROWAVE POWER NOT INTERRUPTED