“OBSERVATION OF NEUTRONS AND TRITIUM IN A WIDE VARIETY OF LENR CONFIGURATIONS : BARC RESULTS REVISITED”

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(Formerly of BARC)

ACS Symposium on

“New Energy Technologies”

Salt Lake City, Utah, USA

23rd March 2009

LENR RESEARCH AT BARC

- Phase i : 1989 to 1991 (ICCF 1/Provo)

  (Most productive era !)

- Phase ii : 1992 to 1995 (ICCF 3,4,5)

  (Post Iyengar period)

- Phase iii : 1996 to 2007 (12 years)

  (India totally blanked out !)

- Phase iv : 2008 Hopes of revival

  (Following NIAS meeting of 9th January 2008)

HIGHLIGHTS OF EARLY BARC WORK

(Started on 24th March 1989)

- BARC has > 50 Divisions & 3000 Scientists!
- 12 teams (~ 50 scientists) took up challenge
- To verify "nuclear origin" of phenomenon
- Looked for neutrons & Tritium (Not excess heat)
- Within months all teams reported both n & T
- Among first groups to find branching ratio anomaly namely (n/T) = ~ 10^{-7}
- ICENES Karlsruhe 4th to 7th July 1989
- Report BARC 1500 (Aug '89) (historical role!)
- ICCF 1, Provo Conf. & Fusion Technol. paper of Aug '90 with 50 authors summarize this work

MILTON ROY Pd-D_2O ELECTROLYTIC CELL

- Neutron Physics Division was lucky !
- Fortuitous coincidence that on 24th March 1989, the "worlds largest cold fusion cell" (300 cm^2 cathode area) was all set & ready to be switched on!
- Had been imported from M-R co. of Ireland and adapted to generate "pure" D_2 gas.
- Uses Pd-Ag alloy tubular cathodes (16 nos)
- Inner/outer Ni pipes as anode.
- Max current capacity ~100 amps

SCHEMATIC OF MILTON-ROY ELECTROLYTIC CELL

300 cm^2 cathode area; 100 amps current; Largest?

Ready to be operated with NaOD on 24th March 1989 !

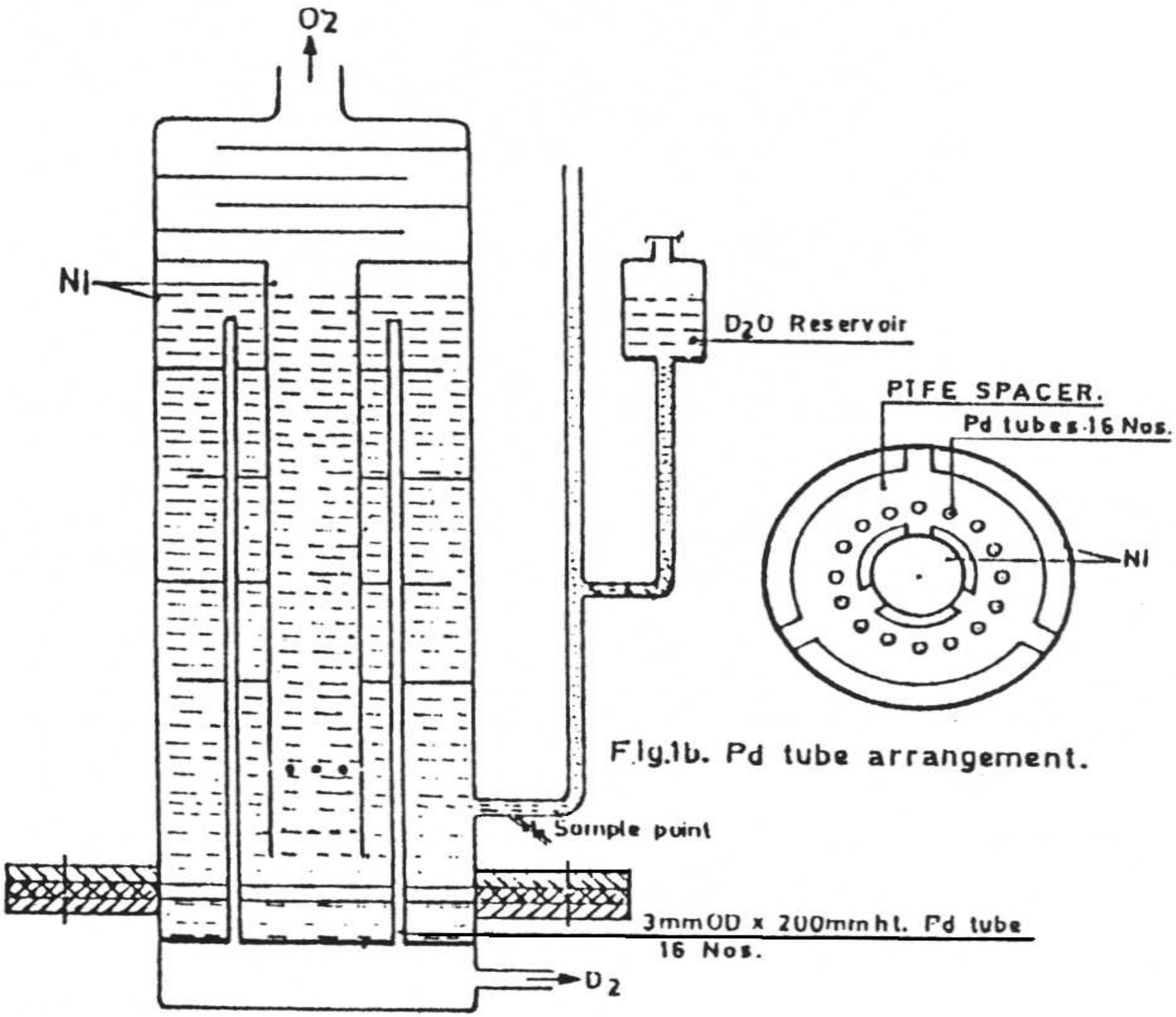


Fig.1b. Pd tube arrangement.

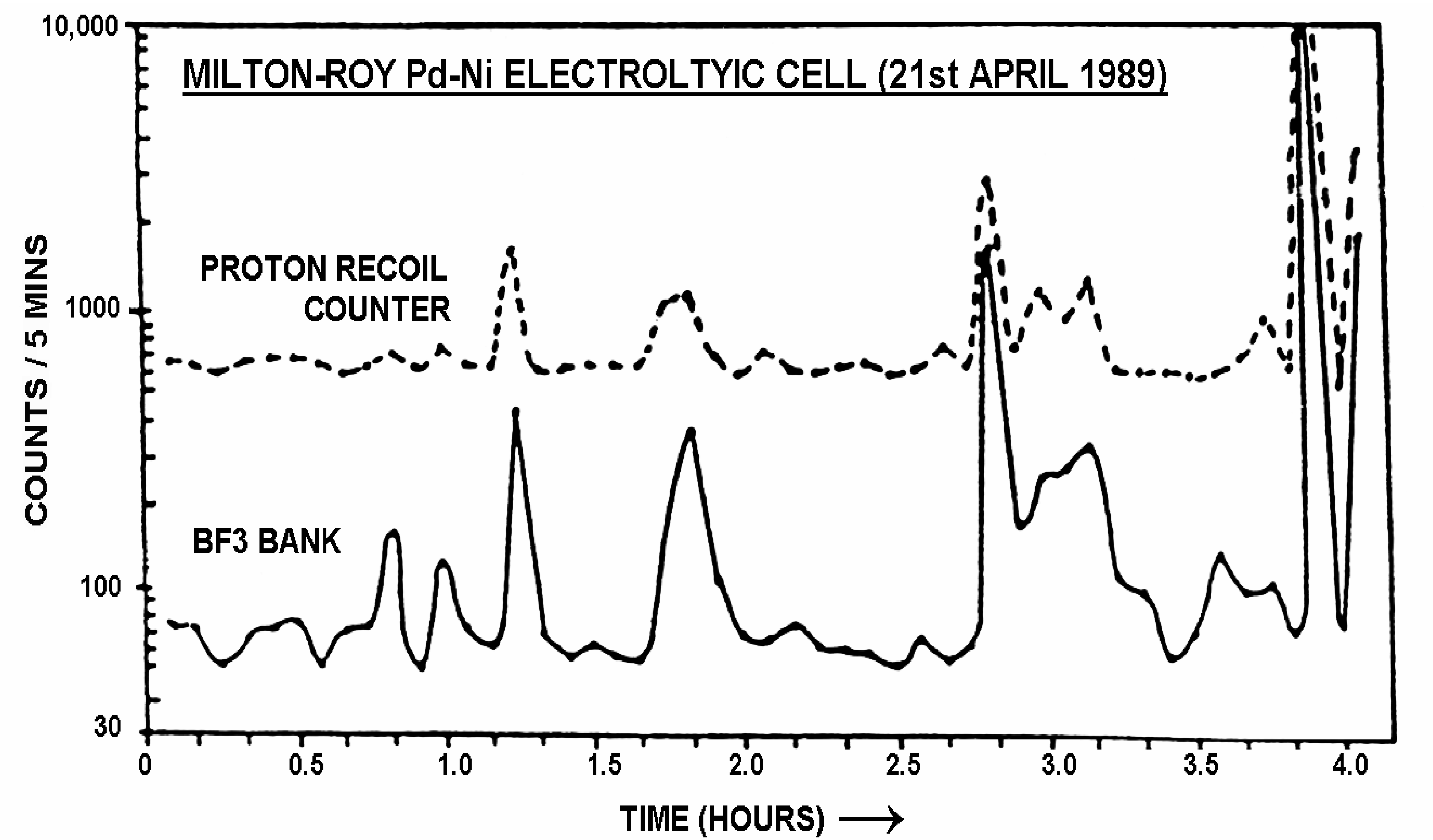
New Energy Times

NEUTRON DETECTION CHANNELS

- Three channels : Two for foreground,
  One for background
- Foreground 1 : Three BF_3 counters embedded in a large paraffin block (thermal neutron detector)
- Foreground 2 : Recoil type plastic scintillator fast neutron monitor
- Background monitor : He^3 counters embedded in paraffin

VARIATION OF NEUTRON COUNTS DURING RUN NO.1

Current slowly increased to 100 A when a huge n episode occurred & cell tripped due to overheating!



New Energy Times

Temporal characteristics of "n" emission : nomenclature used

- Distinguish between "spike type episodes" and neutron "bursts".
- In "burst "events multiple neutrons emitted "simultaneously".
- "Steady neutron output" or "spike type episodes" could in turn comprise of a series of rapidly occurring "bursts".
- Discussed further in second paper

Tritium in Electrolyte Sample

- Electrolyte samples sent for tritium analysis
- Sample from MR cell showed massive amount of 1.5 µCi/ml after the 21st April 89 incident!!
- Pre electrolysis value in stock D_2O was only 0.075 nCi/ml (Increased by factor of 20,000 !)
- This corresponded to total T production of 8.10^{15} atoms
- Total neutron yield in 4 hr run was : 4.10^{7}
- Hence (n/T) ratio ......5.10^{-7}
- First hint of branching ratio anomaly!

BARC ELECTROLYSIS EXPERIMENTS (1989-90)

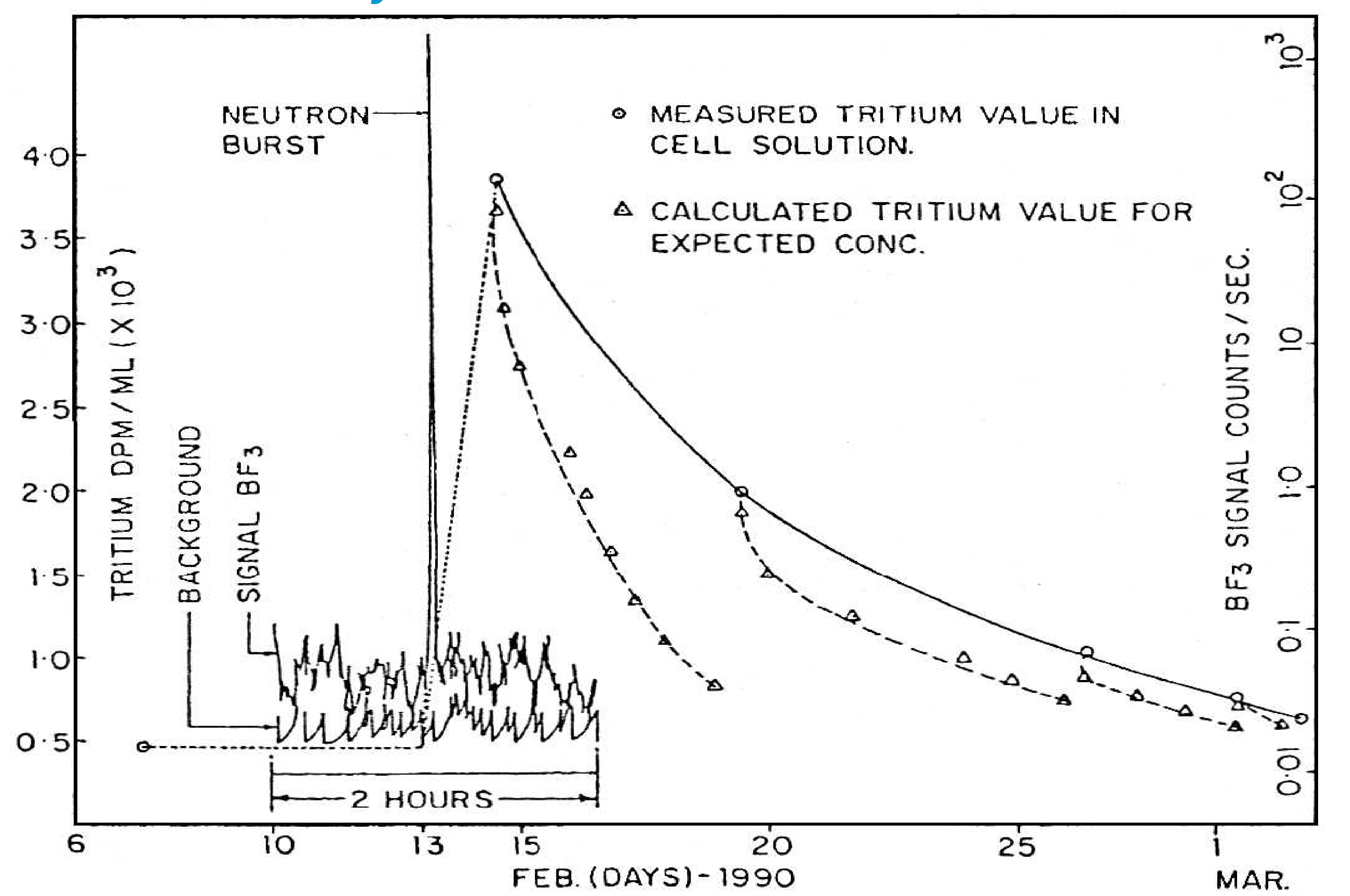
Division	Cathode: Matl	Geom	cm2 Area	Anode	Neutron Yield	Tritium Yield	n/T Ratio
1 Desalin *	Ti	Rod	104	ss pipe	3.10^{+7}	$1.4\ 10^{+14}$	2.10^{-7}
2 Neut. Phy.*	Pd-Ag	Tubes	300	Ni Pipes	4.10^{+7}	8.10^{+15}	5.10^{-7}
3 HWD *	"	"	300	"	9.10^{+7}	$1.9\ 10^{+15}$	5.10^{-7}
4 HWD *	"	5 Disks	78	Porus Ni	5.10^{+4}	4.10^{+15}	$1.2\ 10^{-9}$
5 Anal.Ch.@	Pd	Hol.Cyl.	5.9	Pt Mesh	3.10^{+6}	$7.2\ 10^{+13}$	4.10^{-8}
6 ROMg @	"	Cube	6.0	"	$1.4\ 10^{+6}$	$6.7\ 10^{+11}$	$1.7\ 10^{-4}$
7 ROMg @	"	Pellet	5.7	"	3.10^{+6}	4.10^{+12}	1.10^{-4}
8 App.Chem @	"	Ring	18	"	$1.8\ 10^{+8}$	$1.8\ 10^{+11}$	1.10^{-3}

Electrolyte : * 5M NaOD @ 0.1M LiOd

New Energy Times

NEUTRON AND TRITIUM OUTPUT ROMG CELL

11 mm Cyl. Pd Pellet cathode -13th Feb 1990



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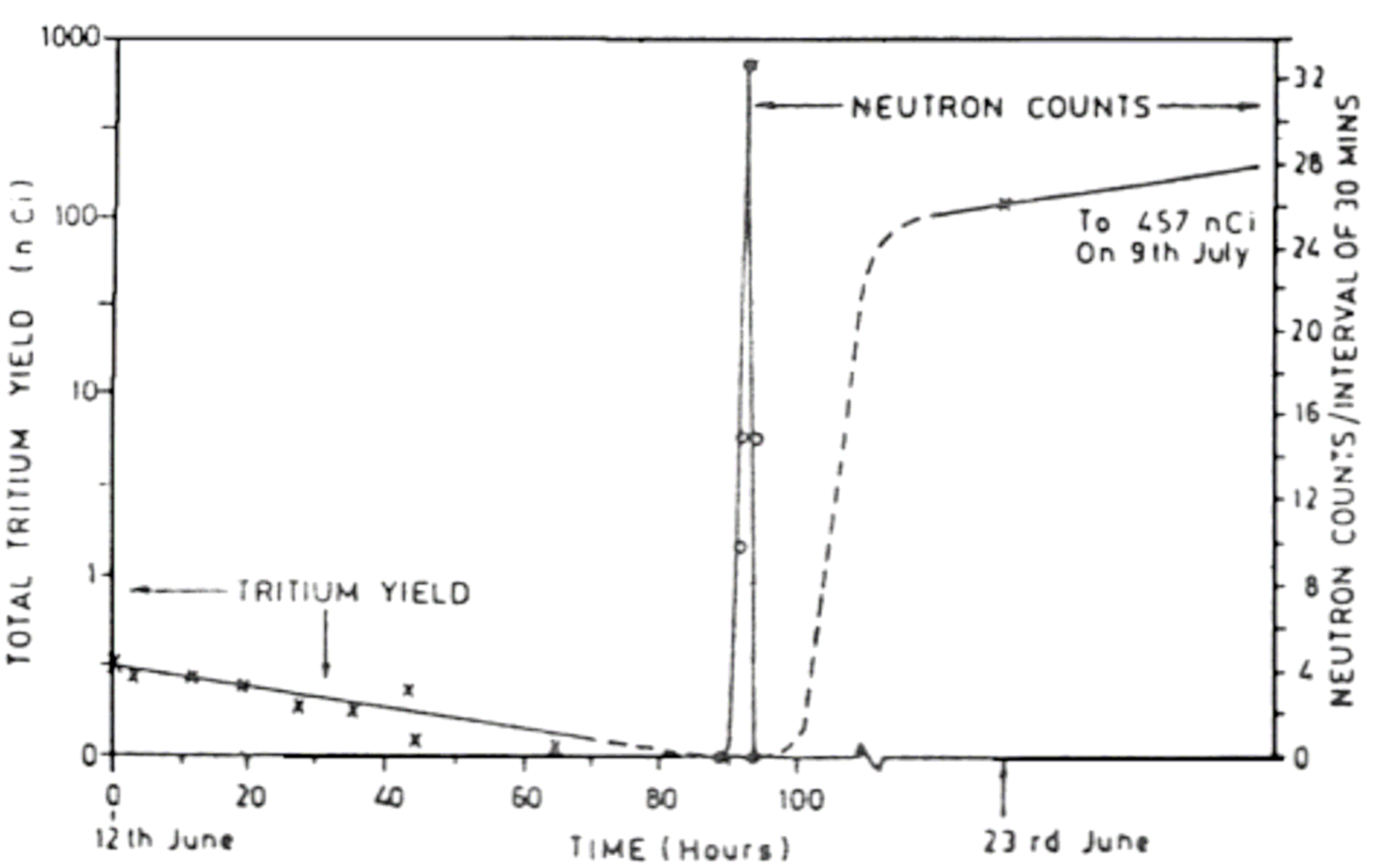
NEUTRON & TRITIUM YIELD DURING RUN NO. 2

(Milton-Roy Cell - 12th June 1989)

Tritium levels in electrolyte measured daily

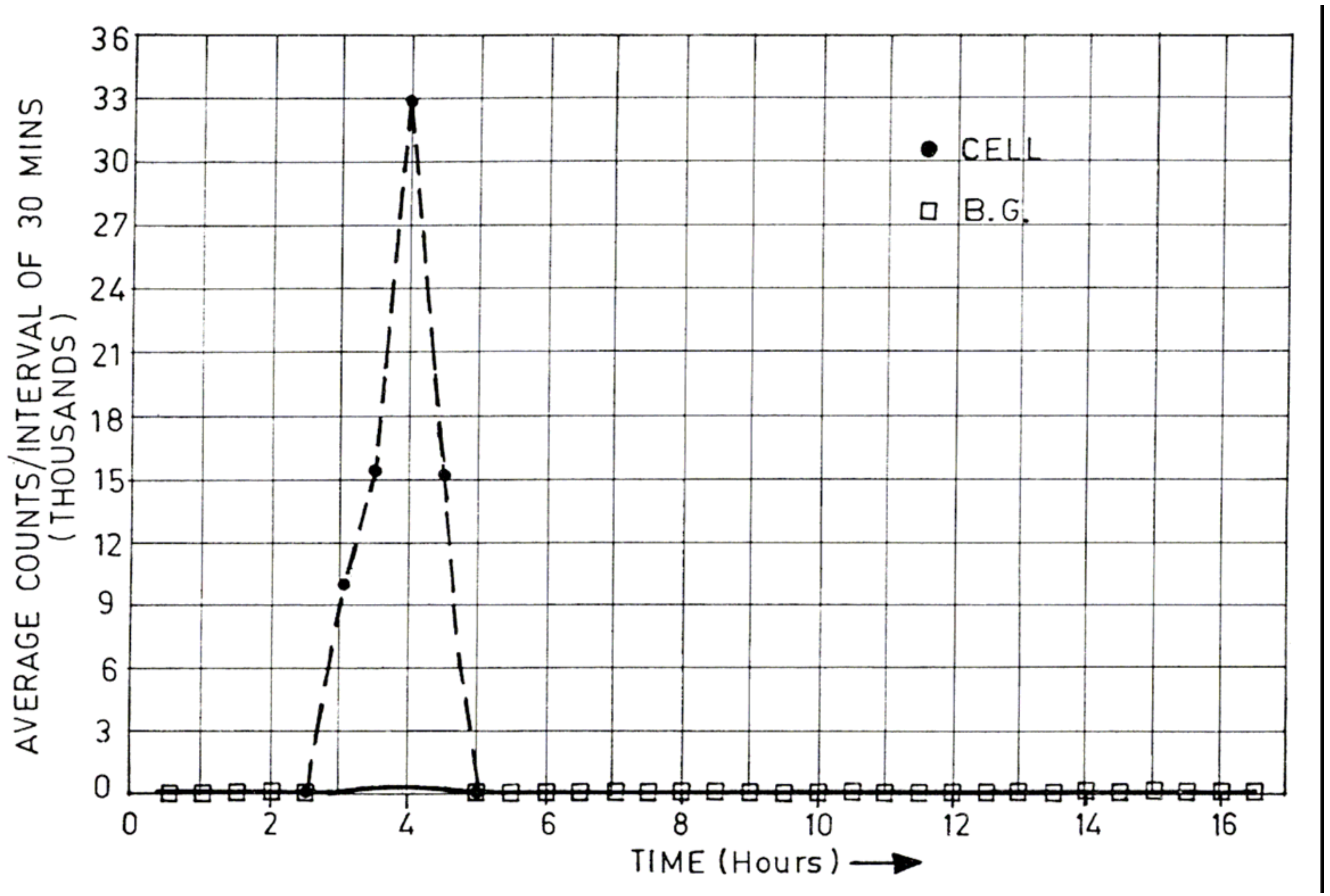


New Energy Times

MILTON ROY CELL : NEUTRON EMISSION EPISODE

50 HRS AFTER CURRENT PUT OFF (16th June 1989)

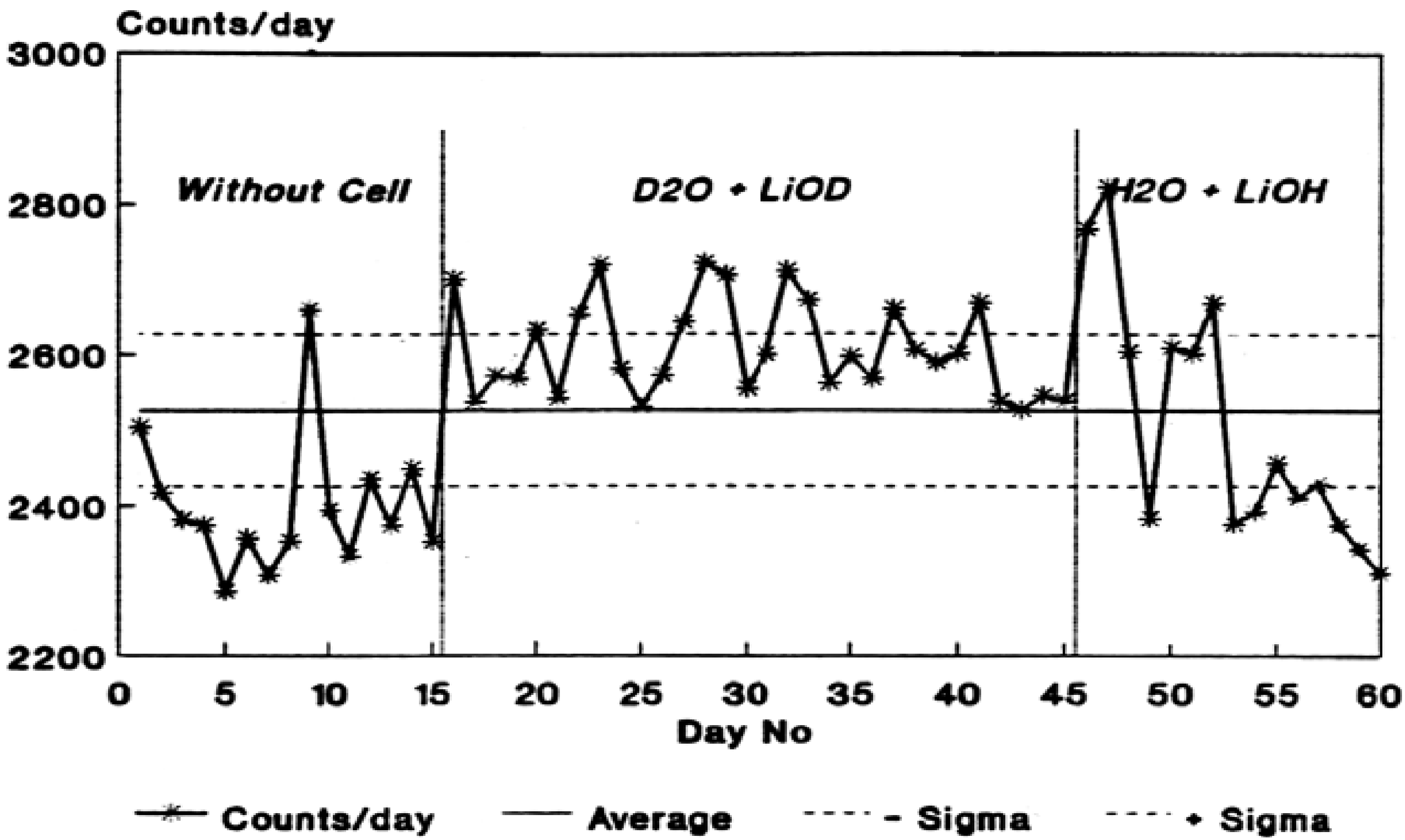
Multiplicity Distribution also Measured



Conclusions From Above Results

- Tritium is produced whenever neutrons are generated;
- Both branches of d-d reaction seem to take place more or less simultaneously even if it be with different probabilities?
- More on implications of this later .

NEW MILTON-ROY CELL (1994)
NEUTRON YIELD VARIATION



STUDY OF DEUTERATED TITANIUM TARGETS

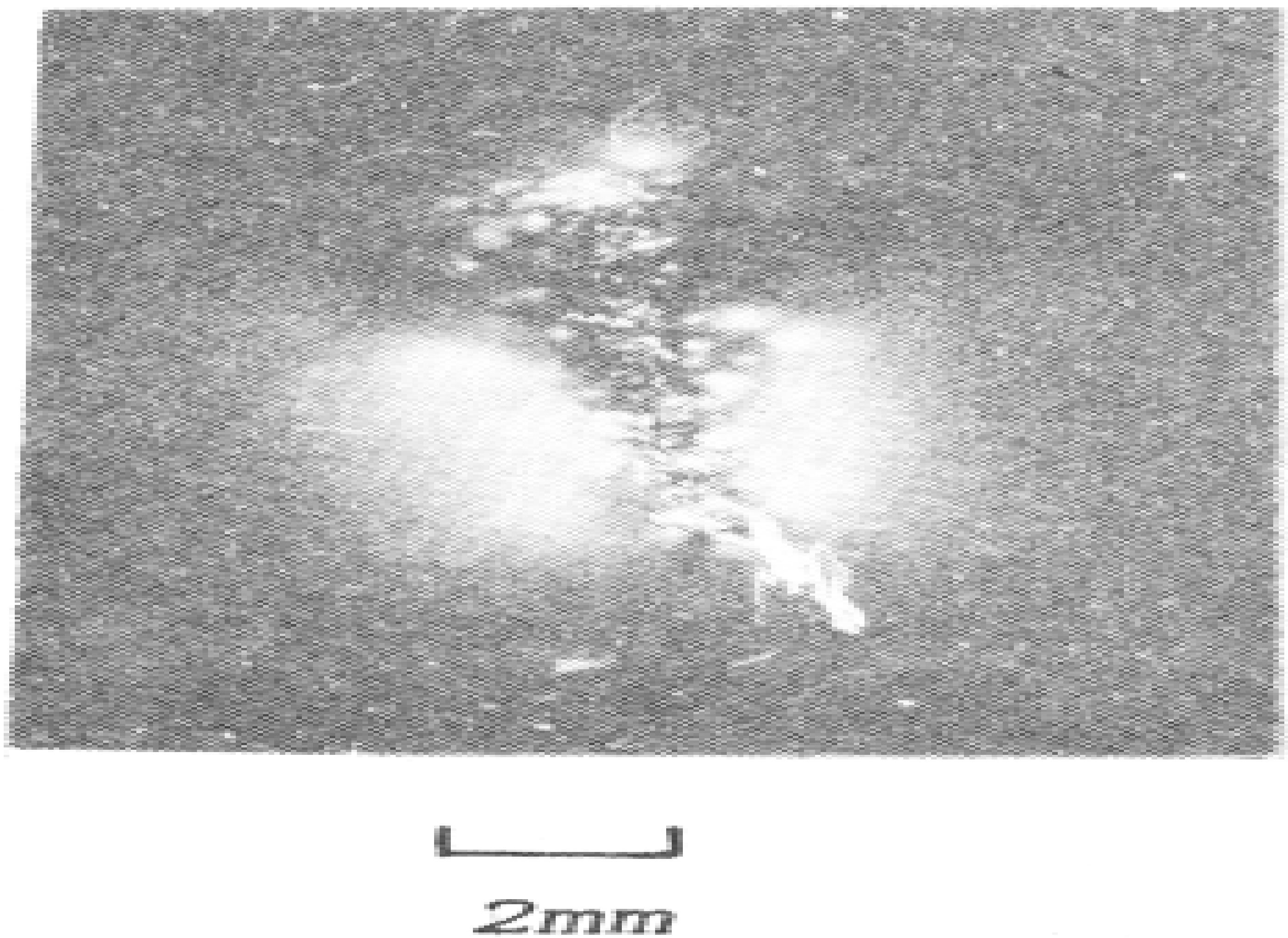
(Gas/Plasma Loaded)

Got interested in TiD targets following Scaramuzzi's work!

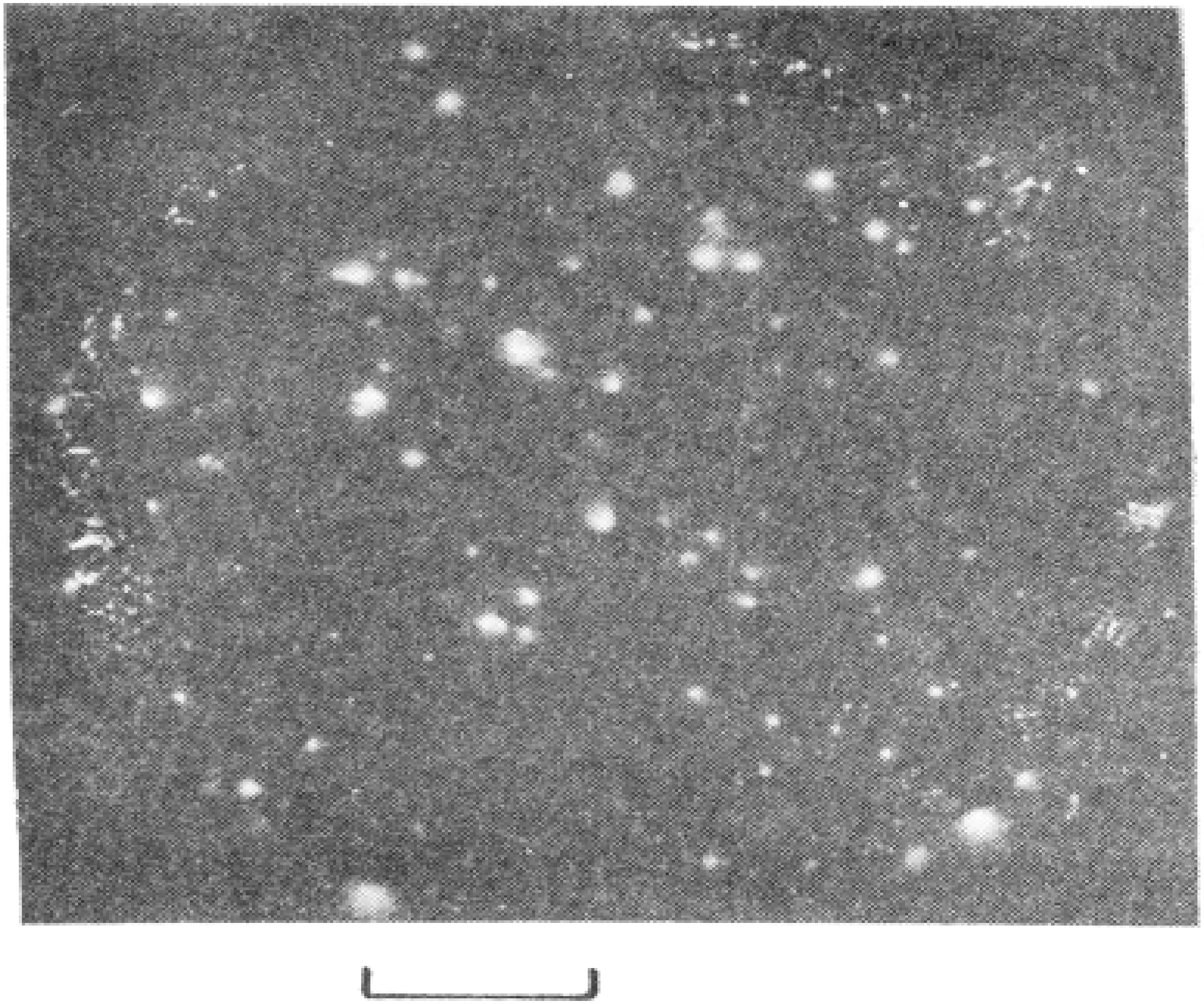
We used autoradiography as a very effective tool !

AUTORADIOGRAPH OF DEUTERATED CONICAL Ti ELECTRODE

(Used in Gas Discharge Expts years ago!)



AUTORADIOGRAPH OF Ti DISC TARGET SHOWING ACTIVE SPOTS



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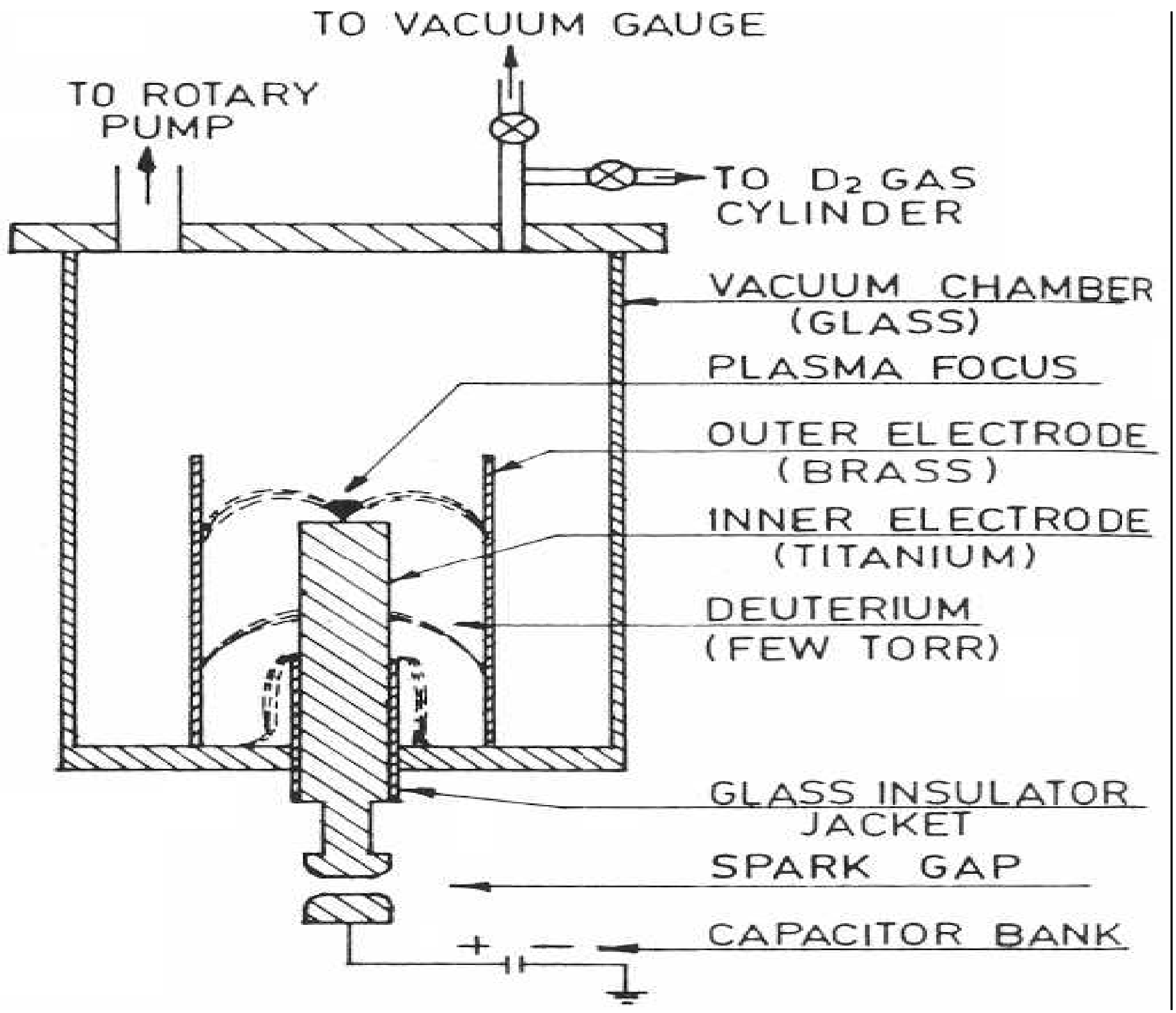
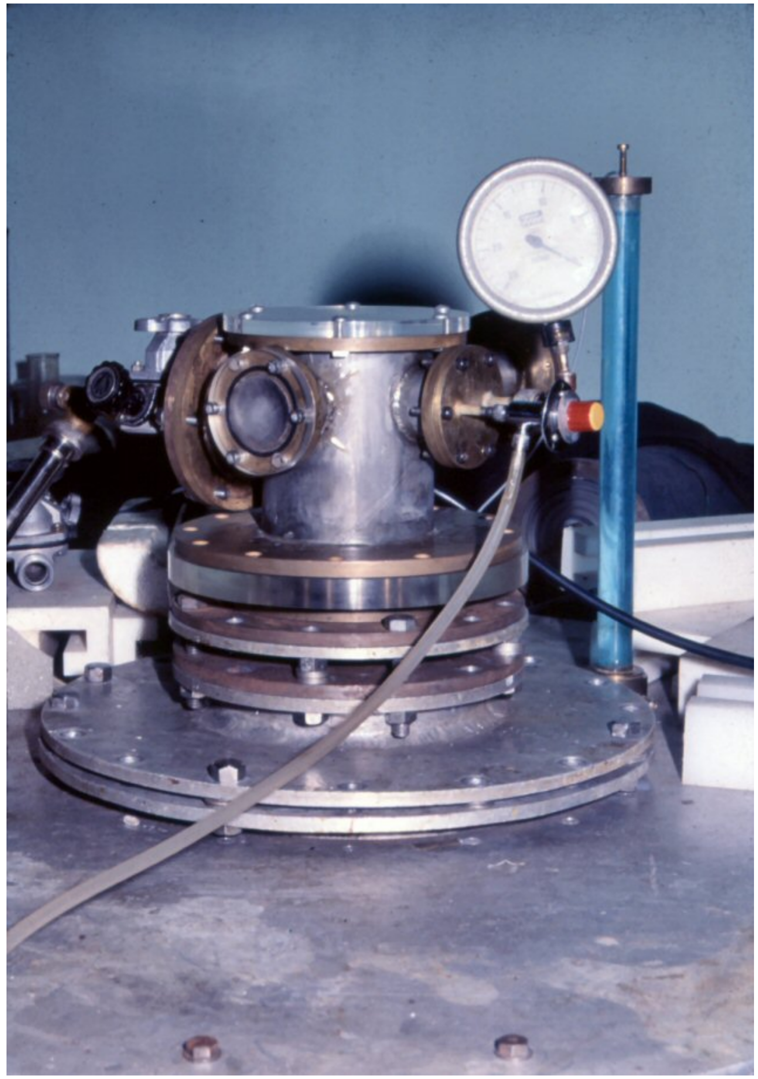
SCHEMATIC OF PLASMA FOCUS DEVICE (Hot Fusion)

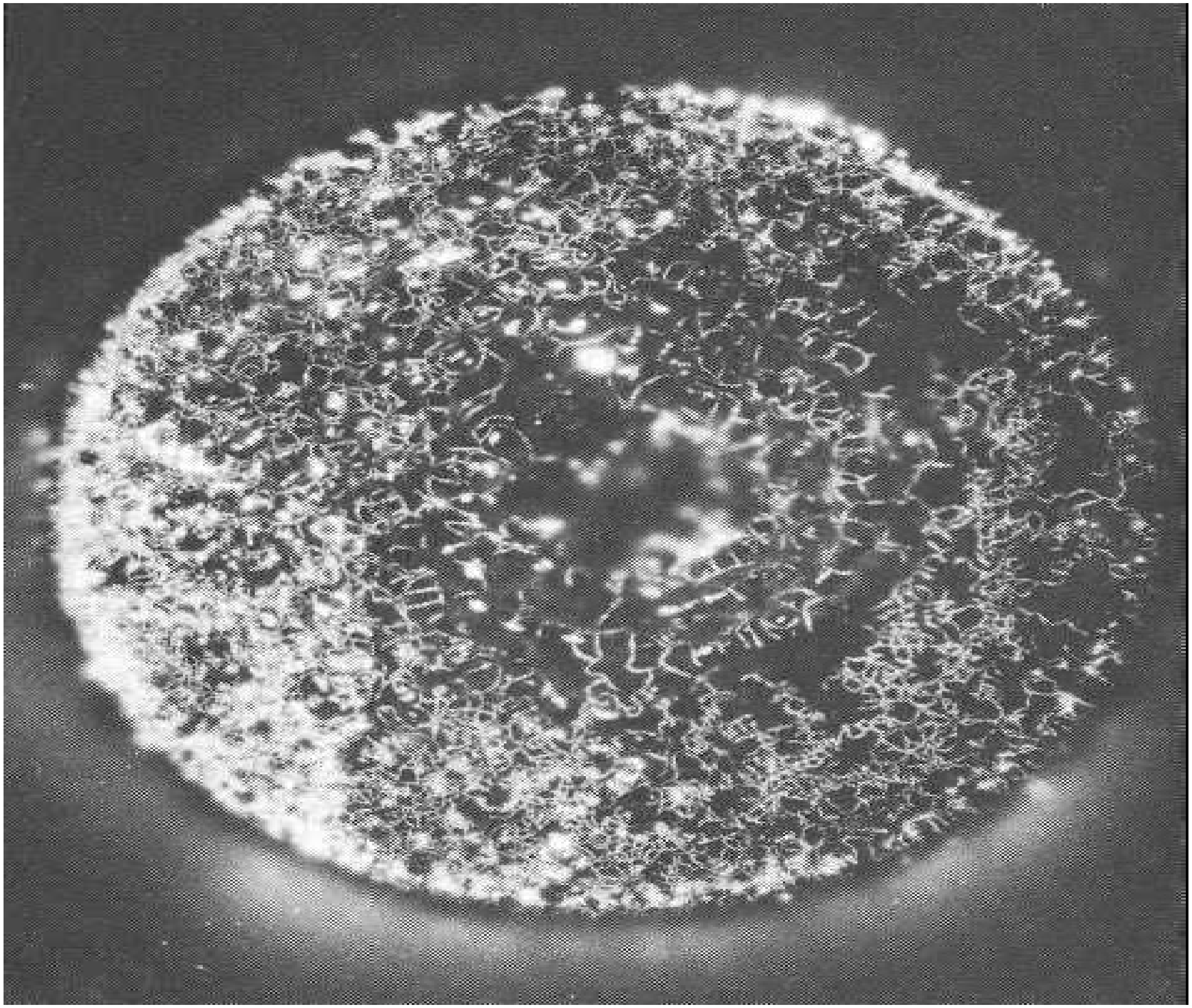




PLASMA FOCUS SET UP

New Energy Times

AUTORADIOGRAPH OF Ti ANODE OF PF DEVICE AFTER 50 DISCHARGE SHOTS



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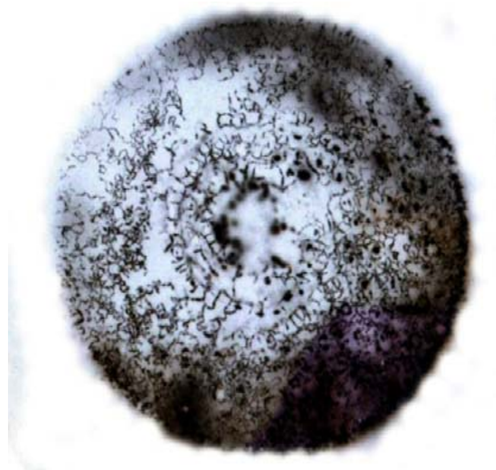
130290

150290

260690



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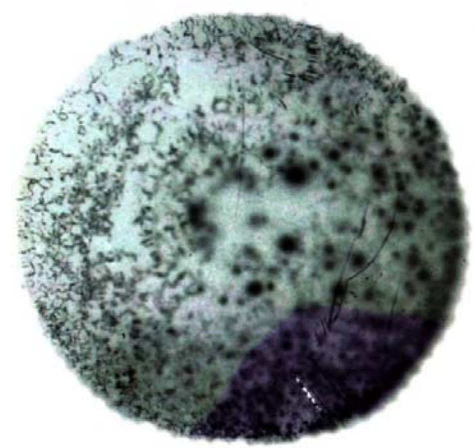

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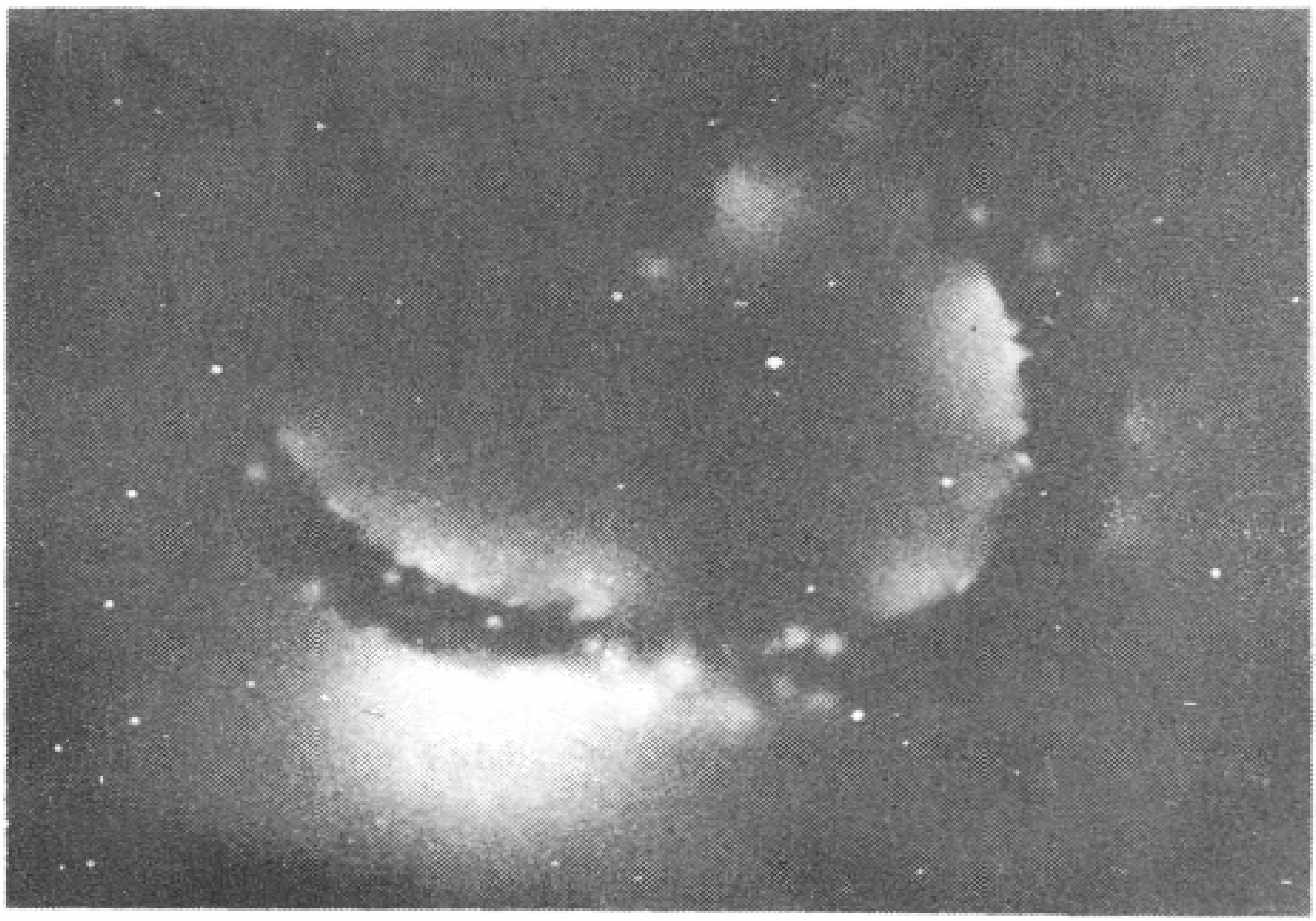
AUTORADIOGRAPH OF A DEUTERATED Ti SHAVING INDICATING TRITIUM – CONTAINING HOT SPOTS

(Kaushik, T. C. *et al, Indian J. Technol,* 1990, 28, 667)



SECOND PAPER

"Observation of High Multiplicity Neutron Emission Events from Deuterated Pd and Ti Samples at BARC : A Review"

STATISTICAL CHARACTERISTICS OF NEUTRON EMISSION

- ***Are the neutrons emitted one at a time in a random fashion following Poisson Statistics?***
- ***Or are there neutron bursts wherein many neutrons are emitted in a bunch implying chain reaction events ?***
- **Experimental method exploits fact that slowing down time of fast neutrons in moderator assembly surrounding thermal neutron detector is ~ 30 microsecs!**
- **Hence two or more neutrons from same event can be separately detected.**

PUBLICATIONS

(Give complete theoretical considerations)

- *"Statistical Analysis of Neutron Emission in Cold Fusion Experiments"*, Srinivasan M. et al, (ICCF 1, 1990)
- *"Observation of High Multiplicity Bursts of Neutrons During Electrolysis of Heavy Water with Palladium Cathode Using the Dead-Time Filtering Technique"*, Shyam A et al, (ICCF 5, 1995)

Theoretical Considerations
For Poisson Distribution (Random)

- N_o...> count rate due to random events
- t....> counting time interval (say 20 ms)
- $N_o t$—> Prob. of registering 1 count
- For case when $N_o t << 1$
- $N_o t$—> prob. of registering 1 count
- $(N_o t)^2/2!$ —→ of 2 counts
- $(N_o t)^3/3!$ —→ of 3 counts and so on

Theory For Burst Events
(Binomial Distribution)

- S.....> burst events/sec, emitting
- V ....> neutrons in each burst
- ε ....> efficiency of neutron detection
- Contn of burst events to count rate...> SVε
- For V >> and ε <<1
- Prob P_r of getting r counts in time t given by
- P_r......$[(V\varepsilon)^r/r!]e^{-\varepsilon V}$
- Peaks for multiplicities close to product "Vε"

TABLE I

Expected Frequency Distribution of Counts for Poisson and Bunched Neutronic Events for Typical Sets Parameters

Multiplicity Of counts	Frequency of Counts in 20ms Intervals for 10^5 samples					
	Poisson Events		Bunched Events ($S=10^{-2}$ per sec)			
	N_0=0.3 cps	N_0=3.0 cps	$\nu = 100$	$\nu = 100$	$\nu = 500$	$\nu = 500$
			$\varepsilon = 0.005$	$\varepsilon = 0.015$	$\varepsilon = 0.005$	$\varepsilon = 0.015$
			$S\nu\varepsilon = 0.005$	$S\nu\varepsilon = 0.015$	$S\nu\varepsilon = 0.025$	$S\nu\varepsilon = 0.075$
0	99940	99402	99992	99984	99980	99980
1	60	597	6.1	6.6	4.00	0.07
2	$\sim10^{-2}$	1.7	1.5	5.0	5.1	0.3
3	$\sim10^{-9}$	$\sim10^{-2}$	0.2	2.5	4.2	0.8
4	$\sim10^{-9}$	$\sim10^{-5}$	0.03	1.0	2.6	1.5
5	$\sim10^{-13}$	$\sim10^{-8}$	0.003	0.33	1.3	2.2

TABLE II

Frequency Distribution of Background counts in Two Detector Banl

Counting interval	20 ms
Total counting time	63 hrs

Multiplicity of counts	Frequency	
	BF_3 Bank	He^3 Bank
0	750035	743948
1	339	6413
2	1	14
3	0	0
4-20	0	0
N_0	0.023cps	0.43cps
$N_0\tau$	5×10^{-4}	0.0086

TABLE II: MULTIPLICITY DISTRIBUTION OF NEUTRON COUNTS IN 10 ms INTERVALS
(Milton-Roy Electrolytic Cell: Friday 16th June 1989)

Time	BF$_3$ Counter Bank (Signal)															^{3}He Counter Bank (Background)		
(Hrs)	1 *	2 *	3 *	4 *	5 *	6 *	7 *	8 *	9 *	10 *	11 *	12 *	13 *	14 *	15 *	1 *	2 *	3 *
18.55	124	21	4	1	-	-	-	-	-	-	-	-	-	-	-	2	1	-
19.00	54	9	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
19.05	335	54	7	2	1	-	-	-	-	-	-	-	-	-	-	4	-	-
19.10	320	82	10	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-
19.15	243	13	4	-	1	-	-		-	-	-	-	-	-	-	5	-	-
19.20	315	35	3	1	-	-	-	-	-	-	-		-	-	-	4	-	-
19.25	295	24	-	1	-	-	-	-	-	-	-	-	-		-	5	-	-
19.30	492	51	3	2											-	4	-	-
19.35	447	42	2	1	-	-	-	-	-	1	-	1	-	-	-	9	-	-
19.40	104	13	4	-	-	1	-	-	-		-	-			-	5	-	-
19.45	355	49	1	1	-	1	-	-	-	-	-		-	-	-	33	1	-
19.50	395	99	16	2	-	-	-	-	1	-	-	-	-	-		22	3	-
19.55	55	24	7	33	2	1	1	1	1	1	2	2	1	-	5	6	2	-

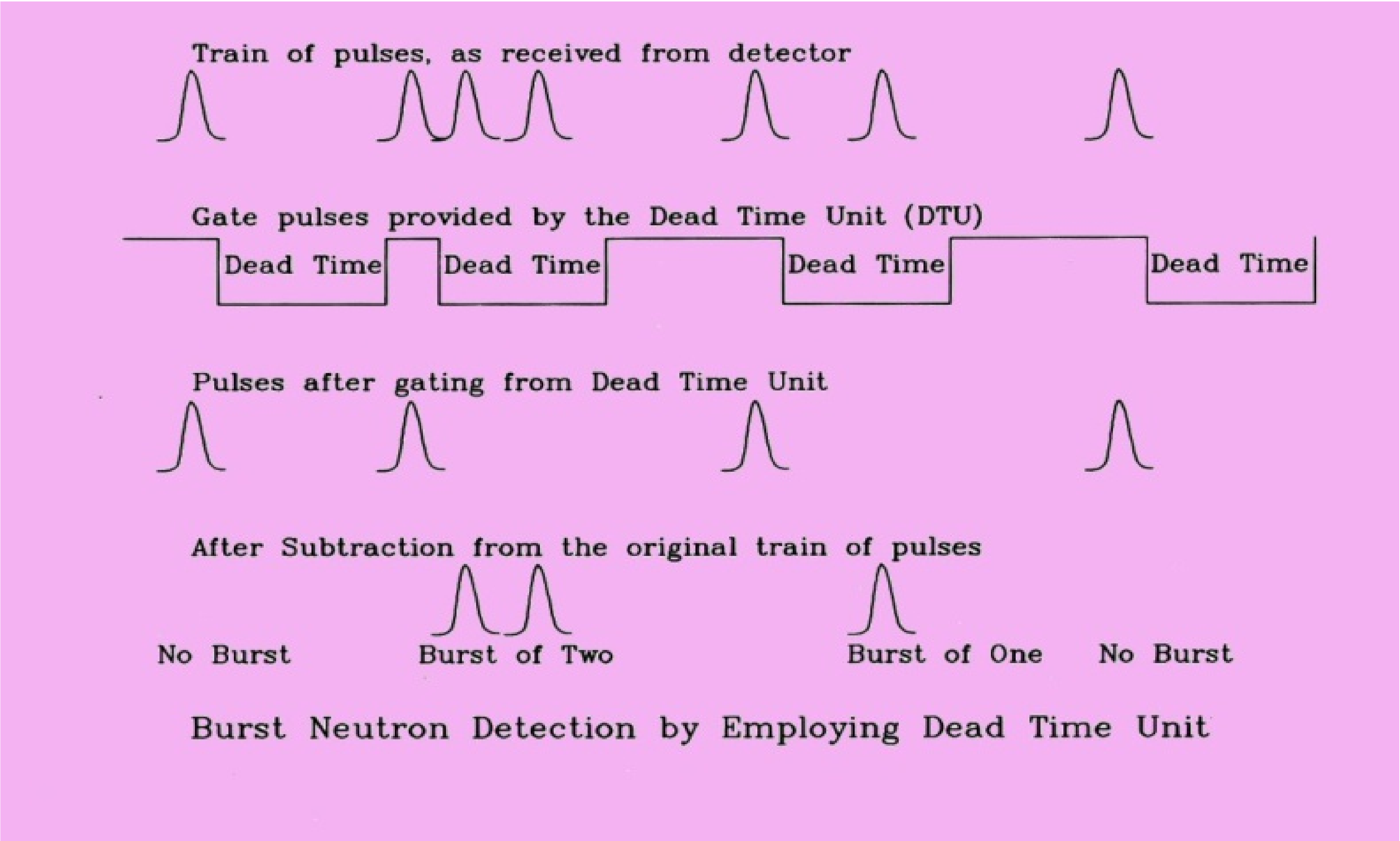
(*) Starred numbers represent the multiplicity of counts obtained in a single 10 ms interval. The respective frequency of occurrence (per 1000 gated intervals) is given in the corresponding column below.

TABLE III

Frequency Distribution of Counts in BF_3 Bank and Plastic Scintillator with Quiescent Milto

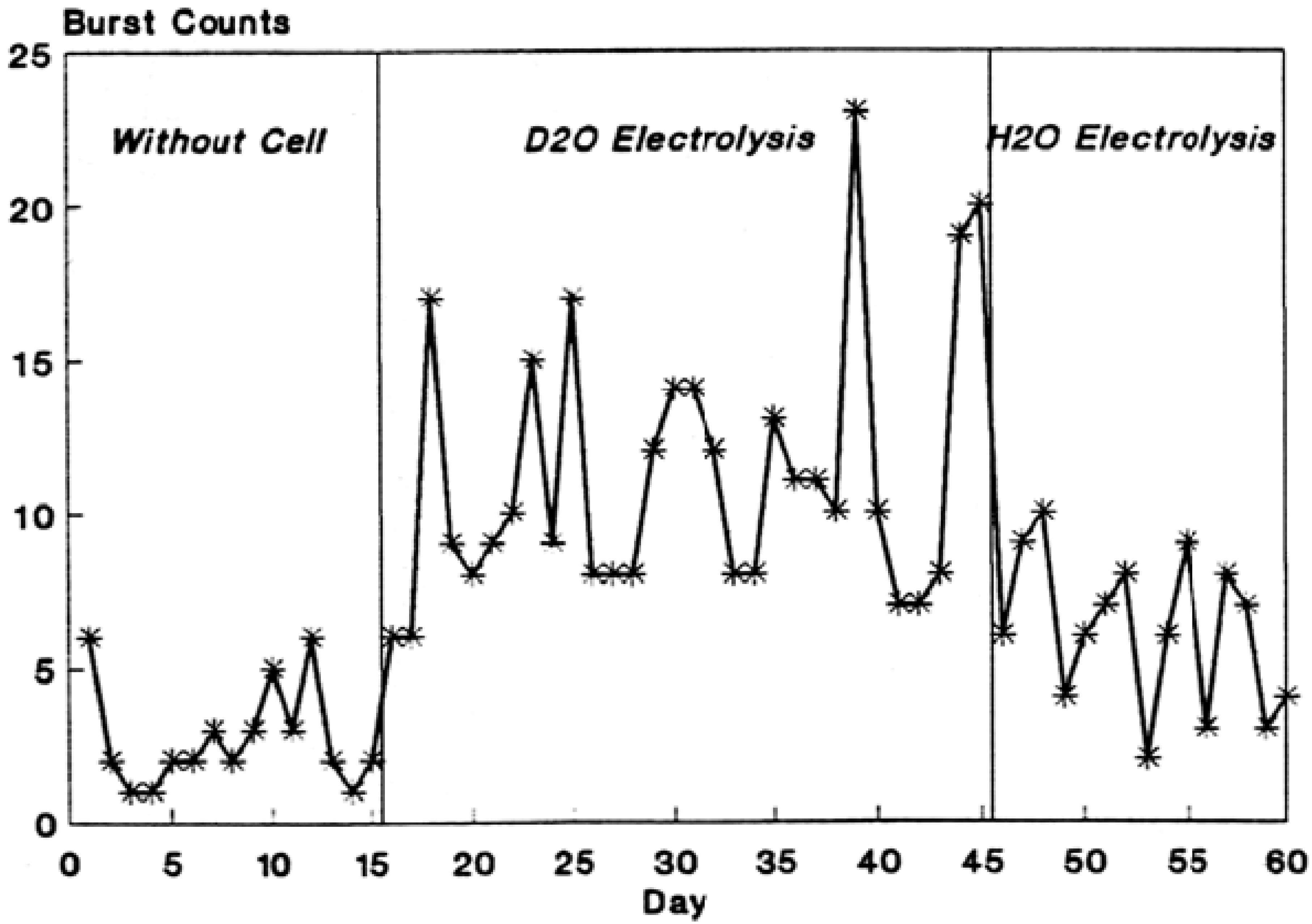
Counting period	12 hrs
Counting interval	20 ms
Total number of sampling	144000 intervals

Multiplicity of counts	Gross Frequency	Frequency in those samples in which plastic scintillator records a count
1	11941	114
2	2760	31
3	111	0
4	19	0
5	2	0
6	13	0
7	9	0
8	3	0
9	5	0
10	1	0
11	0	0
12	1	0
13	0	0
14	0	0
15	1	0
16	0	0



Principle of Dead Time Method

DAYWISE VARIATION OF TOTAL BURST COUNTS



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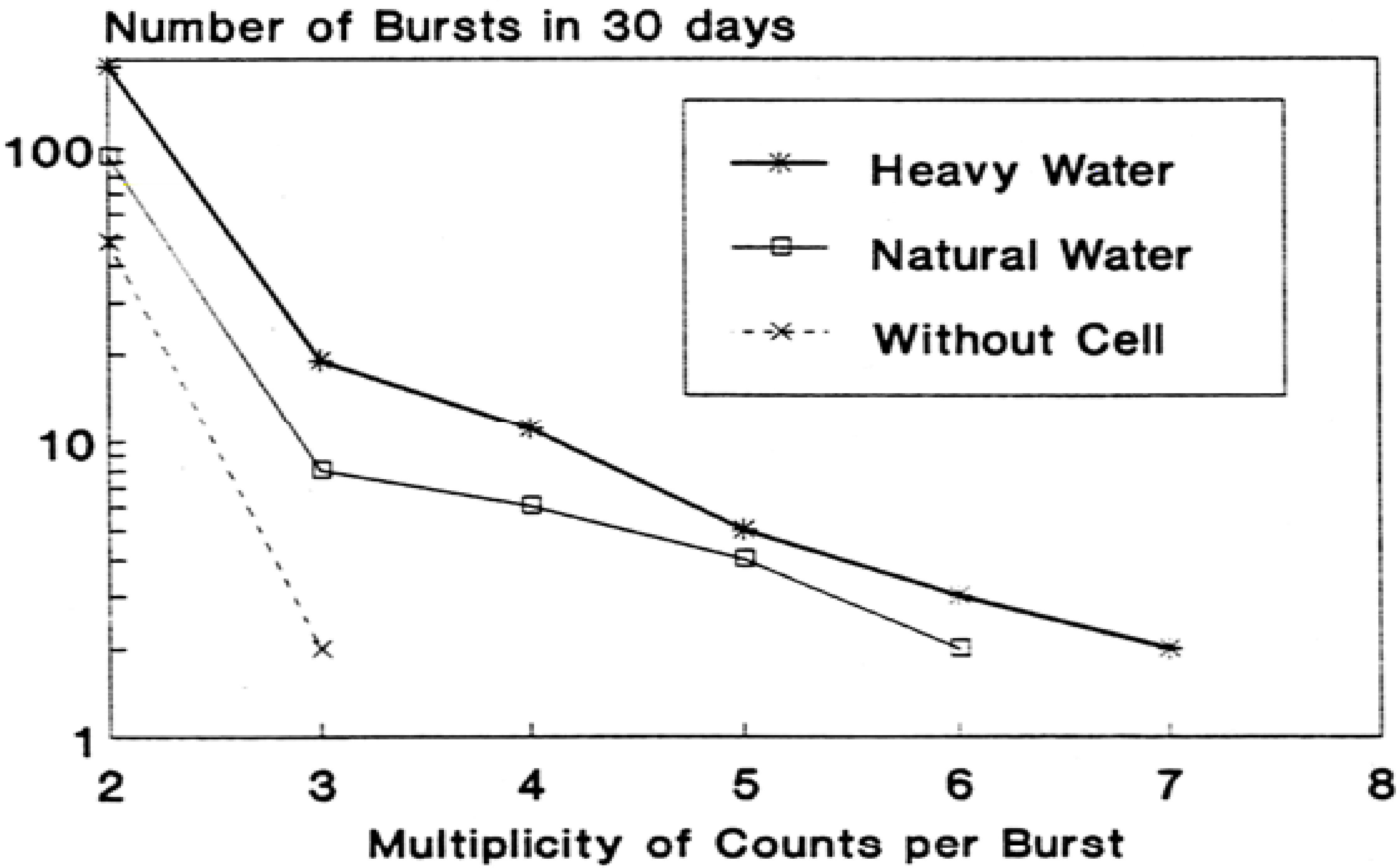
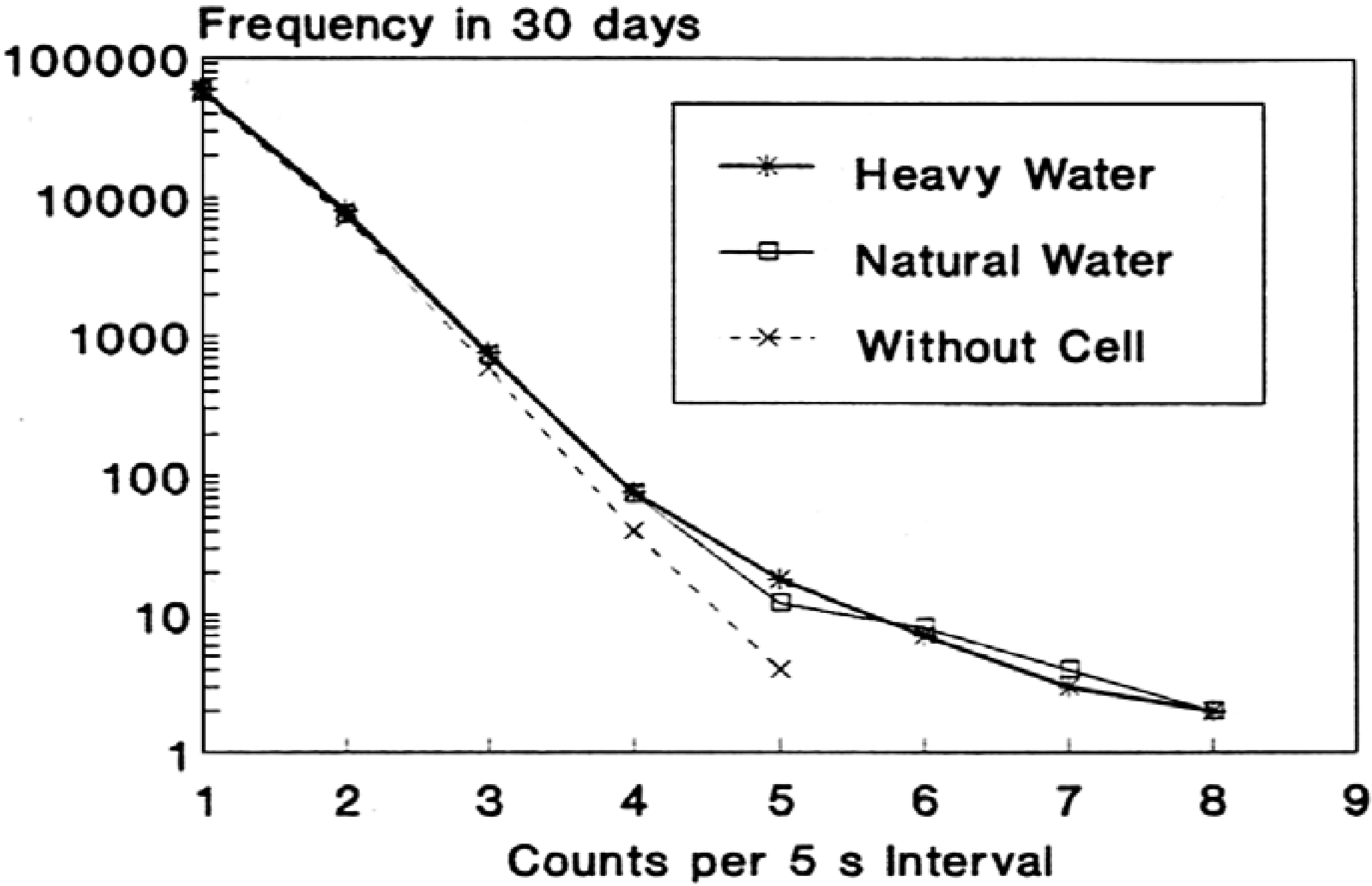
FREQUENCY DISTRIBUTION OF BURST COUNTS INTEGRATED OVER 30 DAY PERIOD



FREQUENCY DISTRIBUTION OF 5 SEC COUNTS INTEGRATED OVER 30 DAY PERIOD



NEUTRON OUTPUT FROM A DEUTERATED Ti DISC

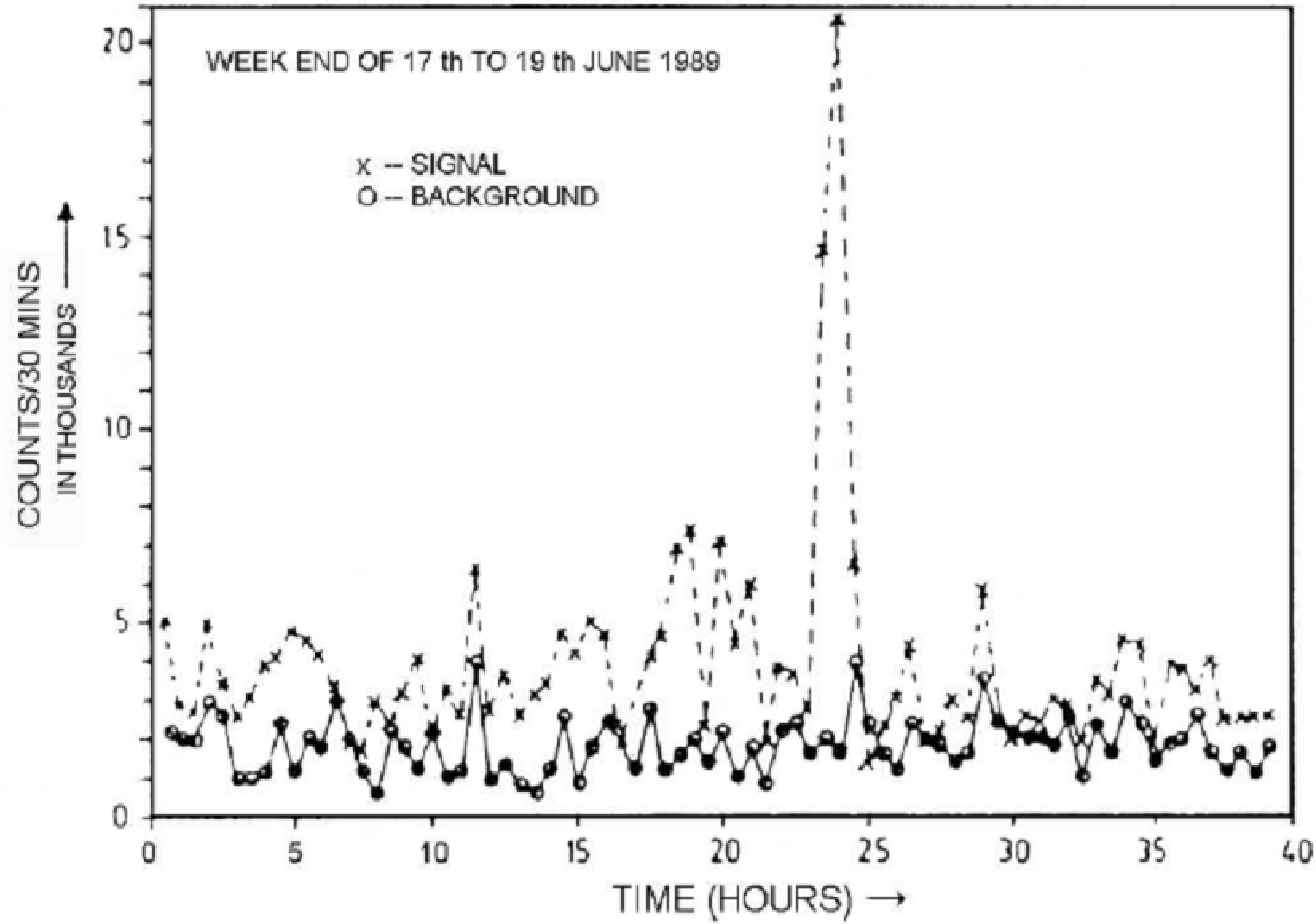


Fig. 2. Neutron Output from a Deuterated Ti Disc.

CONCLUSIONS OF “n” MULTIPLICITY STUDIES

- 10 to 20 % of neutrons produced could be attributed to high multiplicity events wherein > 20 neutrons are generated per burst!
- Majority (>80%) neutrons detected however obeyed Poisson statistics, i.e single detection events. But that does not necessarily prove they were in fact emitted only as singles!
- For example if 10 neutrons emitted in a sharp burst, even our set up with 10% detection efficiency may not have detected multiplicity!

OVERALL CONCLUSIONS FROM THE EARLY BARC STUDIES

SWITCH ON TIME FOR NEUTRONS

- A dozen groups of novices set up cells using Pd samples lying about in the laboratory and yet detected neutrons and tritium within the first day itself !
- "Switch on time" : 6 out of the 11 cells detected first neutron signal within 9 hours, one gave within 24 hrs; 2 cells yielded in a couple of weeks!
- But on continued electrolysis all stopped yielding neutrons →poisoning effects !
- For "n" →high loading clearly not needed.

FOUR MOST IMPORTANT FINDINGS OF BARC EXPERIMENTS

- Neutrons are emitted in bunches of 10s or even 100s.
- n & T seem to be produced simultaneously with (n/T) ~ 10^{-7} (branching ratio anomaly)
- In case of titanium targets, tritium found in cold worked defect sites ... hot spots.
- The generated tritium stays put in same spot for years → poor diffusion rate in titanium !

IMPLICATIONS

- (n/T) ~ 10^7 —> means on an average one n emitted for every 10 million tritons !
- Since neutrons themselves occur in bursts of 10s to 100s, follows that T produced in zillions....sort of chain reaction or micro nuclear explosion (MNP)!
- Superimpose on this finding that tritium found in highly localized hot spots which serve as NAE sites!
- Forced to speculate that MNP occurs in single nano particle ?

MICRONUCLEAR EXPLOSION HYPOTHESIS !

- Speculate that at an NAE site somewhere between 10^6 to 10^{10} tritium producing reactions occur in some sort of avalanche type nuclear reactions or micro nuclear explosion (within time span of nano seconds?) at a highly localized NAE spot.
- It is for theoreticians to come up with a mechanism for such chain events!

POSSIBLE DOUBTS

- **How come no one else has observed bunched neutron emission ?**

  Ans : ***No one has looked for it!***

- **If the neutron detection efficiency is say 1 % and one neutron count is registered, it could still have resulted from a single burst of 100 neutrons on account of the 1% detection efficiency!**
- **If 10 counts are registered during a 1 minute interval it could imply either that there were 1000 events in which 1 neutron each were emitted (single neutron events) or there may have been 10 burst events each of which emitted 100 neutrons each!**

- **How come in case of Pd, autoradiographs don't show spotty behavior?**
- **Ans: In Pd diffusion rate is probably very high; so tritons, even if produced in a localized NAE site, quickly redistribute.**
- **(Online thermal cameras have detected thermal hot spots on Pd cathode surface.)**

STRONGLY RECOMMENDED

More experimental groups should attempt neutron multiplicity measurements, preferably using the Dead Time Technique.

Revival : NIAS Meeting 9th Jan 2008

- One Day Meeting on "Emerging New Energy Concepts for the 21st Century" on 9th Jan 08
- Held at the "National Institute of Advanced Studies" (NIAS), Bangalore.
- Former Chmn, AEC Dr.M.R.Srinivasan present;
- Michael McKubre, Steven Krivit & M.Srinivasan gave talks;
- Video talk of Ed Storms screened.
- Director BARC sanctioned meeting on "Materials issues in CMNS devices" in Feb 2009! But unfortunately postponed due to terrorist attack !

THANK YOU !

NICKEL HYDROGEN EXPERIMENTS

TRITIUM PRODUCTION IN HYDROGEN LOADED NI WIRES

(Variation along length of wire)

- Table 2. OBSERVED TRITIUM ACTIVITY IN DISSOLVED CUT PIECES OF Ni WIRE SUBJECTED TO SEVERAL HYDROGEN ABSORPTION / DESORPTION CYCLES

Sr. No.	Dissolved Cut Wire Sample #	Average Excess Over Background Counts * per 10 minutes (1 ml Solution)	Total Tritium Activity in Cut Wire piece (5 ml Solution) (Bq)
1	23/1	313	13
2	501/1	532	22
3	504/4	152	6
4	504/5/I	70	3
5	504/5/II	103	4
6	24/1	440	18
7	24/2	690	28
8	24/3	1150	47
9	27/1	950	38
10	27/2	704	28
11	27/3	57650	2333
12	30/1	1560	63
13	30/2	220	9
14	30/3	550	22
15	Standard	4200	170

- * Background count rate was approximately 250 counts in 10 minutes. 10 % in excess of BG represents limit of sensitivity

- Comment on sensitivity of n and T detection

One of Earliest Review Papers of CMNS Field

"Nuclear fusion in an atomic lattice: An update on the international status of cold fusion research"

M. Srinivasan

Neutron Physics Division, BARC
Trombay, Bombay 400 085, India

Abstract

" It is now two years since the first reports of the occurrence of nuclear reactions at ambient temperatures in deuterated metals such as Pd or Ti were published. 'Cold fusion', as this phenomenon has now come to be known, has however, become embroiled in intense controversy with the scientific community becoming sharply polarized into 'believers' and 'non-believers' of this novel phenomenon. This ambivalence ……………………………."

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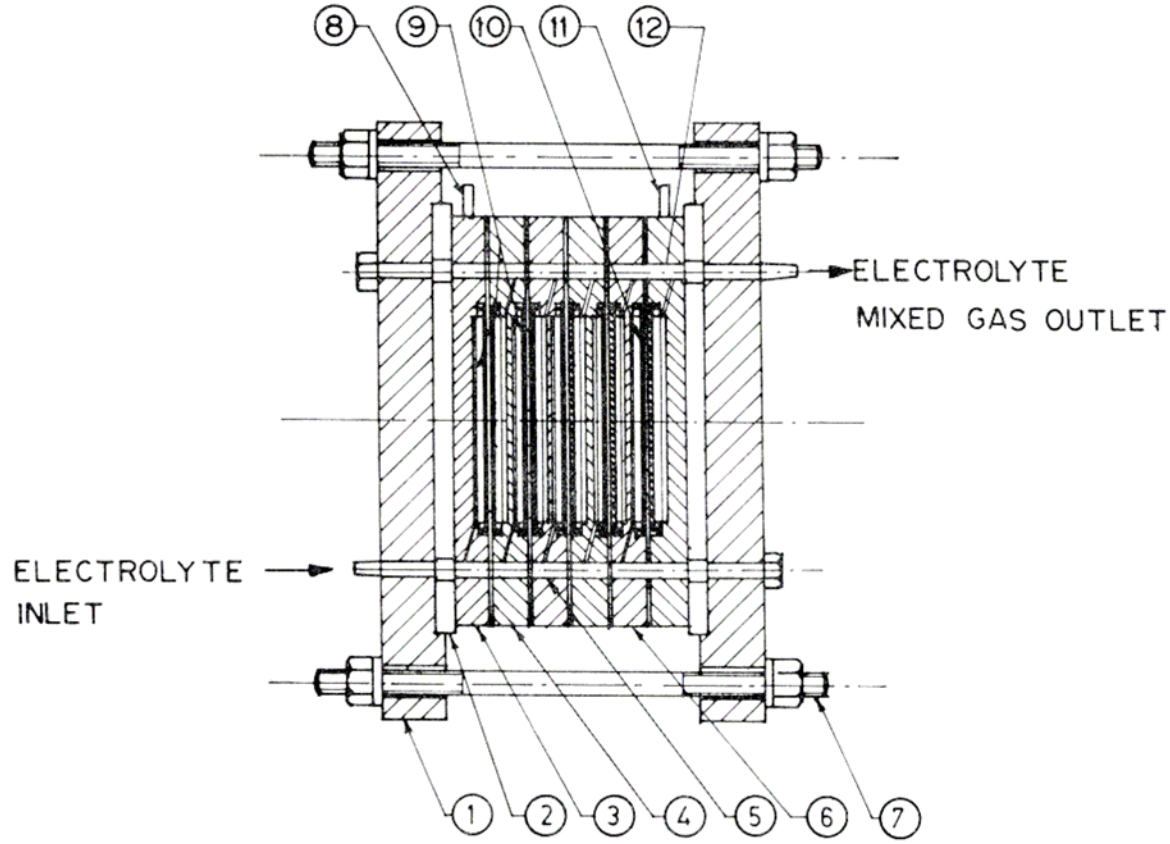
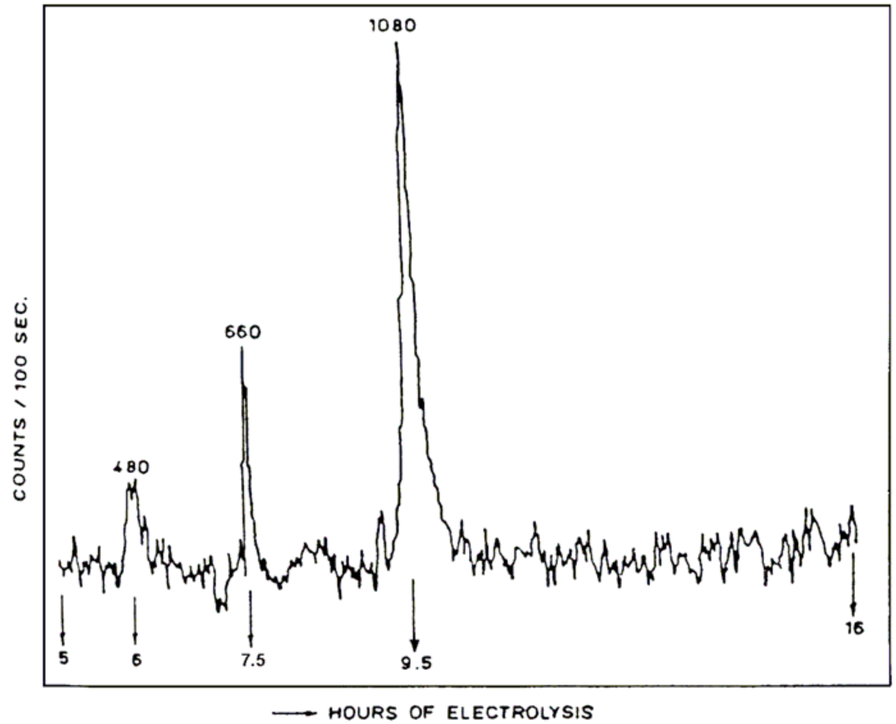
* Current Science, 1991. **60: p. 417**

TABLE I: TRITIUM PRODUCTION IN ELECTROLYTIC

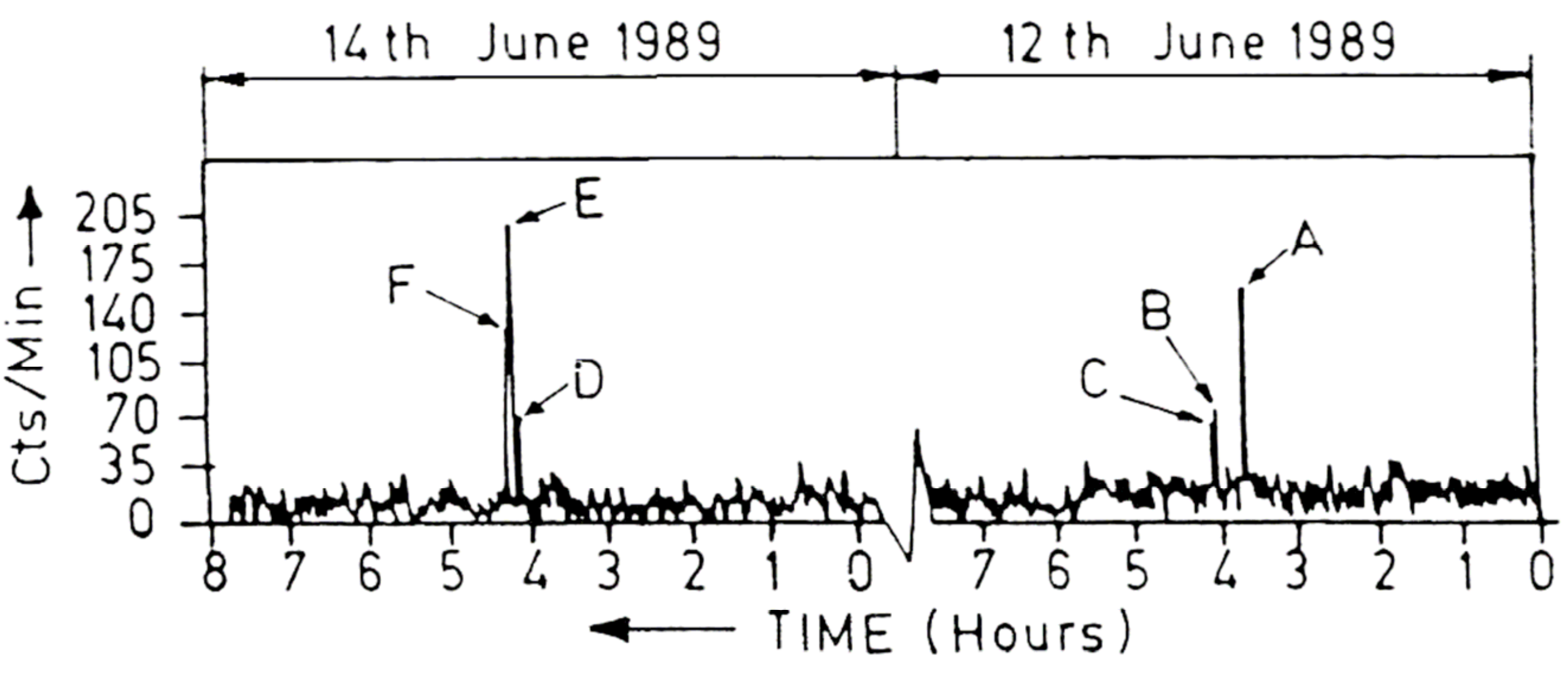
Sl No	DIVISION /GROUP	CATHODE MATERIAL /SHAPE	ELECTROLYTE	VOL. OF D_2O SOLN.	MAX. CELL CURRENT (Amps)	TRITIUM LEVELS (Bq/ml) INI-TIAL	FINAL (10^3)	TRITIUM PRODUCTION (Bq) (10^6)	Atoms (10^{14})
1.	HWD/NtPD	Pd-Ag Tubes (M-R Cell)	5 M NaOD in D_2O	250 ml	100	2.6	55.6	13.9	80
2.	"	"	"	"	"	10.0	4.4	1.1	6
3.	HWD/DD/ NtPD	Pd Sheets	"	1000 ml	65	2.0	7.0	7.0	40
4.	"	Ti Rod	"	135 ml	40	2.0	1.8	0.24	1.3
5.	ACD-(i)	Pd Cylinder	0.1 M LiOD in D_2O	45 ml	1-2	31.3	16.6	0 75	4
6.	ACD-(ii)	Pd Ring	"	65 ml	1-3	18.1	8.8	0.57	3



Five module Pd – Ni electrolizer



Time variation of 1186 kev Gd capture gamma ray counts (Anal. Chem. divn cell



Neutron Bursts of Initial Part of Run Number 2 of Milton Roy Cell.

SAME Ti ROD – RADIOGRAPH REPEATED AFTER SEVERAL MONTHS

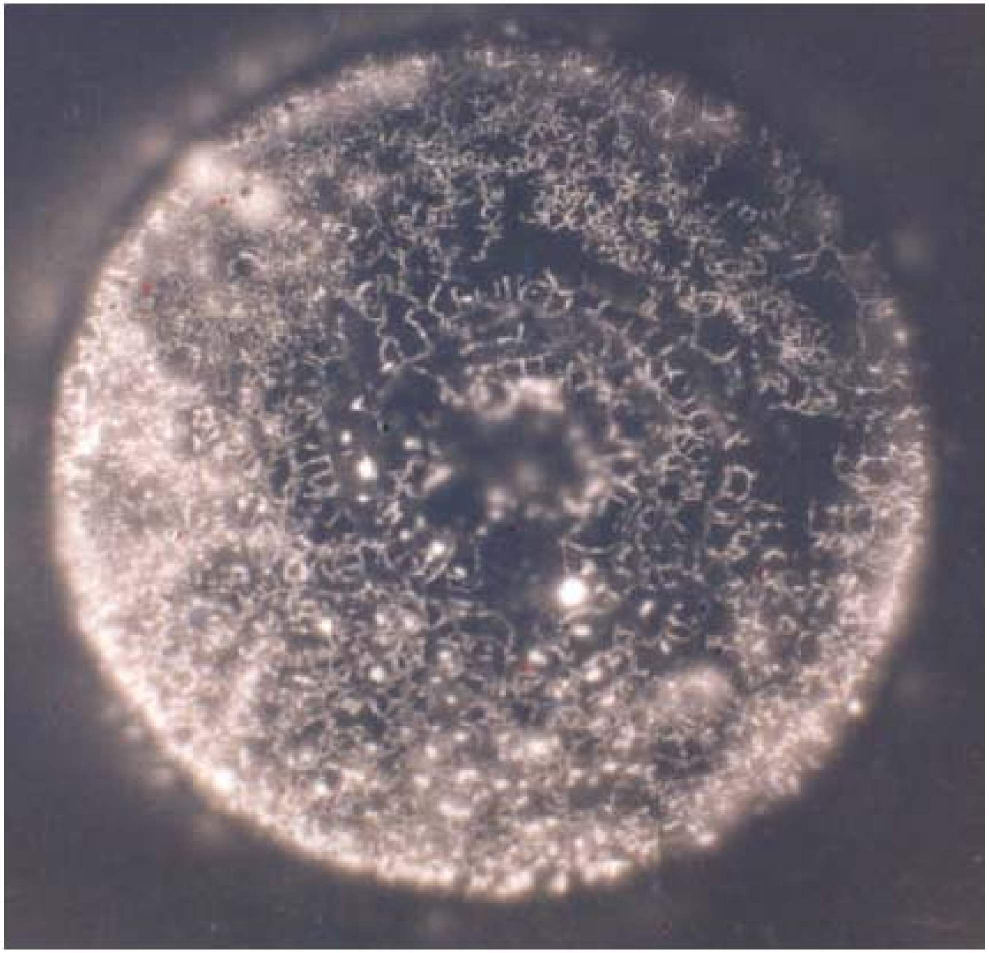


Fig. 3. Typical Autoradiograph of a Deuterated Ti Disc Showin (Black and White Reverse Image)