GOVERNMENT OF INDIA

NUCLEAR DATA MEASURING FACILITIES IN INDIA

Indian Nuclear Data Group
Nuclear Physics Division
Atomic Energy Establishment Trombay
Bombay-72, India

December, 1963

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I. CRYSTAL SPECTROMETERS

1. Single Crystal Spectrometer

1.	Organisation responsible for: design, construction and operation	Nuclear Physics Division, Atomic Energy Establishment Trombay
2.	Location	: Apsara Reactor, Atomic Energy Establishment Trombay, Bombay 74, India
3.	Main purpose of apparatus	: Cross section measurements (both scattering and absorption scattering measurements) and spectra from crystals for studying high order contamination etc.
4.	Status	: Year of first operation 1957
5.	Scientist in charge of experimental programme	: K.R. Rao, Nuclear Physics Division, Atomic Energy Establishment Trombay
6.	Number of staff employed	: Three to four
7.	Available reference for more detailed description	: Nil
8.	Literature on neutron research already accomplished	(1) Higher order contamination in a single crystal spectrometer V.P.Duggal, K.Raghavendra Rao C.L.Thaper and V.Singh Proc. of Nuclear Physics Symp. Waltair (1960), published by Department of Atomic Energy, Bombay.
		(2) Anamolous reflections in a single crystal spectrometer V.P.Duggal, K.Raghavendra Rao C.L.Thaper and V.Singh Proc, Ind. Acad. of Sc. Vol.LIII No. 2,59 (1961)
		(3) Thermal Neutron Inelastic Scattering effects in a single crystal Neutron Spectrometer V.P.Duggal Nucl. Sc. and Engg. 6, 76 (1959)

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(4) Removal of Higher order in the thermal region from a Neutron Crystal Spectrometer
V.P.Duggal and C.L.Thaper
Rev. Sci. Instr. 33, No. 1, 49(1962)

(5) Neutron Cross Section Measurements in basal and subthermal energy range
V.P.Duggal and C.L.Thaper
Proc. of Nucl. Phys. Symposium, Madras (1962), published by Dept. of Atomic Energy, Bombay.

(6) Frequency Distribution of Atomic vibrations in Solids and resonant absorption of slow neutrons
K.R. Rao and C.L.Thaper
Proc. of Nucl. Phys. Symposium Bombay (1963), published by Dept. of Atomic Energy, Bombay.

9. Programme in progress : The spectrometer is being used at present for studies of resonant absorption of resonant scattering in Iridium and its compunds

10. Future Programme : Similar lines

11. Special Specifications:

- Type: Single crystal, plane crystal
- Collimater : Cross section area of the collimator sometimes 1 mm x 5 cms, sometimes 5 mm x 5 mm
- Crystals available: Various crystals have been used from time to time Be(1122), Ge(111), Al(111), NaCl(200) KCl etc.
- Energy range: With Be(1122) max. energy 3 ev., .005 ev. to 0.3 ev
- Sample: Useful area 5 cm x 5 cm.
- Specifications: Distance for crystal to detector 150 cms
- Other details: Accuracy in angular position is 1 minute.

II. PILE OSCILLATORS

1. Pile Oscillator

1.	Organisation responsible for design, construction and operation	: Reactor Engineering Division Atomic Energy Establis'ment Trombay
2.	Location	: Engineering Hall No. 1, Atomic Energy Establishment Trombay Bombay 74, India
3.	Main purpose of the apparatus	: Measurement of absorption cross sections of reactor materials
4.	Status	: Scheduled date for completion: August 1964
5.	Scientist in charge of experimental programme	: M.Srinivasan Reactor Engineering Division, Atomic Energy Establishment Trombay
6.	Number of staff employed	: 4
7.	Available references for more detailed description	: Nil
8.	Future programme	: Includes measurement of absorption cross section of organic coolants and Zircolloy and other reactor grade material produced in India
9.	Important characteristics not included in the list	: -
10.	Reactor at which the monochromator is installed	: ZERLINA (Trombay)

11. Special specifications:

- Principle of oscillation: Overall modulation
- Location in the reacor : Core
- Medium surrounding the oscillator: Heavy water
- Nature of neutron flux at oscillator position: Thermal
- Gradient along oscillator direction : Cosine

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- Sample used as reference: boron (exact form in which it is to be used has yet to be finalised.
- Maximum size and dimensions of the tested sample: Not yet optimized
- Oscillation wave: Shape: square
  Period: 20 to 50 seconds
  Stroke: 100 to 160 cms
- Sensitivity or minimum absorption detectable: It is expected that the sensitivity of the above oscillator would be 0.01 cm^2

III. PARTICLE ACCELERATORS

1. 5.5 MeV Van de Graaff Accelerator

1. Organisation responsible for
   a. Design and construction : High Voltage Engineering Corpn., Burlington, Mass., U.S.A.
   b. Operation : Nuclear Physics Division, Atomic Energy Establishment Trombay
2. Location : Van de Graaff Laboratory North Site, Atomic Energy Establishment Trombay, Bombay 74, India.
3. Main purpose of the apparatus: Charged particle reaction studies, neutron scattering studies, fast neutron fission studies.
4. Status : Started operation in February 1962
5. Scientists in charge of experimental programme : A.S.Divatia and N.Sarma Nuclear Physics Division Atomic Energy Establishment Trombay
6. Number of staff employed
   a. Operation and development : 9
   b. Research experiments : 25
7. Available reference for more detailed description : A.S.Divatia et. al AEET/NP/5 (1962)
8. Programme in progress : 1. Proton and alpha particle scattering
   2. He^3 induced reactions
   3. (p, n'γ) reactions
   4. Fission studies
   5. (n, α)reactions
9. Future programme : Same lines as the present programme
10. Special specifications:
    - Type of accelerator : HVEC type CN 5.5 MeV Van de Graaff Accelerator Manufactured by the High Voltage Engineering Corporation, USA
    - Nature of accelerated particles: Protons and alpha particles; arrangements for accelerating He^3 ions are being made at present
    - Energy : 1 MeV - 5.5 MeV
    - Energy stabilization : 0.1% (Slit controlled corona stabilization)

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- Maximum beam current: 10 micro amps upto 5 MeV and 5 micro amps between 5 and 5.5 MeV
- Current stabilization: ± 10%
- Targets available : Lithium and tritium targets for neutron production`

2. 400 kev Van de Graaff Accelerator

1.	Organisation responsible for	
	a. design and construction	: High Voltage Engineering Corpn. (Europa), Amsterdam
	b. Operation	: Nuclear Physics Division Atomic Energy Establishment Trombay
2.	Location	: Engineering Hall No. 1 North Site, Atomic Energy Establishment Trombay, Bombay 74, India
3.	Main purpose of the apparatus:	To study the feasibility of a method for estimating non-destructively the plutonium content in an irradiated fuel rod using a lead spectrometer
4.	Status	: The machine was installed in August 1962
5.	Scientist in charge of experimental programme	: M.P.Navalkar Nuclear Physics Division Atomic Energy Establishment Trombay
6.	Number of staff employed	: 8
7.	Available reference for more detailed description	: -
8.	Literature on neutron research already accomplished	: -
9.	Programme in progress	: Trying to establish whether the method for non-destructive testing of plutonium is feasible or not using pure samples of plutonium and U-235

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10. Future programme : Once the feasibility experiments are completed, the experiment will be extended to the actual estimation of plutonium in an irradiated rod

11. Important characteristics not included in the list : A slowing down time spectrometer has been constructed with about 100 tons of lead

12. Special Specifications:

- Type of accelerator: PN-400 neutron generator manufactured by High Voltage Engineering Corporation (Europa), Amsterdam
- Nature of accelerated particles : Deuterons
- Energy : 100 - 400 kev
- Energy stabilization : ± 10 percent
- Maximum beam current : 150 microamperes on D.C. and 100 microamperes on pulsed condition
- Current stabilisation: ± 10 percent
- Targets avilable : Tritium target
- Neutron energy - 14 MeV
- Pulsation system : Makes use of a pulsing electrode at the base of ion source bottle
- Pulse length: Variable in six steps
  1. 200 microseconds
  2. 200 ,,
  3. 200 ,,
  4. 150 ,,
  5. 50 ,,
  6. 10 ,,
- Pulse repetition rate: Variable in six steps
  1. 1 pulse per second
  2. 10 ,, ,, ,,
  3. 100 ,, ,, ,,
  4. 500 ,, ,, ,,
  5. 1000 ,, ,, ,,
  6. 10,000 ,, ,, ,,

  Maximum duty cycle is 10 percent
- Peak neutron yield per second during the pulse: 10^8 neutrons per second
- Neutron flight path : -

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- Neutron detector: Different detectors are being used. Some of these are as follows:
  1. BF_3 counters
  2. Proton recoil counter
  3. Scintillation counter using different fast and slow neutron crystals
  4. Long counter
- Time analyser: Ten channels, 20 microseconds, 10,000 pulses per second

3. TIFR Cockcroft Walton accelerator

1.	Organisation responsible for	
	a. design and construction	: Phillips Company, Netherlands
	b. operation	: Tata Institute of Fundamental Research Bombay
2.	Location	: Tata Institute of Fundamental Research Colaba, Bombay-5, India.
3.	Main purpose of the apparatus: Study of nuclear reactions	
4.	Status	: In operation from 1953
5.	Scientist incharge of experimental programme	: E.Kondaiah
6.	Number of staff employed	: 16
7.	Available reference for more detailed description	: -
8.	Literature on neutron research already accomplished	: 1. E.Kondaiah et. al, Nucl. Phys. 5, 346 (1958) 2. E.Kondaiah, et al, Nucl. Phys. 9, 561 (1958) 3. E.Kondaiah, et al, Nucl. Phys.27. 166 (1961) 4. R.Ramanna et al, Jour. Nucl.Energy Vol. 2, 1956 5. R.Ramanna et al, Proc. Ind. Acad. Sc. Vol. XLV, 1957

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6. S.B.D.Iyengar et al, Proc. Ind. Acad. Sc. Vol. XLV, 1957
7. V.C.Deniz et al, Proc. Ind. Acad. Sc. Vol. XLV, 1957
8. S.B.D.Iyengar et al, Proc. Ind. Acad. Sc. Vol. XLV, 1957
9. V.P.Duggal and S.M.Puri Jour. of Applied Phys. P 675 (1958)
10. R.Ramanna et. al, Nuvo Cimento Ser. 10, 1 No. 4, 1955
11. S.B.D.Iyengar et al, Proc. of Nuclear Phys. Symp., Madras (1962)

9. Programme in progress : Study of (n,α), (n, p) reactions

10. Future programme : 1. Systematic studies of (n, α) and (n, p) reactions

: 2. Determination of multiplication constants of U-BeO lattices using pulsed neutron technique

11. Important characteristics not included in the list : The accelerator has two accelerating tubes (referred to hereafter as a and b) working on the same high tension. The second one was added in 1963

12. Special specifications:

- Type: Cockcroft Walton type
  a. Phillips - 0 to 1 MeV - Main
  b. Home made - 0 to 400 kev - auxiliary unit
- Nature of accelerated particles : Protons and deuterons
- Energy : a. 0 - 1 MeV in main unit
  b. 0 - 400 kev in auxiliary unit
- Energy stabilization : Nil
- Maximum beam current : a. 200 mA in main unit
  b. 400 mA in auxiliary unit
- Current stabilization: Nil
- Targets and reactions available: Be, H^3, and H^2
- Neutron yield in 4 geometry during continuous operation: 10^{10} to 10^{11} neutrons/second
- Neutron energy : 2 MeV - 14 MeV
- Pulsation system: Electronic pulsing of ion source probe voltage

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- Pulse length : 10 usec. to 10 msec.
- Pulse repetition rate : 50 c/s to 500 c/s
- Neutron detector : Plastic scintillator and BF_3 counter
- Time analyser : Number of channels: 50
  Minimum channel width: 3 usec.

4. Saha Institute Cockcroft Walton Accelerator

1.	Organisation responsible for design, construction and operation	: Saha Institute of Nuclear Physics
2.	Location	: Saha Institute of Nuclear Physics, 92, Acharya Prafulla Chandra Road, Calcutta-9
3.	Main purpose of apparatus	: Study of fast neutron reactions, cross sections & fast neutron induced transmutations with β-γ spectroscopy
4.	Status	: Year of first operation 1959
5.	Scientist in charge of experimental programme	: D.M. Kundu
6.	Number of staff employed	: 5
7.	Programme in progress	: Study of fast neutron reactions, cross sections and fast neutron induced transmutations
8.	Future programme	: To change the site to make improvement so as to enhance neutron flux
9.	Special specifications:	

- Type of accelerator: Cockroft-Walton generator (home made)
- Nature of accelerated particles : Deuterons
- Energy : 400 kv
- Energy stabilization: Voltage stabilization 0.1%

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- Maximum beam current: 1.2 mA
- Current stabilization: nil
- Targets available (admissible current on target): Tritium about 1 mA over $\frac{1}{4}$ inch diameter
- Neutron yield in 4π geometry: 10^{11}/sec.
- Neutron energy : 14 MeV.

5. Saha Institute Cyclotron

1. Organisation responsible for design, construction and operation : Saha Institute of Nuclear Physics
2. Location : Saha Institute of Nuclear Physics 92, Acharya Prafulla Chandra Road, Calcutta- 9
3. Main purpose of apparatus : Internal beam irradiation of targets for producing isoioisotopes for $\beta - \gamma$ spectroscopy
4. Status : Full beam operation 1959
5. Scientist in charge of experimental programme : D.N. Kundu
6. Number of staff employed : 8
7. Programme in progress : Beam extraction
8. Future programme : Experiments on external beam
9. Special specifications:
   - Type of accelerator: Cyclotron (Home made)
   - Nature of accelerated particles: protons
   - Energy: Fixed - about 3.5 MeV
   - Energy stabilization: Nil
   - Maximum beam current: 40 uA average; the machine operates on 50 cycles A.C.

   Targets available : Only internal beam facility is available.

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6. 3.5 MeV Electron Linear Accelerator

1. Organisation responsible for design, construction and operation	: Tata Institute of Fundamental Research, Bombay
2. Location	: Tata Institute of Fundamental Research, Colaba, Bombay-5, India.
3. Purpose	: Experience in Accelerator design, and construction: use as an electron irradiation source
4. Status	: Completed as 1.5 MeV accelerator in 1960; as 3.5 MeV in 1962
5. Scientist in charge	: R.V.S. Sitaram
6. Number of staff	: 6
7. Programme in progress	: Study of: 1. Solid state and Biological irradiation effects 2. Bremstrahlung properties 3. Accelerator techniques 4. Nuclear resonance fluorescence
8. Future programme	: Same lines as present programme
9. Important characteristics not included in the list	: It is a travelling wave electron linear accelerator operating at 3 G.C./sec. 2 usec pulses. Pulse repetition rate variable upto 400 P.P.S. continuously operated at 100 P.P.S. with peak pulse current of about 30 mA. It is powered by a 2 M.W.magnetron

10. Special specifications:
    - Nature of accelerated particles: Electrons
    - Energy : 3.5 MeV fixed
    - Energy stabilization : About ± 10 percent
    - Maximum beam current : 30 mA pulse - 25 us. max. average
      10 uA average continuous operation

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- Current stabilization: ± 10% of value set
- Targets available : (1) Provision to incorporate any target in vaccum chamber; (2) Electron beam comes out of thin window for irradiation purposes
- Pulsation system: 5 M.W. line type pulse modulator, 2 usec pulse upto 400 P.P.S.
- Pulse length : 2 usec.

IV. MASS SEPARATORS

Mass Separator

1. Organisation responsible for design, construction and operation : Nuclear Physics Division Atomic Energy Establishment Trombay

2. Location : Tata Institute of Fundamental Research, Colaba, Bombay-5, India

3. Main purpose of the apparatus : To supply inactive pure isotopic targets for nuclear reactions, spectroscopy experiments etc.

4. Status : Scheduled for completion in early 1964

5. Scientist in charge of experimental programme : K.K.Damodaran

6. Number of staff employed : 6

7. Special specifications:

   - Ion source : Extraction voltage - 30 KV; Ion current in the beam - 10 mA
   - Deflection magnet : Weight - 5 tons; Power supply - 600 V 20 A D.C. Motor generator; Stabilization - expected one in 5,000; Max. field - expected 12 K gauss
   - Vacuum : 10^{-6} mm of Hg
   - Radius of curvature : 50 cms
   - Angular deflection in the ion beam : 60°
   - Collector efficiency : Expected 15%
   - Resolution : 150

V. SPECIAL MASS SPECTROMETER

1. Organisation responsible for design, construction and operation : Saha Institute of Nuclear Physics

2. Location : Saha Institute of Nuclear Physics, 92, Acharya Prafulla Chandra Road, Calcutta-9

3. Main purpose of apparatus : Studies in ion-ion collison, sputtering and other solid state experiments

4. Scientist in charge : D.N. Kundu

5. Number of staff employed : 4

6. Programme in progress : Studies in ion-ion collision sputtering and other solid state investigations

7. Future programme : along similar lines

8. Special specifications:

- Ion source:

	Source a	Source b
Ion density	10^{-11} A/cm^2	7 x 10^{-3} A/cm^2
Extraction voltage	8 KV	5 KV
Ion current in beam	0.1 uA	

- Deflection magnet: Weight - 1¼ ton; Power supply - 2.5 KW
  Stabilization - 1 in 10,000; Maximum field - 3800 gauss
- Vacuum : about 10^{-5} mm
- Curvature radius of ion path : 38 cm
- Angular deflection of the ion beam : 255°
- Resolution : 125

VI. RESEARCH REACTORS

1. Apsara

Name	:	Apsara
Situated	:	Trombay, Bombay 74
Critical	:	August 1956
Type	:	Pool type, highly enriched uranium, light water moderated, cooled and reflected.
Owner	:	Government of India
Operator	:	Atomic Energy Establishment Trombay
Designer	:	Atomic Energy Establishment Trombay
Use	:	Experimental neutron physics, isotope production, biological irradiation and training
Power	:	1 MW maximum
Fuel	:	Uranium enriched to 46%
Flux	:	Average thermal : 7.6×10^{12} n/cm^{2}sec
		Peak thermal : 2×10^{13} n/cm^{2}sec
		Average fast : 1×10^{13} n/cm^{2}sec

Experimental Facilities

Designation	No.	Position	Useful dimensions (cm)	Neutron flux (n/cm^2 sec.)	Remarks
Horizontal beam tubes reaching reflector	4 3	(1) (2)	10 diam. 15 diam.	-	-
Horizontal through tube tangential to core	1	(3)	10 diam.	-	-
Shielding corner	1	(4)	245 high 245 wide on each side		Concrete wall replaced by 1 in(2.5 cm) Al + removable concrete blocks
Thermal column	1	(5)	126 x 126 258 long		Cd ratio: max 455; at the end of thermal col. 280
Vertical in lattice positions (for isotope production	4		5 diam.	Th.max.10^{11}	Flux: 10^6 r/hr. temp. 35°C

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2. Canada India Reactor

Name : Canada India Reactor

Situated : Trombay, Bombay 74

Critical : 10th July 1960

Type : Heavy water moderated, light water cooled, Graphite reflected, Natural uranium type

Owner : Government of India

Operator : Atomic Energy Establishment Trombay

Designer : Atomic Energy of Canada Ltd.

Power : 40 MW

Fuel : Natural Uranium

Flux : Average thermal: 2.4×10^{13} neutron flux (n/cm^2 sec.)

Peak thermal : 6.7×10^{13} ,, ,,

Average fast : 1.6×10^{13} ,, ,,

Peak fast : 4.4×10^{13} ,, ,,

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Experimental Facilities

Designation	No.	Position	Useful dimensions (cm)	Neutron flux (n/cm^2 sec.)	Remarks
Horizontal experimental holes reaching reflector	20	(1)	10.2 diam.	th.max.1.2×10^{13}	7700r/sec
	5	(2)	30.5 diam.	th.max.1.7×10^{13}	11000r/sec
"Self serve" units horizontal reaching reflector	6	(3)	6.35 diam.	th.max.1.7×10^{13}	11000r/sec
Thermal columns	2	(4)	178x178 228.6 long	th.10^{8}-10^{11}	
Central thimble ("in pile")	1	(5)	14.6 id.	th.av.3.7×10^{13} th.max.5.9×10^{13} f..av.2.4×10^{13} f.max.3.9×10^{13}	11000 r/sec
Loops ("in pile")	6	(6)	10.2 id.	as (5)	
Tray rods ("in pile")			5.4 diam.	th.av.2.6-6.7×10^{13} th.max1.6-4.3×10^{13}	replacing fuel elements
J-rods (in J-rod annulus)	92	(7)	6.35	th.max 1×10^{13}	3700 r/sec

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3. Zerlina

Name	:	Zerlina
Situated	:	Trombay, Bombay 74
Critical	:	1961
Type	:	Variable fuel, heavy water, uncooled
Owner	:	Government of India
Operator	:	Atomic Energy Establishment Trombay
Designer	:	Atomic Energy Establishment Trombay
Use	:	Lattice investigation
Power	:	Maximum 100 w thermal
Fuel	:	Variable
Flux	:	Variable
Experimental facilities	:	The reactor as a whole may be used for zero energy lattice studies, temperature coefficient measurements, etc. One cadmium shutter for bare reactor studies heavy water heating arrangement for temperature coefficient measurements.

ASD:tr:
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