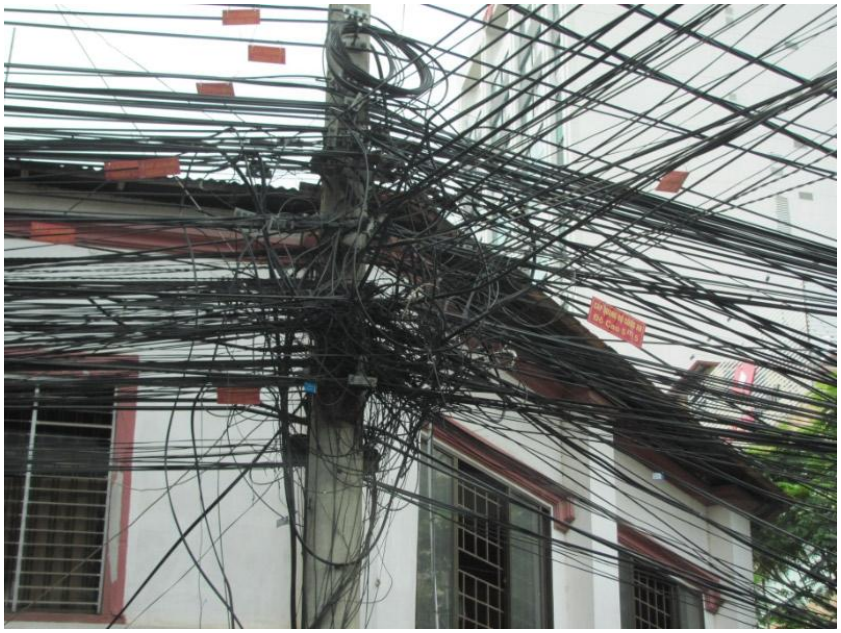
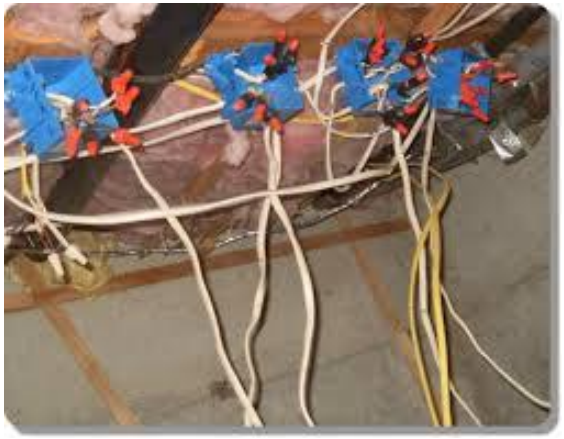
Occupational Hazards With Experimental High Voltage Systems

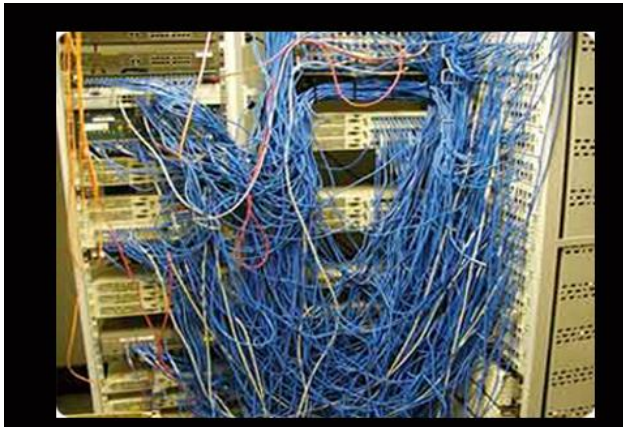
U.K. Baruah
SST-NBI Group, Institute for Plasma Research
Gandhinagar

Hazards from Electricity is generally well recognized across Society

Avoidable mess with Electrical equipments!





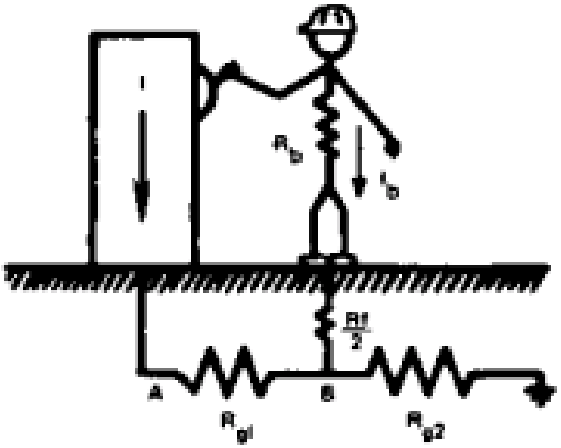


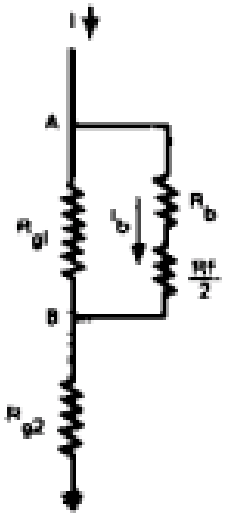
Hazards from using Electricity can arise from:

- Electrical Shock to Humans
- Fire, sometimes Explosive
- Release of Harmful Substances

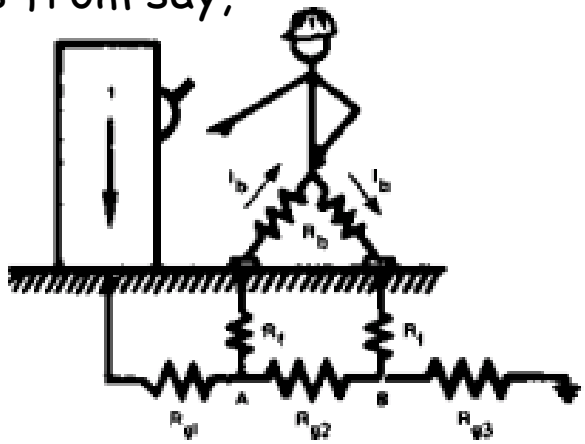
The last two are Secondary Effects originating from Electrical causes.

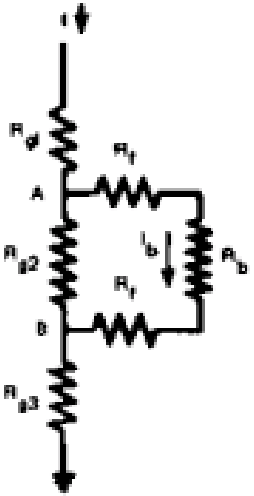
Human Body offers a Conducting path for Electricity





Touch Potential, current path is from say, hand to foot.





Step Potential, current path in body is from one foot to another.

Effects depends on measure of Current in the body

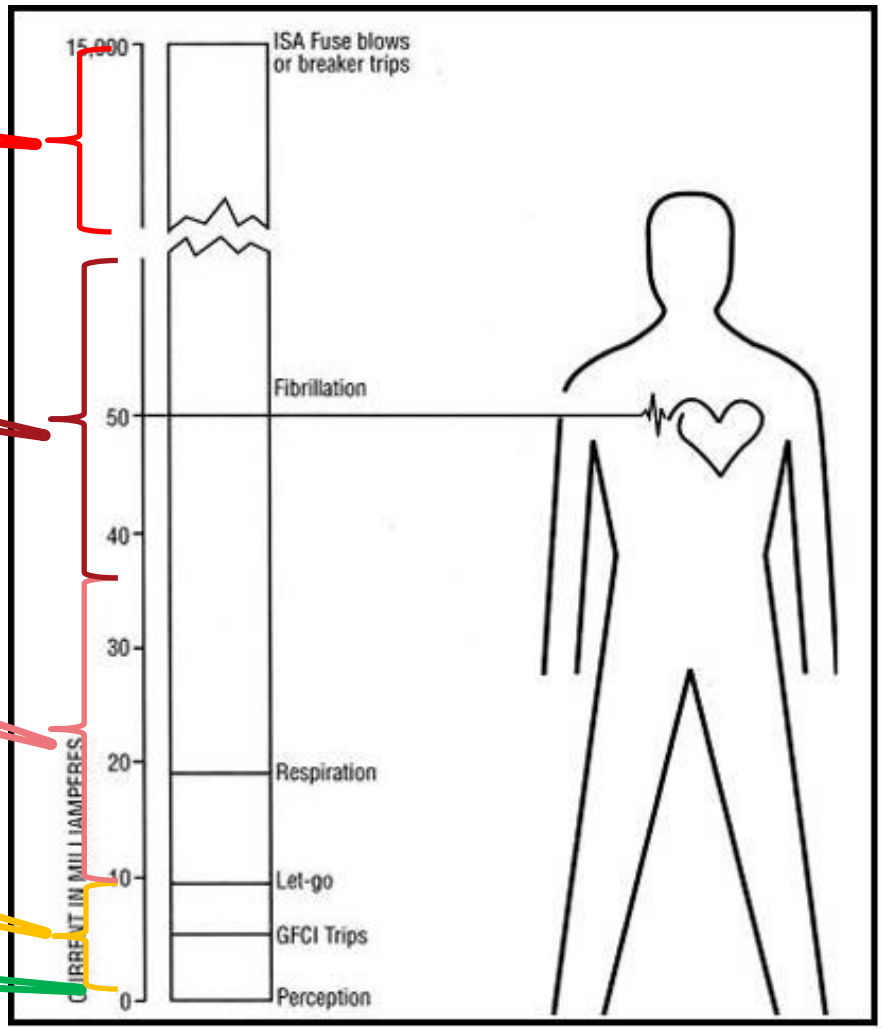
Severe damage- Death, Burn!

40<&<200mA,Vent ricular Fibrillation, Burn, Death!

10<&<40mA, Painful, not Let Go!

1<&<10mA, Feels, Let Go!

<1mA, No Feel!



Laws, Rules, Codes and Standards on use of Electricity

Indian Electricity Act, 2003 is the consolidated Law encompassing all aspects ranging form Generation to Use including trading or electricty.

रजिस्ट्री सं० डीएल-33004/2003 REGISTERED NO. DL-33004/2003

भारत का राजपत्र
The Gazette of India

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इस भाग में भिन्न पृष्ठ संख्या दी जाती है जिससे कि यह अलग संकलन के रूप में रखा जा सके।
Separate paging is given to this Part in order that it may be filed as a separate compilation.

MINISTRY OF LAW AND JUSTICE
(Legislative Department)

New Delhi, the 2nd June, 2003/Jyaistha 12, 1925 (Saka)

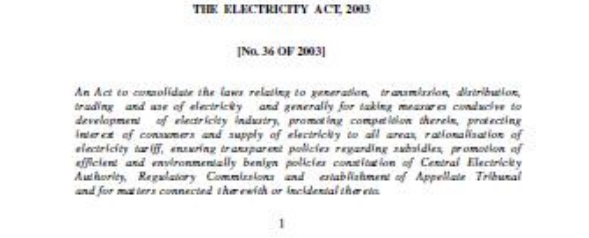
The following Act of Parliament received the assent of the President on the 26th May, 2003, and is hereby published for general information :—

THE ELECTRICITY ACT, 2003

[No. 36 OF 2003]

[*26th May*, 2003]

An Act to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalisation of electricity tariff, ensuring transparent policies regarding subsidies, promotion of efficient and environmentally benign policies, constitution of Central Electricity Authority, Regulatory Commissions and establishment of Appellate Tribunal and for matters connected therewith or incidental thereto.



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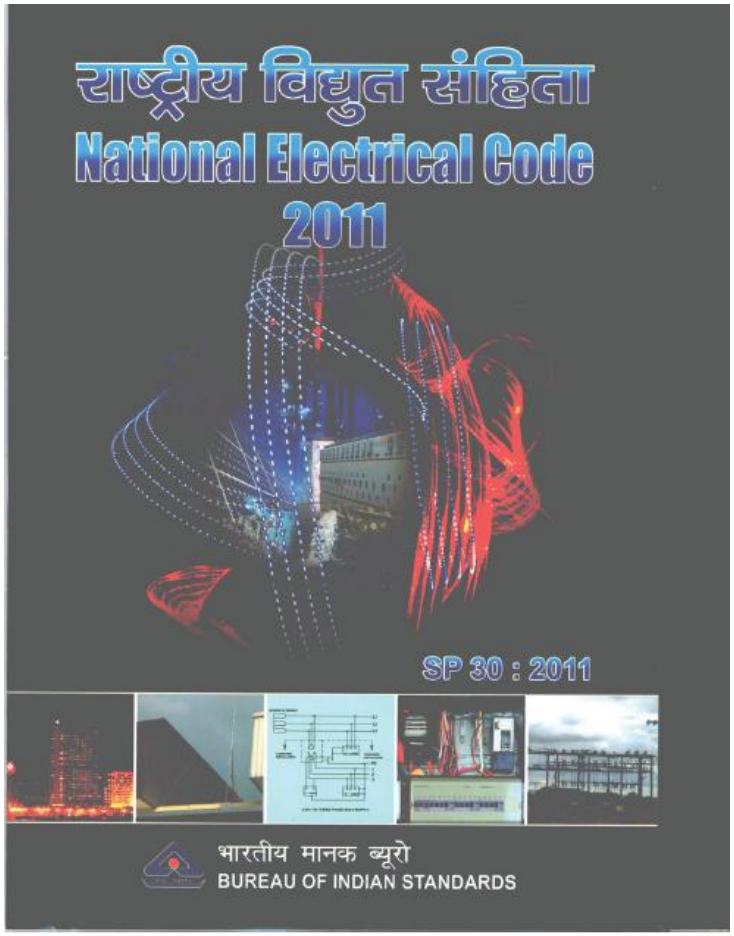
1

Laws, Rules, Codes and Standards on use of Electricity

Bureau of Indian Standards has defined codes and rules to follow.
The National Electrical Code, 2011 defines the Safety Aspects of Electricity usage in public domain.



Laws, Rules, Codes and Standards on use of Electricity

Prescriptions are provided for all different types of installations commonly encountered.

The NEC covers all aspects of installation

Installations in Industrial, Public outdoor area, Agricultural, Hazardous area are also explicitly covered.

CONTENTS

Laws, Rules, Codes and Standards on use of Electricity

Section 19 of the NEC is specific on Safety.

It gives guidelines and also states the associated Indian Standards.

The Section is a valuable tool to verify a system for adequacy in Safety aspects in a design, in Experimental Systems as well.

SECTION 19 SAFETY IN ELECTRICAL WORK

0 FOREWORD

Safety procedures and practices are essential in electrical work. Basic approaches to electrical work from the point of view of ensuring safety which include inbuilt safety in procedures such as permit-to-work system, safety instructions and safety practices are covered in this Section.

It is essential that safety should be preached and practiced at all times in the installation, operation and maintenance work. The real benefit to be derived from the guidelines covered in this Section will be realized only when the safety instructions it contains are regarded as normal routine duty and not as involving extra and laborious operations.

1 SCOPE

This Part 1/Section 19 of the Code covers guidelines on safety procedures and practices in electrical work.

2 REFERENCES

A list of Indian Standards on safety in electrical work are as follows:

IS No.	*Title*
2551 : 1982	Specification for danger notice plates
IS 5216 (Part 1) : 1982	Recommendations on safety procedures and practices in electrical work: Part 1 General
IS 5216 (Part 2) : 1982	Recommendations on safety procedures and practices in electrical work: Part 2 Life saving techniques
8923 : 1978	Warning symbol for dangerous voltages
SP 31 : 1986	Method of treatment of electric shock

any particular work ensure that the portion of the installation where the work is to be carried out is rendered dead and safe for working. All work shall be carried out under the personal supervision of a competent person. If more than one department is working on the same apparatus, a permit-to-work should be issued to the person-in-charge of each department.

NOTE — The words 'permit-to-work' and 'permit' are synonymous for the purpose of this Section.

3.2 No work shall be commenced on live mains unless it is specifically intended to be so done by specially trained staff. In such cases all possible precautions shall be taken to ensure the safety of the staff engaged for such work, and also of others who may be directly or indirectly connected with the work. Such work shall only be carried out with proper equipment provided for the purpose and, after taking necessary precautions, by specially trained and experienced persons who are aware of the danger that exists when working on or near live mains or apparatus.

3.3 On completion of the work for which the permit-to-work is issued, the person-in-charge of the maintenance staff should return the permit duly discharged to the issuing authority.

3.4 In all cases, the issue and return of permits shall be recorded in a special register provided for that purpose.

3.5 The permits shall be issued not only to the staff of the supply undertakings, but also to the staff of other departments, contractors, engineers, etc, who might be required to work adjacent to live electrical mains or apparatus.

3.6 A model form of permit-to-work certificate is given in IS 5216 (Part 1).

NOTES

In an Experimental System,

We take a little bit of deviation in design due to many special situations;

- First of a kind,
- Objective itself may be to prove some kind of limits,
- Non-permanent, quick fix solution,
- Other constraints (cost, etc.),
- Or, any inventive ones!...!

The Basic Principles for Safety, however can't be condoned!

View of the Neutral Beam Injector System at IPR

The example NBI system

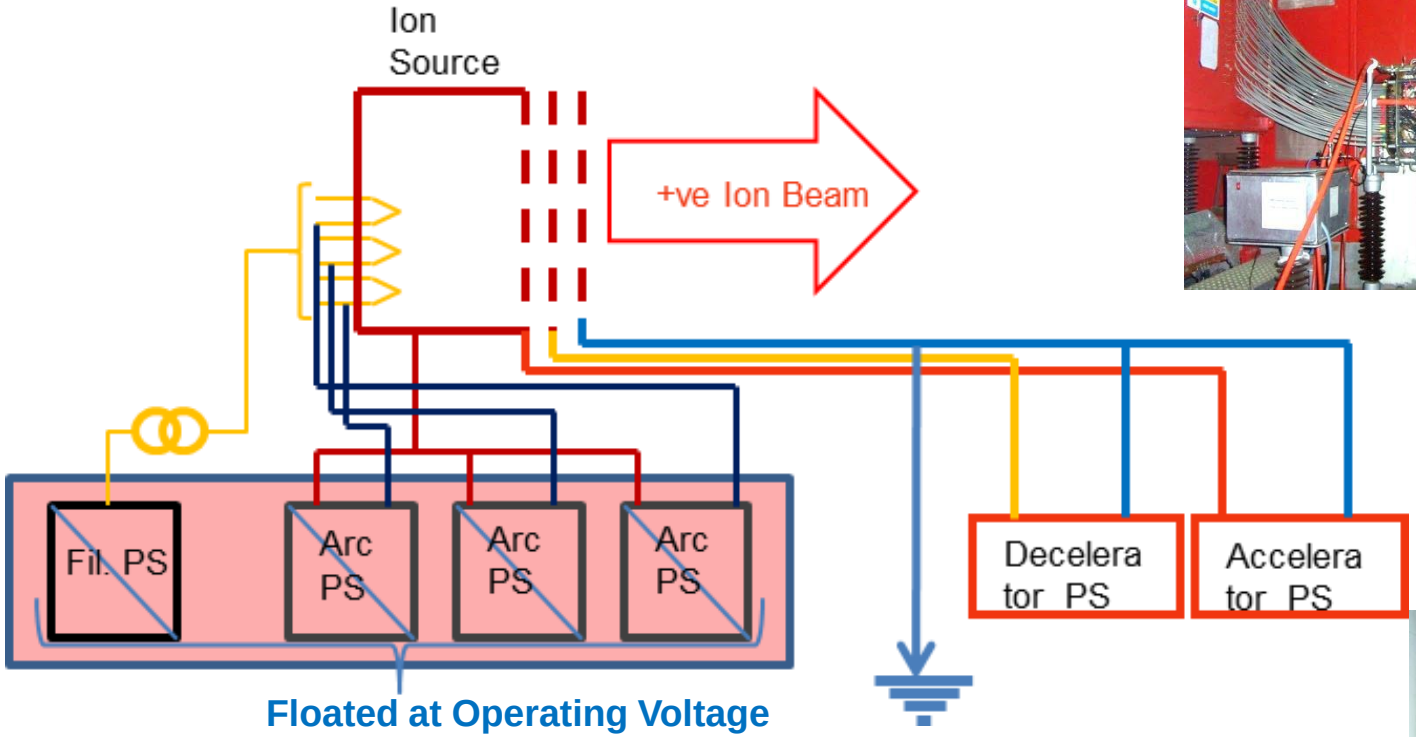
- Used to Heat Up Plasma in a Fusion Experimental Device (Tokamak, etc.),
- Falls in a group of high power Experimental Systems,
- Have generated lot of interest in Indian context,
- Other equipments in the category are Accelerators, High Power Microwave Systems (Klystron, Gyrotrons, etc.)

The System works at Voltage upto 80kV (DC), power drawn at peak operation can be upto 7 MW.

View of the Neutral Beam Injector System at IPR

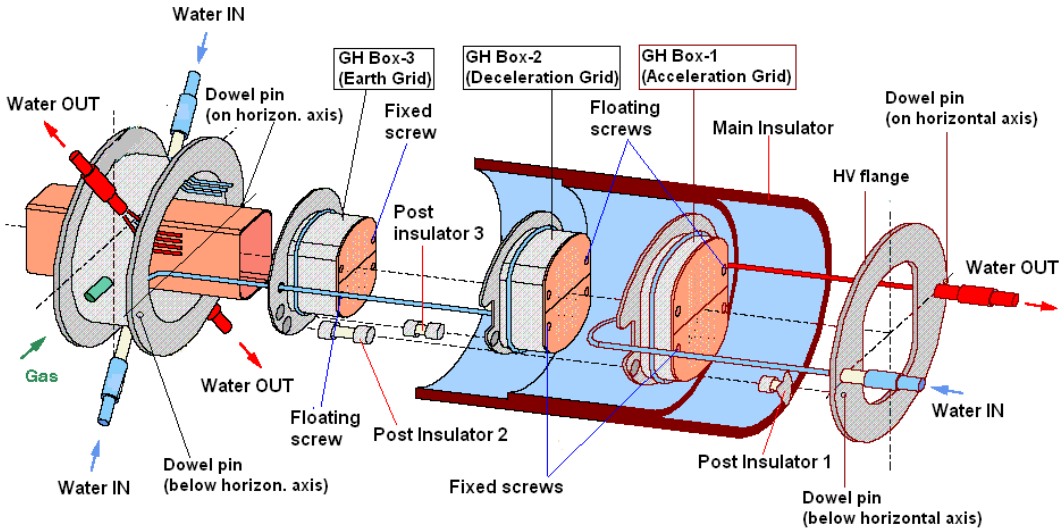
The System in Brief

- Ions are Produced in the Ion Source using ~400kW power,
- Ions get accelerated between the electrodes,
- Accelerator PS is a 80kV, 10MW power supply.



High Stress Design of the Ion Source

Stress between Grids upto 6kV/mm, in vacuum
Stress on Post Insulators upto 1.1kV/mm, in air and vacuum

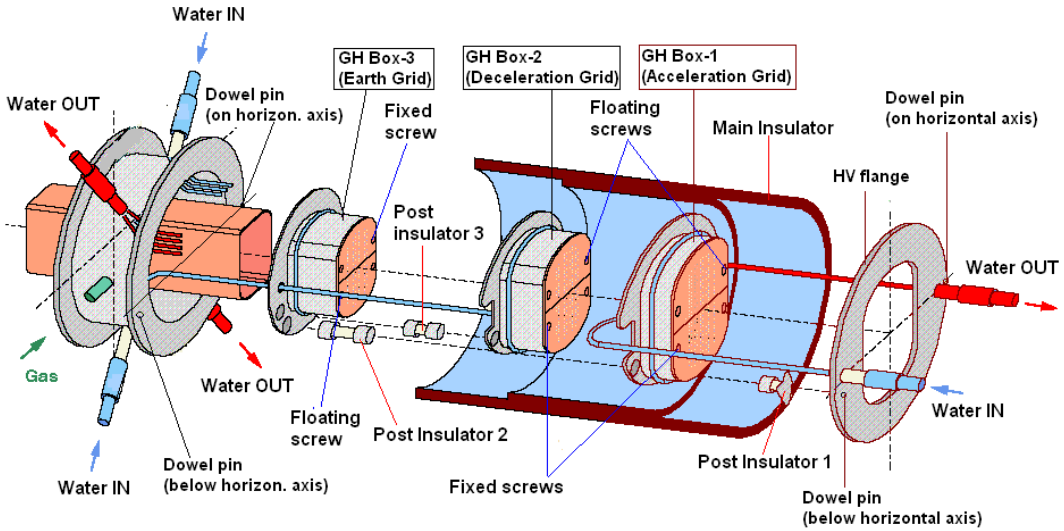


Construction of the Ion Source, the bucket shaped Grids are separated for only 8mm.

Post Insulators, the longer PI holds 80kV.

Design Verification and Quality Control are key

- Manufacturing and Materials QC,
- Prototyping to prove design, Qualifying tests on all Parts,
- Special Prescriptions for Operation .



Construction of the Ion Source, the bucket shaped Grids are separated for only 8mm.

Post Insulators, the longer PI holds 80kV.

Safety Aspect Analysis of each Equipment and System

- Conducted by Designers and Users together,
- Functional analysis done,
- Animated analysis of Failure and unexpected events,
- Prescriptions for O&M prepared.

Safety aspects Analysis helped to improve several aspects during Design as well Manufacturing.

High Voltage Power Supply feeding the NBI (80kV, 130A)

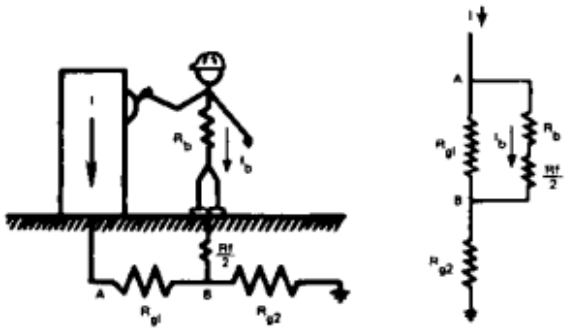
Multisecondary Transformers

HV generated by Switched Power Modules

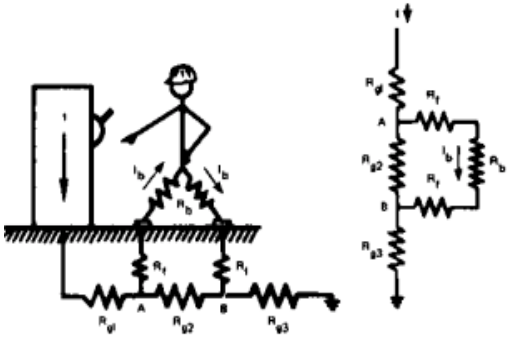
Auxiliary Systems HV Deck, General Arrangements

All high Voltage Power Supplies are Installed on a HV Deck, with a Ground Enclosure.
HV Insulators used for support of all HV Parts

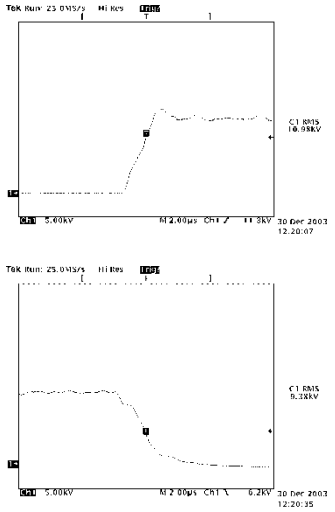
Recalling the Touch and Step Potential,



Touch Potential



Step Potential



Transients in the System

To maintain an Equipotential Plane around the System,

- Grounding and Bonding are done carefully,
- All metallic parts are referenced to known potential,

Grounding and Bonding

- Ground is defined separately,
- all parts are Bonded together and finally connected to Ground,
- Low impedance path is created.

Other Safety Measures;

- **Interlocks,**
  Operating limits are integrated in Operational Controls.

- **Access Controls,**
  - ✓ Incoming power is interlocked with Door Switches to main areas like HV Deck, HVPS area.
  - ✓ Additional Access switches are integrated into Control System Commands.

Other Safety Measures;

- **Barriers,**
  Temporary and Permanent barriers are installed
- **Grounding Sticks**
  HV areas are entered only after removal of residual Charge.
- **Alarms and Beacons,**
  Prominently placed
- **Video Surveillance System,**
  Observation from operator's end.

Other Safety Measures;

- Equipment Layout Design,
- Identified Evacuation Routes ,
- Signage,
- First Aid kits,
  Electrical and other injuries

Operator Training

- Operators of experimental systems are usually well qualified,
- Are Trained on specifics,
- Are knowledgeable about the System and the Design Philosophy,
- Can act independently in case of emergency.

Code of Conduct

Created a simple set of Codes for the Laboratory,

Area wise responsible person.

- Deviations are openly discussed,
- Accidents are recorded, reported and analyzed,
- Information creates consciousness.


Code of Conduct

NBI- Group

On this day of 26 January 2010, we, the team members of NBI, take oath that—

We shall adhere to

1. The safety for working personal
2. The principle of team co-operation for experimental conduct.
3. Our work and focus on the work assigned with careful attention.
4. No-haste policy for HV /PJNI operation.
5. No-relaxation till the HV is "ON".
6. No-trespassing the HV area till the system is properly grounded.
7. No-free to move tendency.

We, in principle, agree to follow

A. Discussions at meeting place only
B. Definite decisions for measurements before experiments
C. No change of variables during operation
D. No crosstalk during operation/HV "ON"
E. Data sharing as soon as possible after set of experiments.
F. The operational requirements

Operational requirements—

1. NBI is reconstituted for experimental reasons as follows
   Line One: LMB, V Prahlad
   Line Two: PJP, MRJ, CC, LKB, PB, VT, VP, KO.
   Line Three: LNG, DT, KO, BC,
   Line four: all ITI, trainees
2. Persons responsible for HV experiments—
   X. LKB, PJP
   Y. VT,LNG,KO
   Z. DT, N

Overall, we had Generally Incident free Operation over years of operations!

What could improve

Integrated Design of Experimental Systems with Buildings,
Civil engineering design integration can result in better approach to;

- Grounding Network,
- Layout design,
- Ease of access to parts of system,
- Exit route plan, etc.

Safety Concepts needs early integration in design.

Acknowledgement:

NBI team members, past and present, Safety Officer and Safety Committee, IPR.

Thank You!