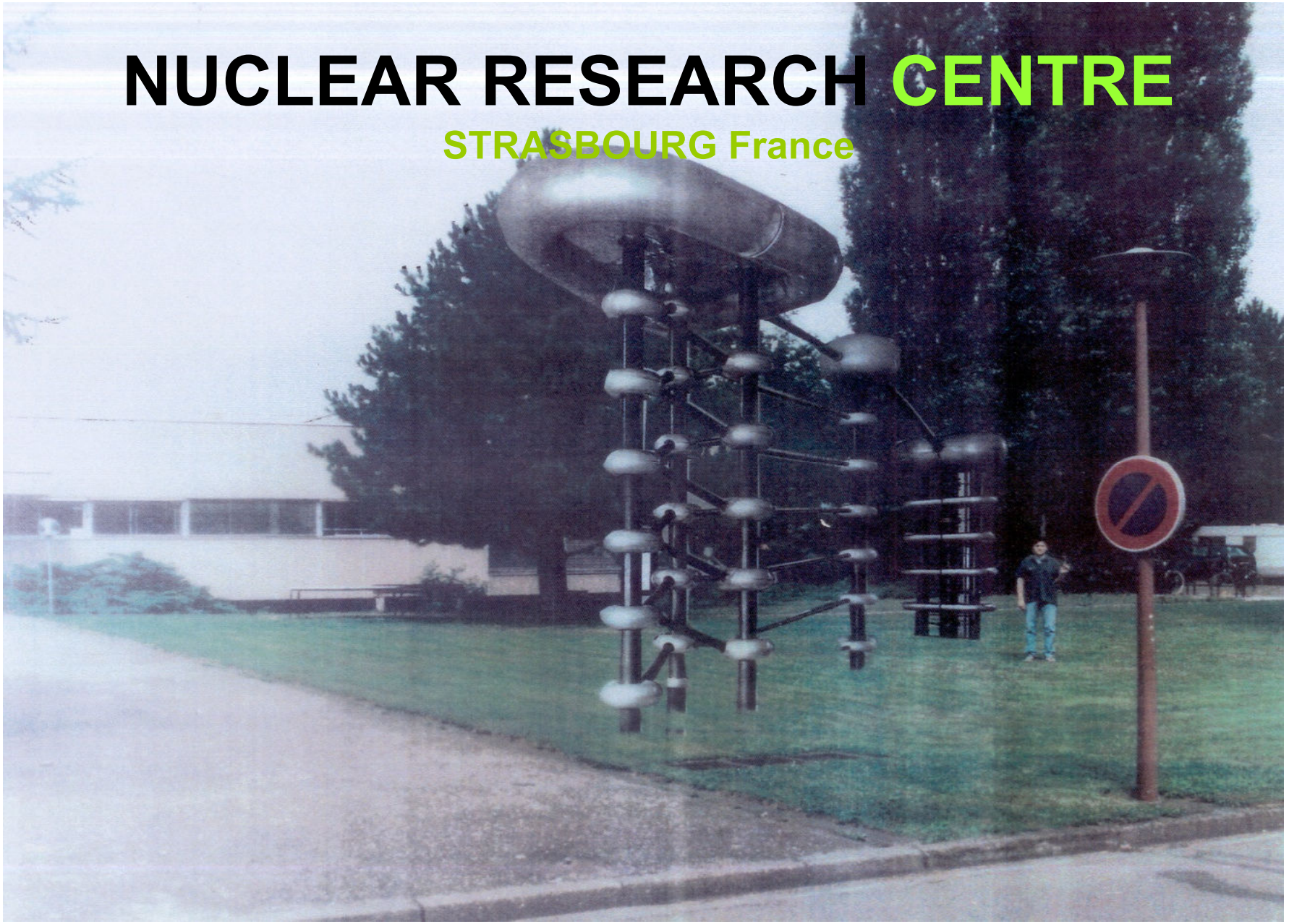
NUCLEAR RESEARCH CENTRE

STRASBOURG France



HISTORIQUE DE VIVIRAD

France

Nuclear Research Centre
(IRES) Strasbourg
CN – 1959
-1.5 MV Cockroft
- 2 MV Phillips
- 2.5 MV – 3 MV – 3 MV – 4 MV – 7 MV
- MP (10 MV → 18 MV)
- 5 MV
- VIVITRON

USA

M.I.T. Boston
Pr. Van de Graaff
Pr. Trump
High Voltage Engineering
Corporation

A – Scientific accelerators ≅ 1 500
* Single stage machines
* Tandem machines

B – Industrial accelerators ≅ 250

Then Vivirad High Voltage Corporation
(Billerica) USA

VIVIRAD SA France

Fusion: - NET : (1 MV-15 A)
- ITER: Cadarache (France)
- ICT Power Supply

ELECTRON PROCESSING SYSTEMS & X-RAY GENERATORS

VIVIRAD'S PRODUCTION OF ACCELERATED ELECTRONS IS BASED ON 3 TECHNOLOGIES :

- ICT's (INSULATED CORE TRANSFORMER)
- AIV'S (RESONANT TRANSFORMER)
- VAN DE GRAAFF'S (BELTS TRANSFORMER)

I C T

VAN DE GRAAFF

A I V

SELF SHIELDED UNITS

VIVIRAD'S PRODUCTION INCLUDES SELFSHIELDED TREATMENT UNITS UP TO 750 KeV WITH MINIMUM SPACE REQUIREMENTS.

SELFSHIELDED UNITS HAVE BEEN MOUNTED ON FULLY AUTONOMOUS TRAILERS WHICH ARE EQUIPPED WITH AIR CONDITIONED CONTROL ROOM AND DIESEL POWER GROUP.

THE VIVIRAD GROUP PROVIDES ITS CUSTOMERS GLOBAL SOLUTIONS FOR FULLY INTEGRATED TREATMENT UNITS.

VIVIRAD GUARANTEE PRODUCTION STARTING AND RESULTS.

GLOBAL SOLUTIONS

HIGH POWER

ICT (INSULATED CORE TRANSFORMER) TECHNOLOGY DEVELOPED AND IMPROVED BY VIVIRAD ALLOWS THE PRODUCTION OF ULTRA HIGH POWER ACCELERATORS UP TO 1.2 MEGA WATTS.

CABLE CONNECTION

ICT POWER SUPPLIES UP TO 800 KeV CAN BE CABLE CONNECTED TO ONE OR MORE ACCELERATORS OFFERING THE POSSIBILITY OF MULTI SHIFT TREATMENT AREAS.

VIVIRAD S.A.

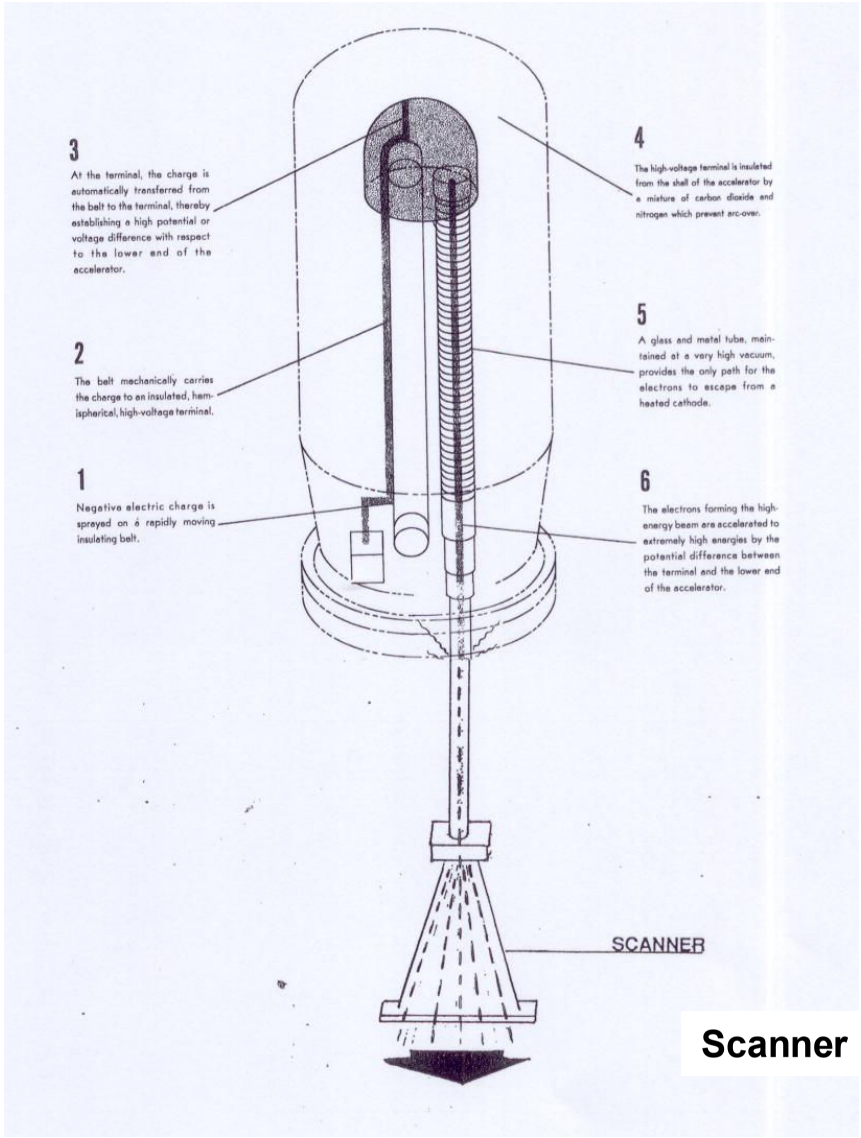
VIVIRAD INDUSTRIAL ELECTRON ACCELERATORS

- ⇨ From 300 Kev to 5 Mev
- ⇨ Powers from 3 to 300 KW
- ⇨ Adjustable in voltage and current
- ⇨ Scanner sizes from 30 cm to 300 cm

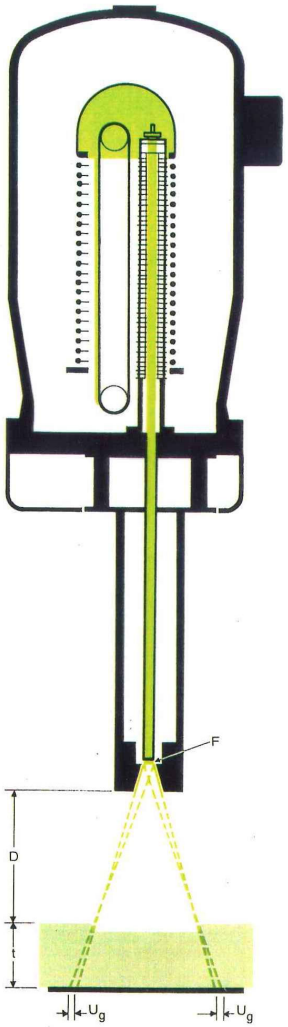
- ⇨ The New and Powerful System : DEXTER, rated 5 Mev-60 mA
  - Direct electrons and X-ray emission
  - Treatment capacity ~ 3 MCi Co_{60} in X-ray mode

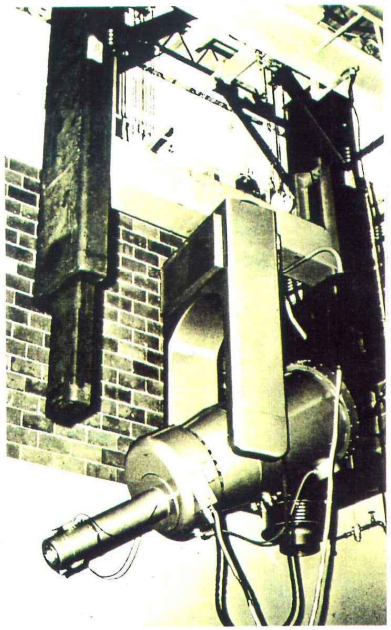
VIVIRAD SA - France
23, rue Principale
F-67117 HANDSCHUHEIM - France
Tel:(33) 388 691 325
Fax:(33) 388 691 618
e-mail: vivirad@aol.com
Web site: www.vivirad.com

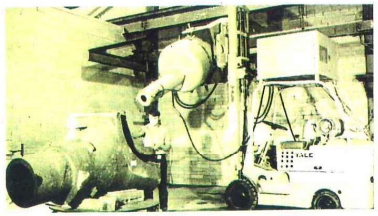
Van de Graaff Electrostatic Accelerator



Scanner

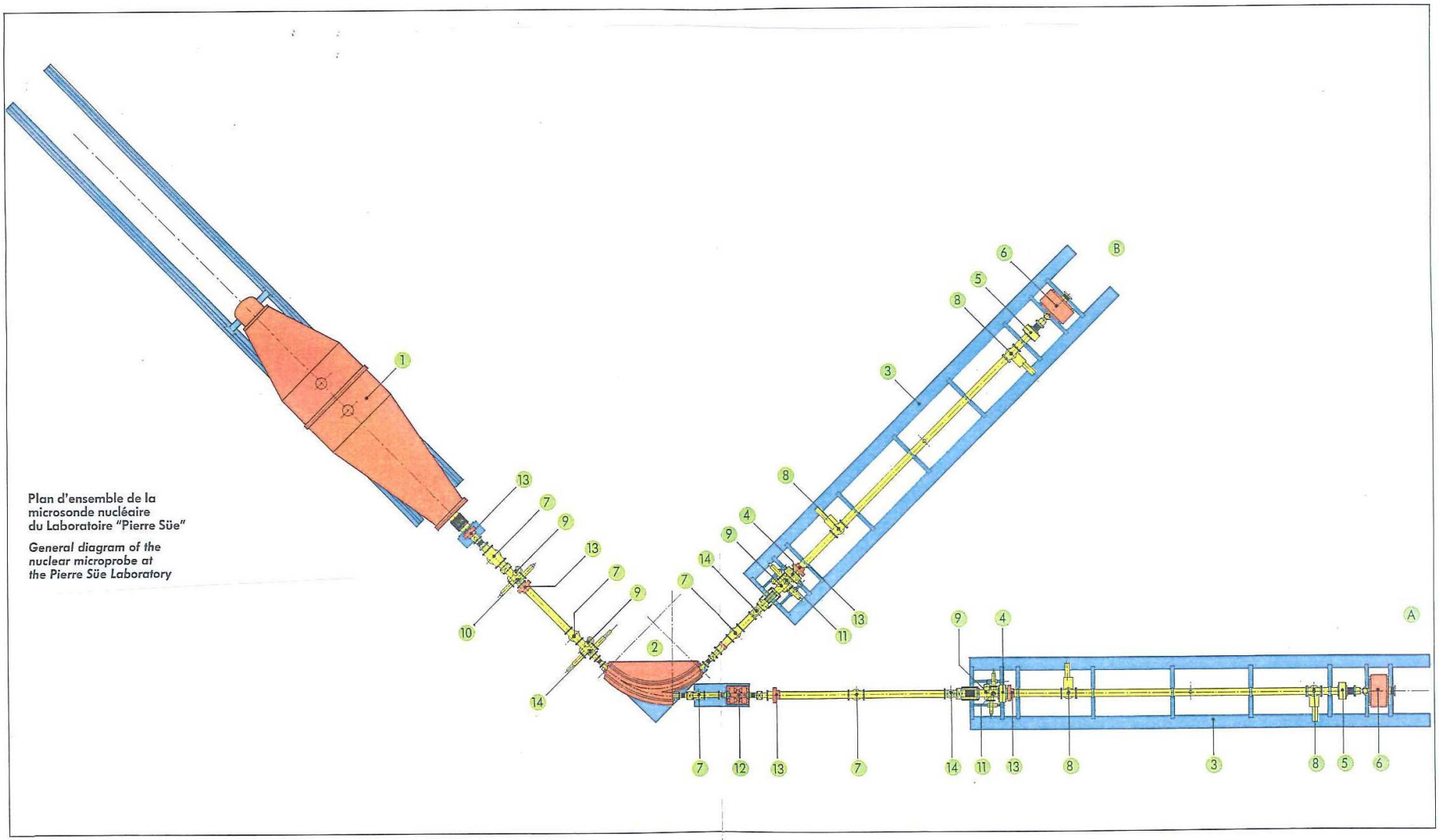






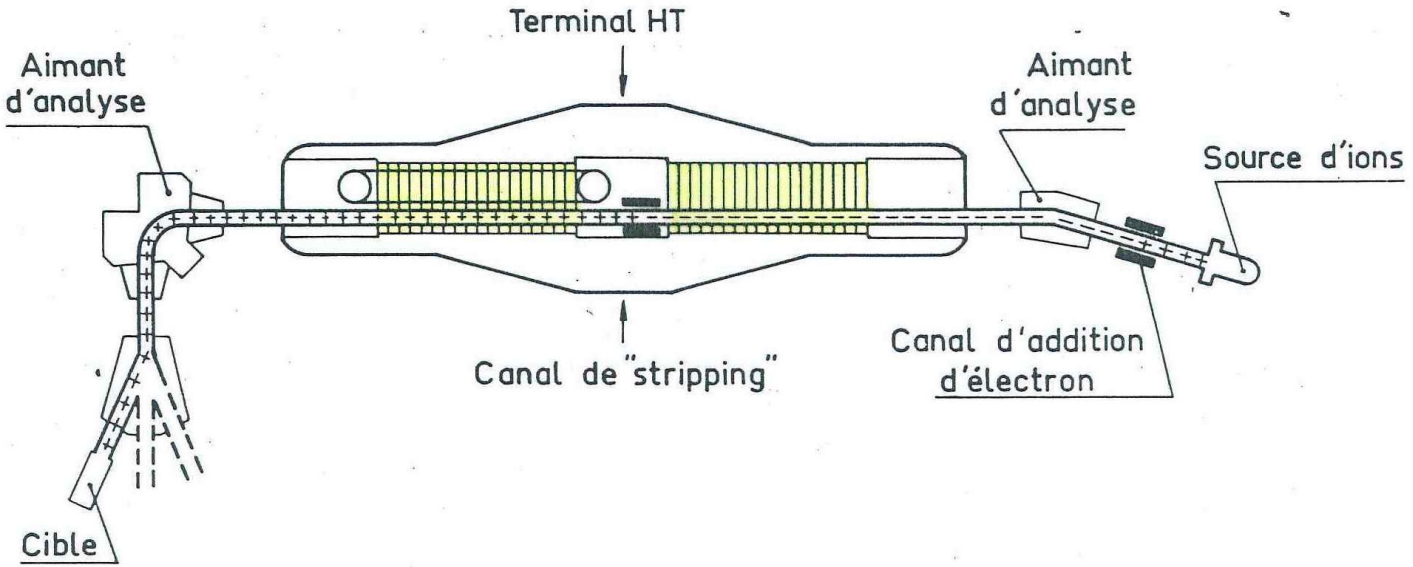
VIVIRAD S.A
23, rue Principale
67117 HANDSCHUHEIM France
☏ (33) 88.69.13.25 · Fax (33) 88.69.16.18
Telex 880885 VIVIRAD

La microsonde nucléaire du Laboratoire "Pierre Süe" • *Nuclear microprobe at the Pierre Süe Laboratory*



Plan d'ensemble de la microsonde nucléaire du Laboratoire "Pierre Süe"

General diagram of the nuclear microprobe at the Pierre Süe Laboratory



ACCELERATEUR VAN DE GRAAFF TANDEM

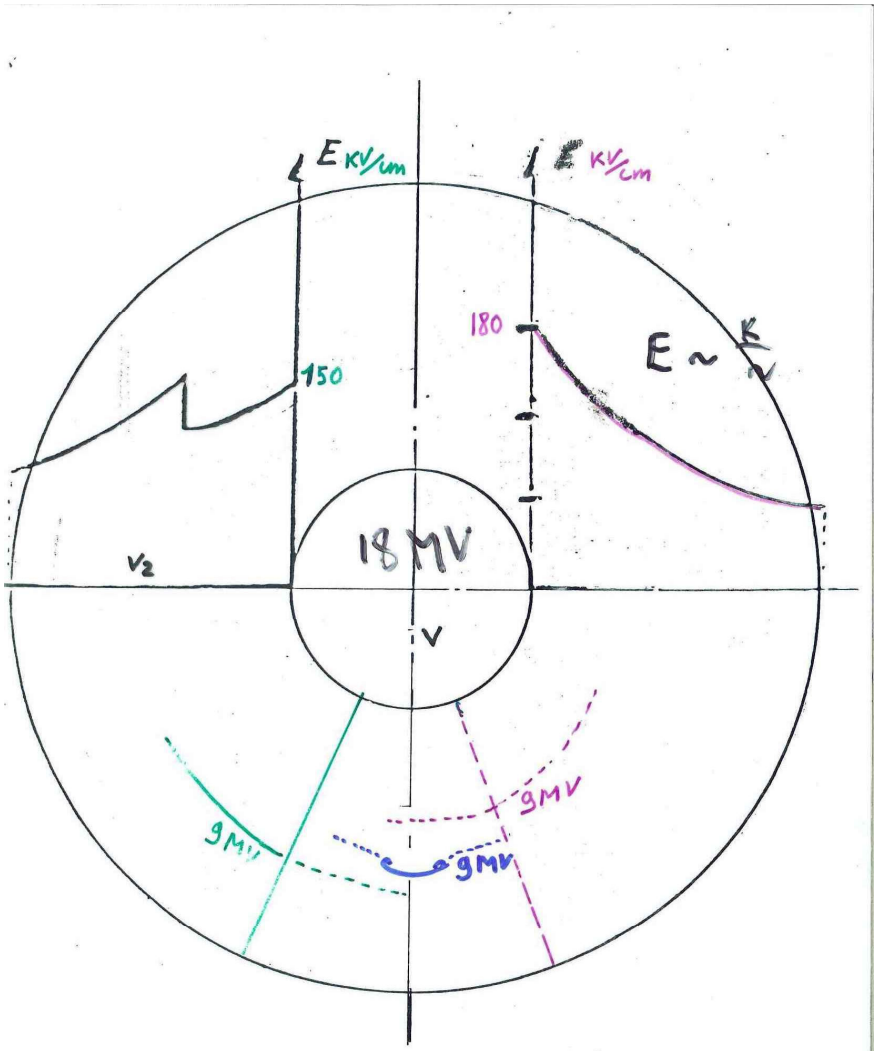
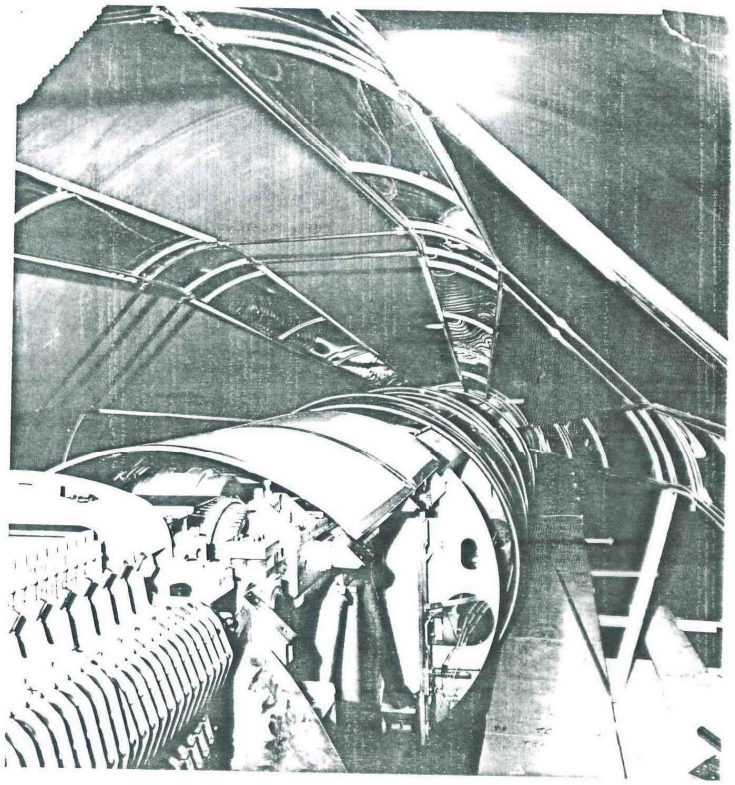
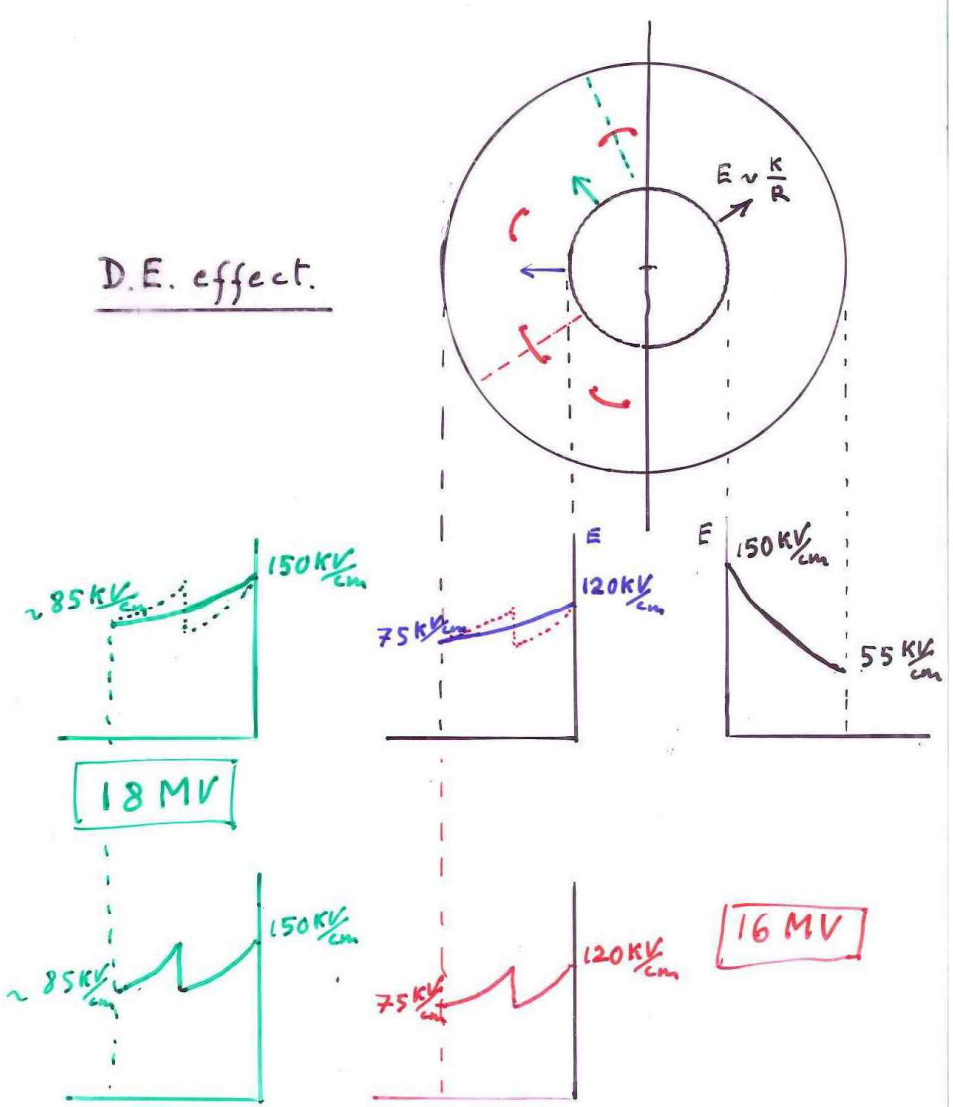


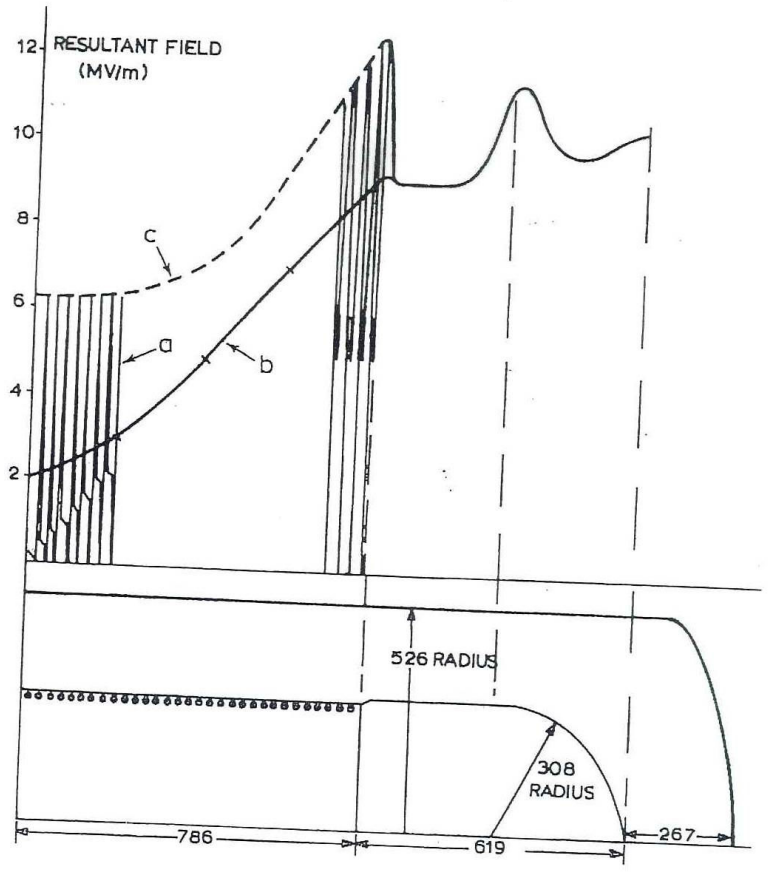
Figure 3

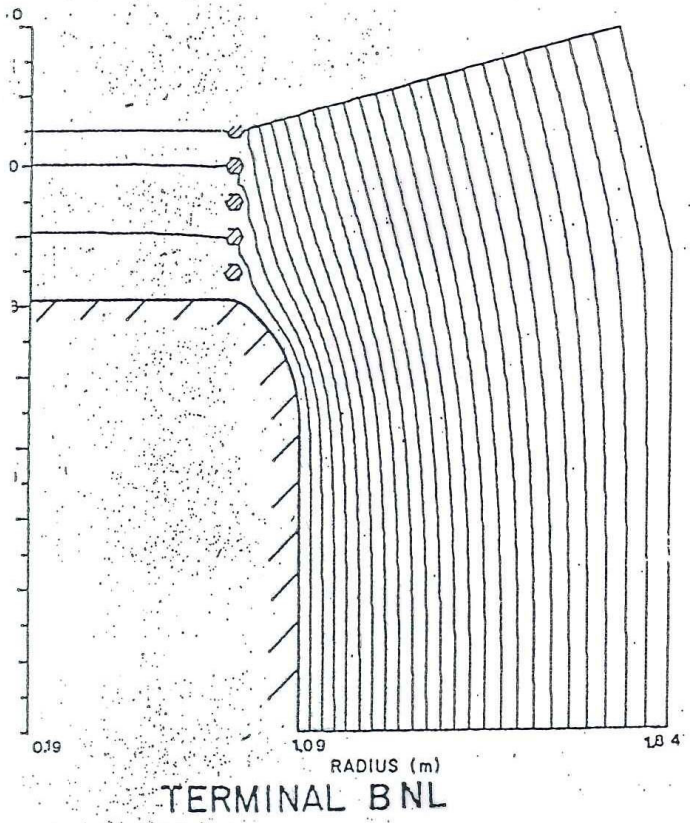


STRASBOURG MP

D.E. effect.




RESULTANT FIELD
(MV/m)
12
10
8
6
4
2
c
a
b
526 RADIUS
308
RADIUS
786
619
267



Field mapping for the MP 7 terminal.

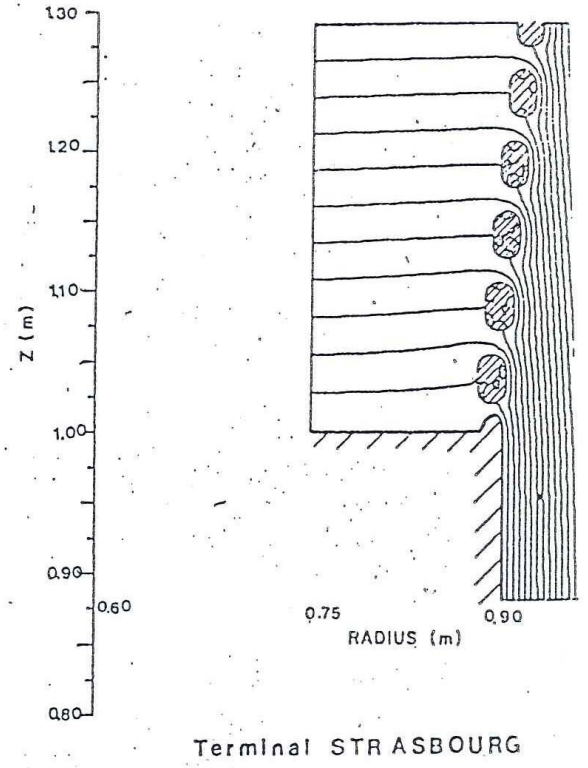
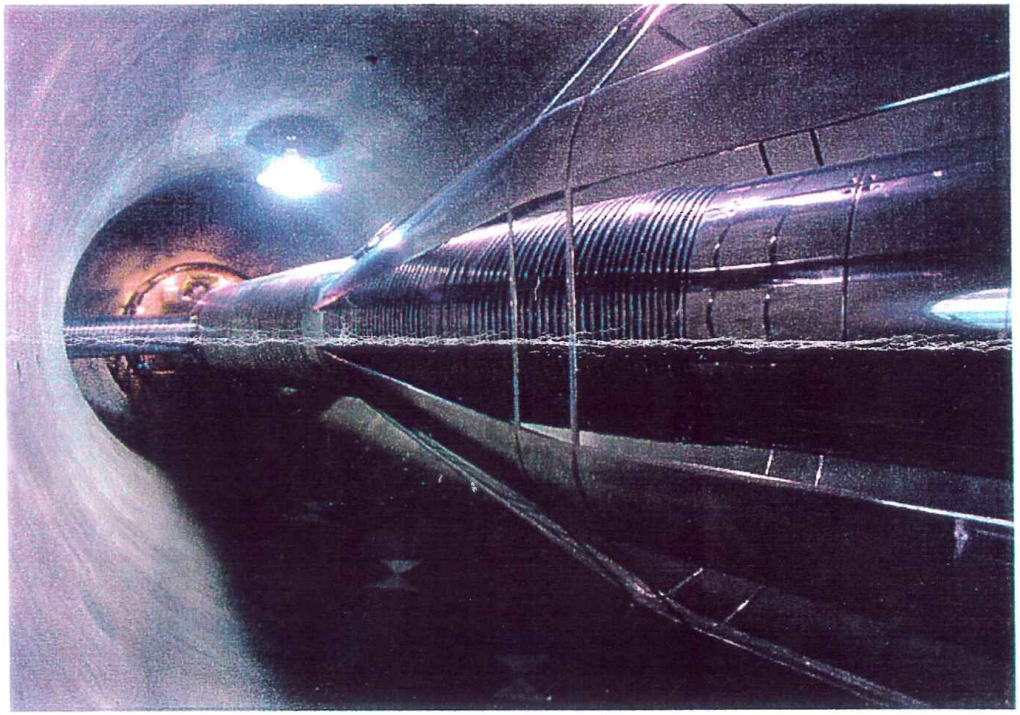


FIG. 4. Field mapping for the MP 10 terminal.

Yale University



The ESTU Tandem

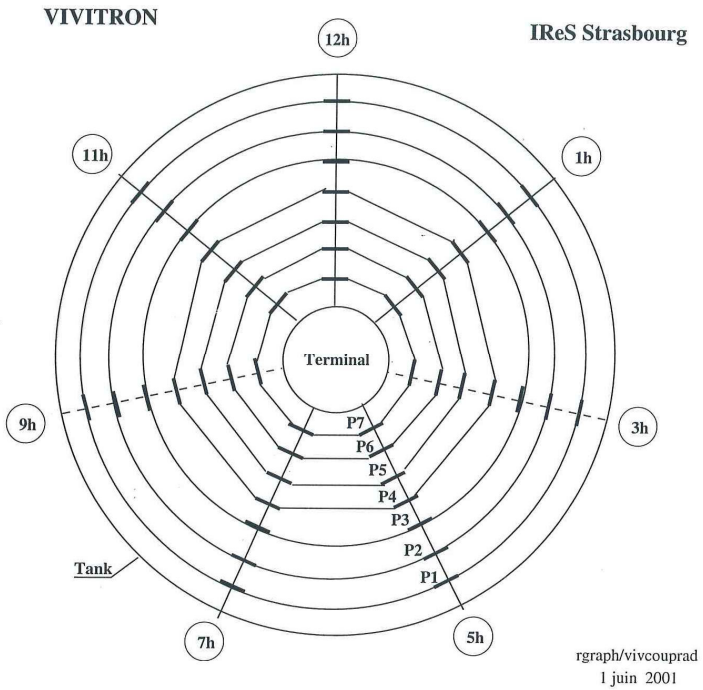
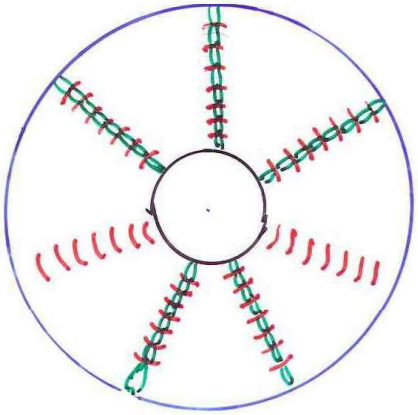
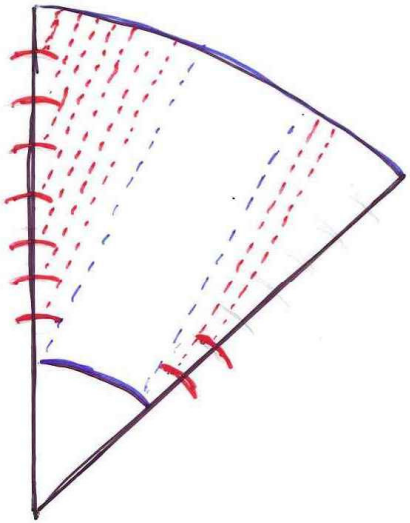


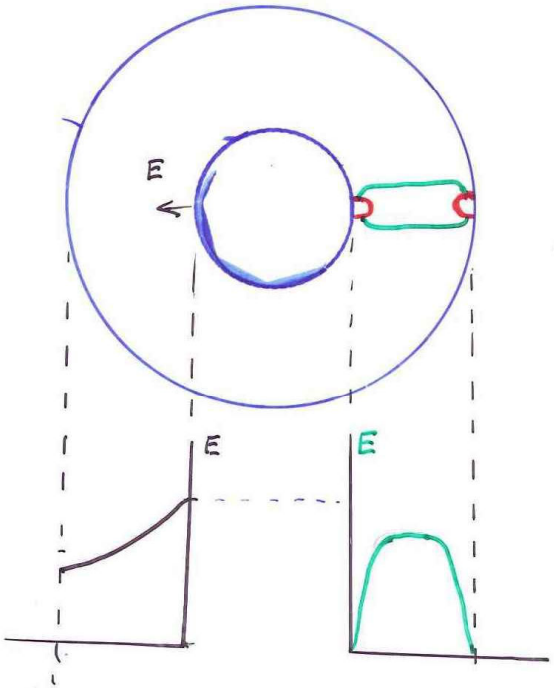
Fig : Coupe radiale du Vivitron au centre de la machine



7 Porticos x 7 D.E.



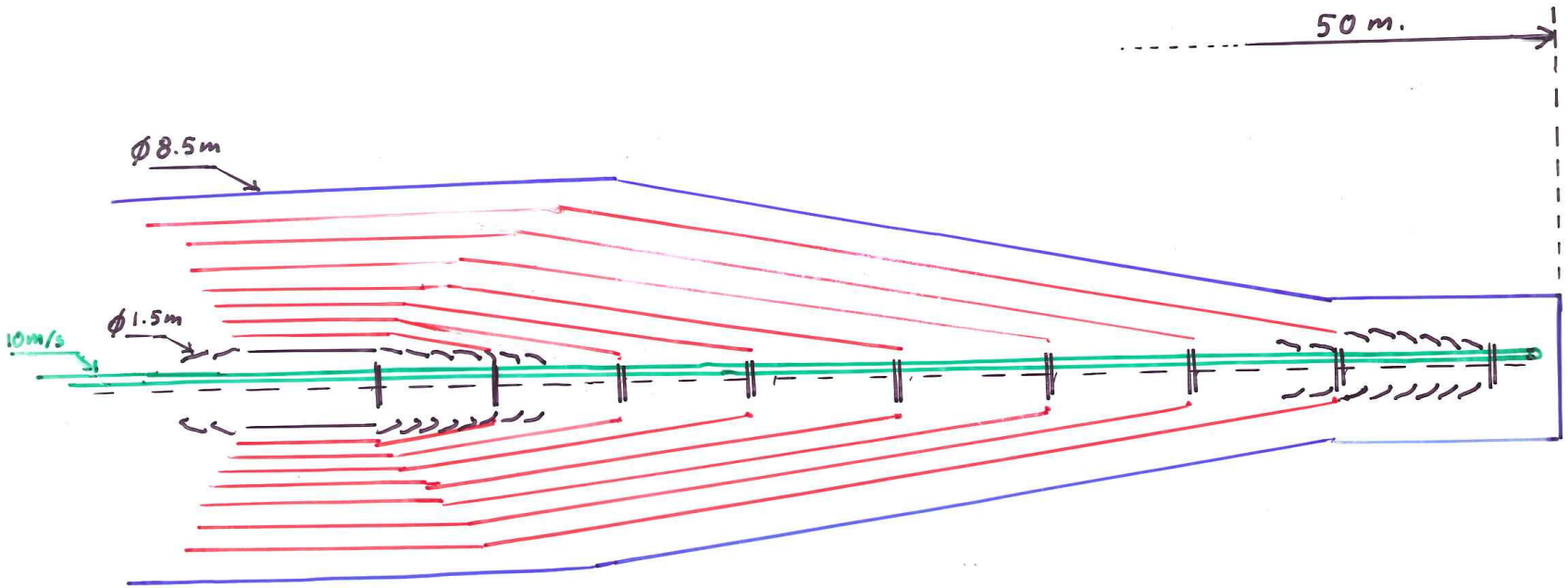
D.E. Conceptual idea.



Post Insulators

VIVITRON

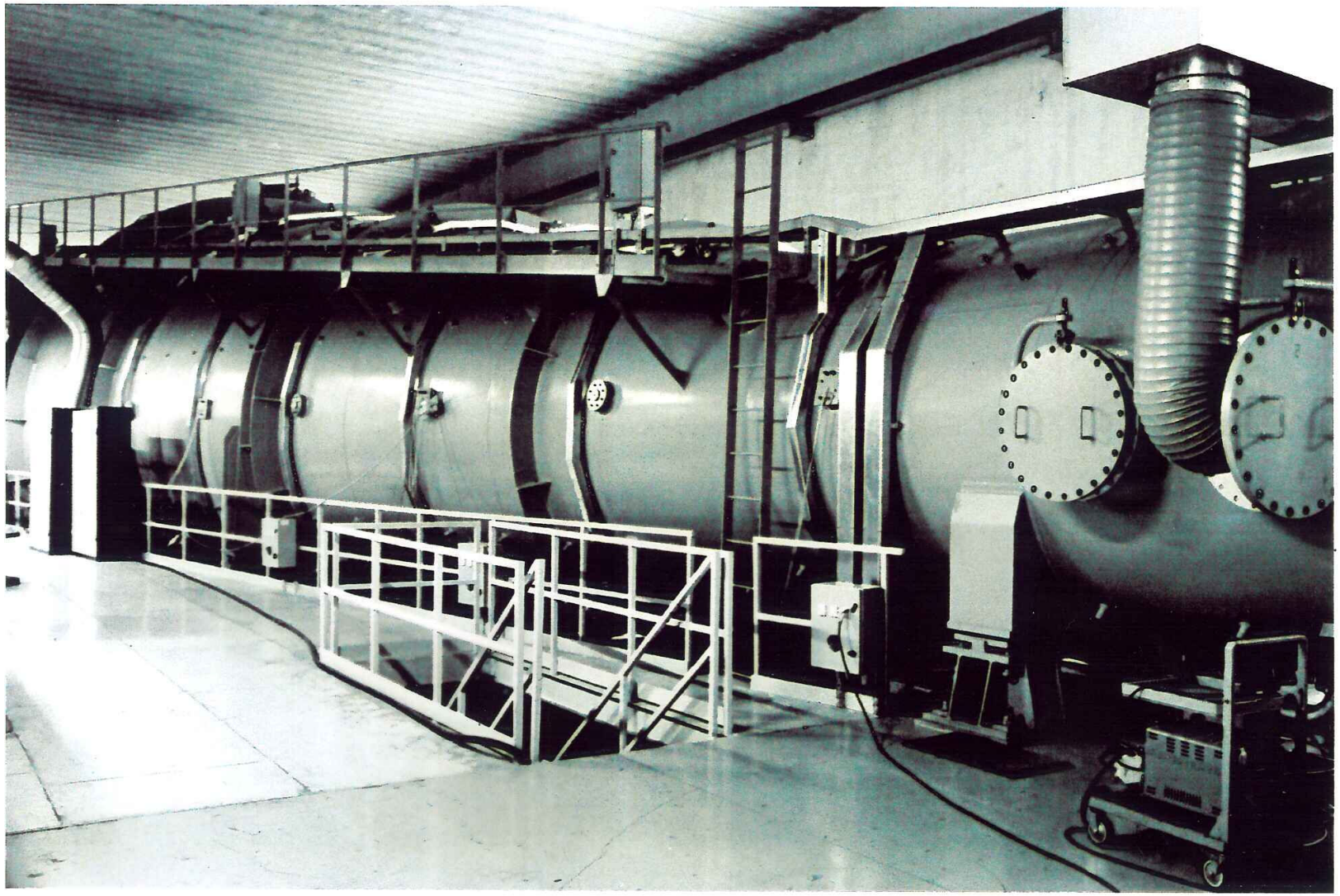
Design : 2 x MP



- 7 porticos of 7 Discrete Electrodes(DE)
- 2 x 8 Acc. tube sections - SS - 100 gaps
- Column Boards : glass fiber + Epoxy
- Conical Column Electrodes
- Post Insulators : 40 cm long

Present Terminal Voltage ~ 20M

Present limitation : Column Boare



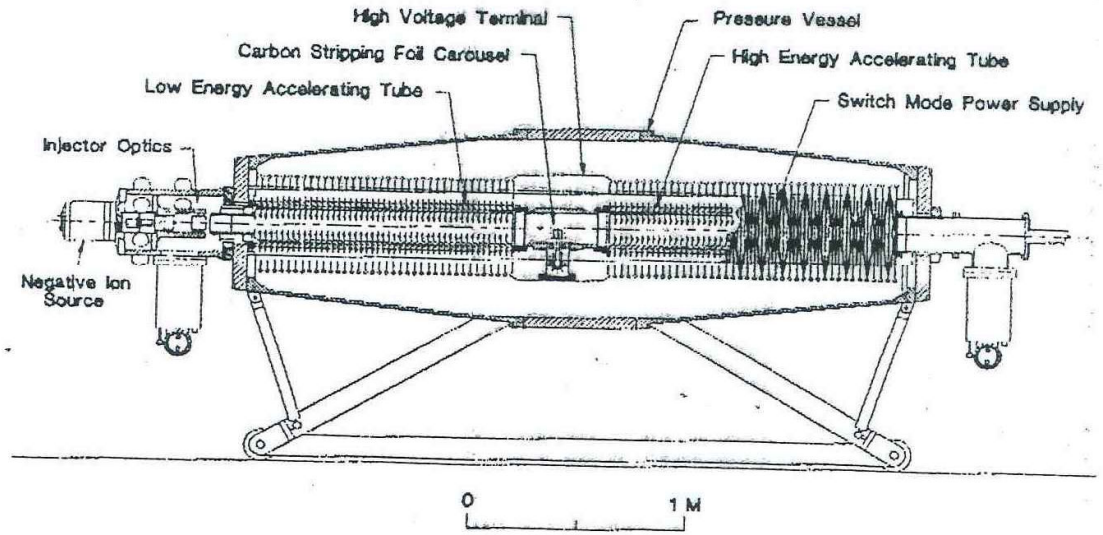


Figure 1: Schematic diagram of high-current tandem accelerator design.

FOM

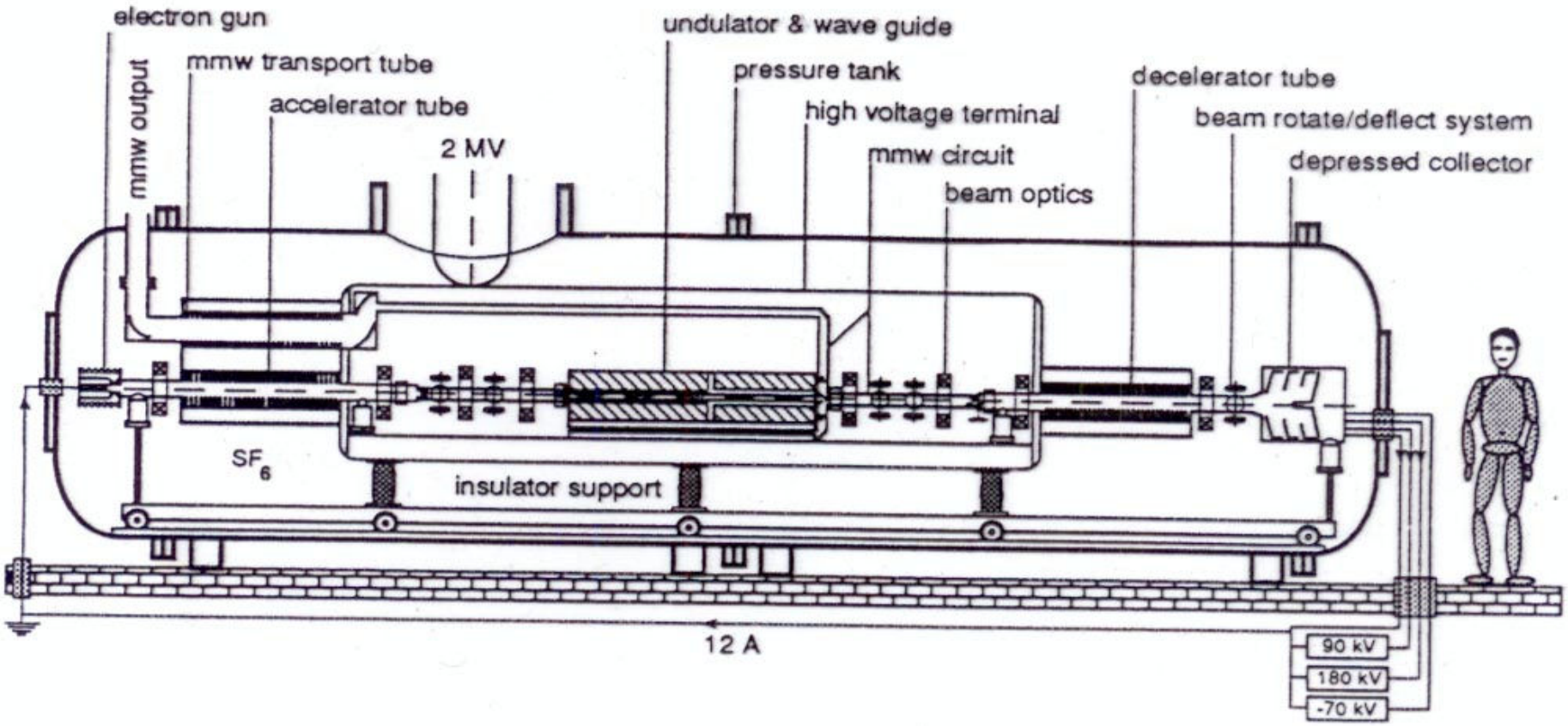
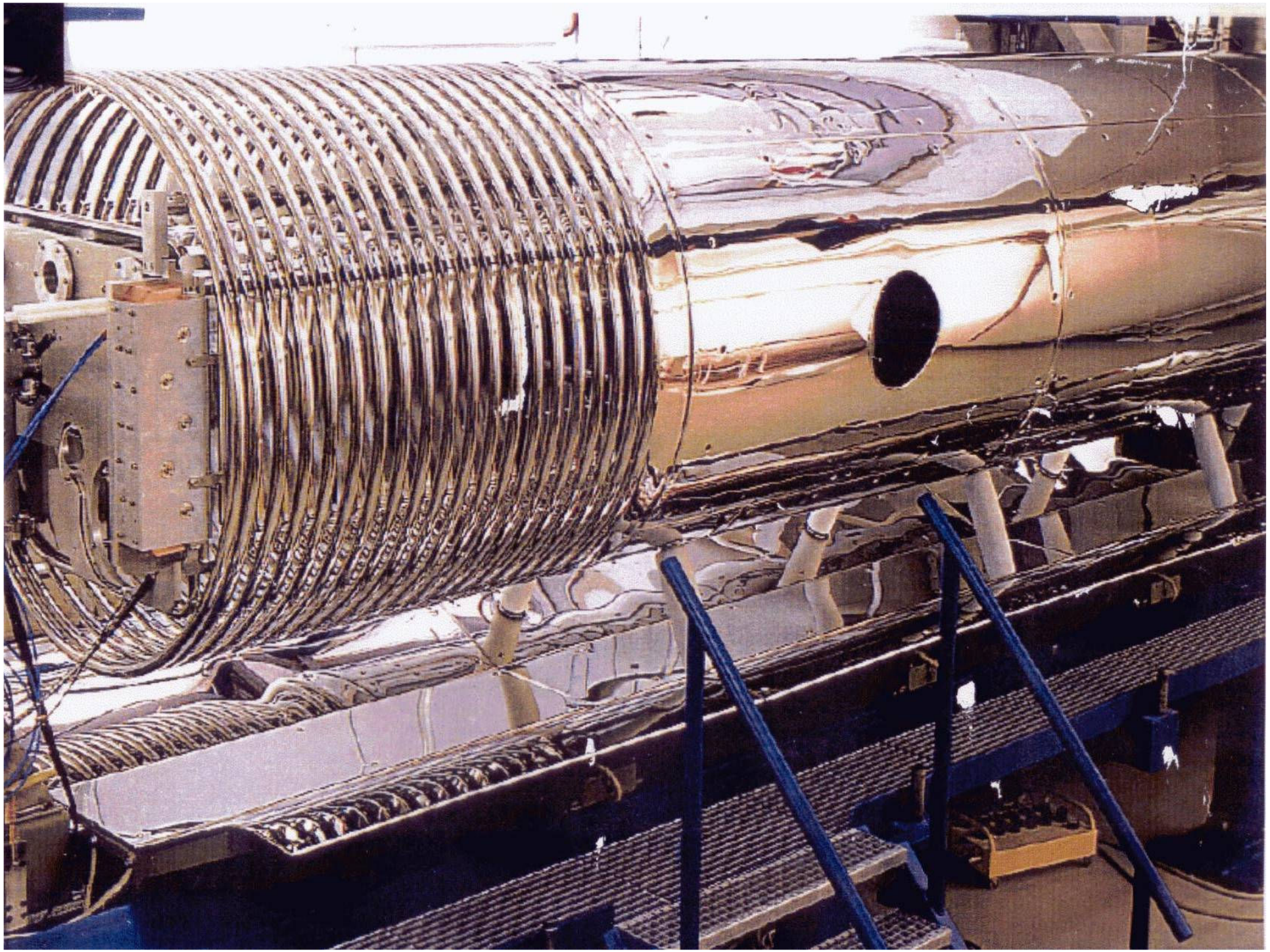


Figure 4.1. Schematic layout of the FEM. The pressure tank measures 10 m in length and 2.7 m in diameter. The mmw output is drawn at the top but will be at the bottom of the pressure tank in reality. The connector to the 2-MV power supply is drawn at the top but will be at the side in reality.



DESIGN OF THE FEM

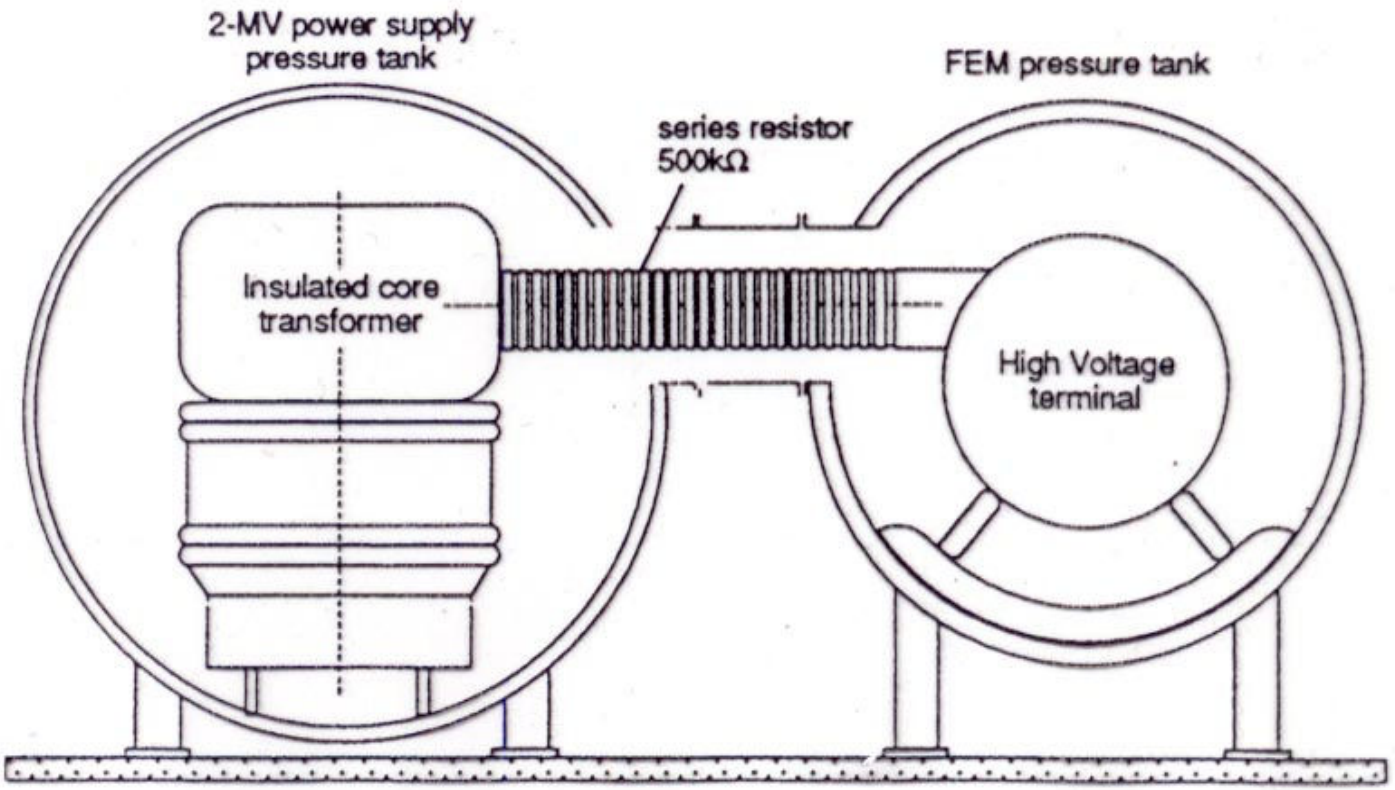
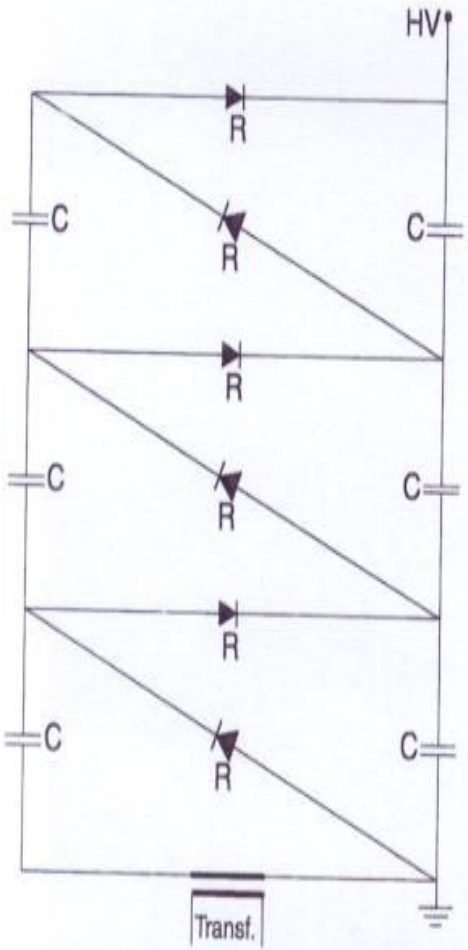
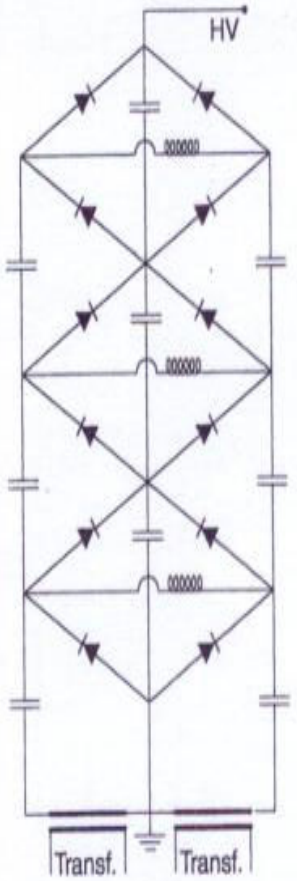


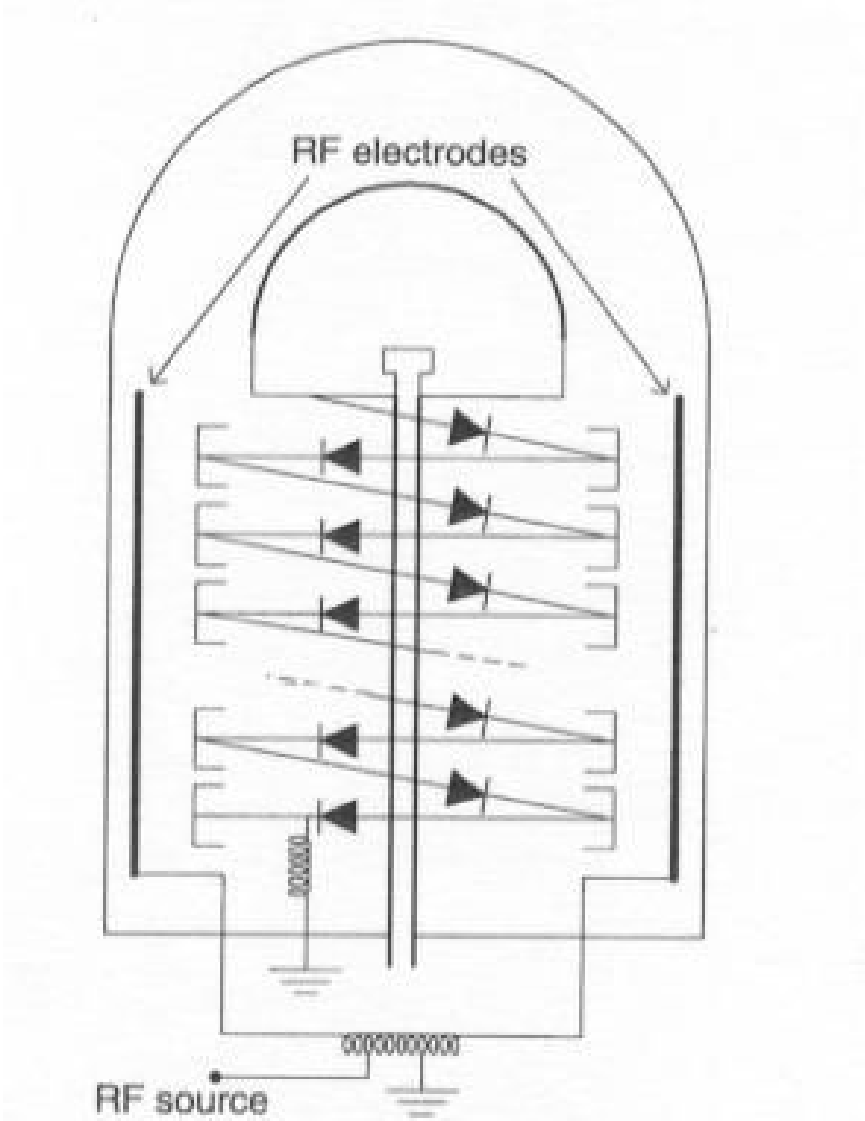
Figure 4.34. Schematic cross section of the FEM pressure vessel with the high voltage terminal and the 2-MV power supply.



Asymmetrical-circuit cascade generator consisting of capacitors C and rectifiers R

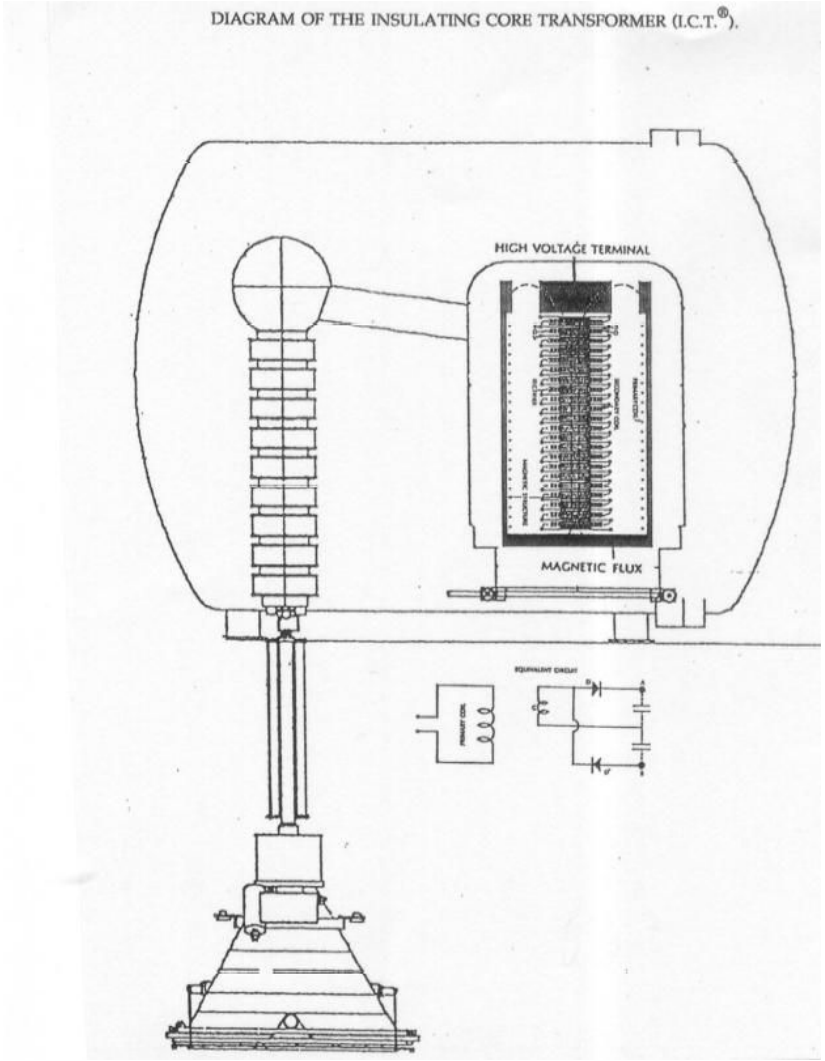


Symmetrical-circuit cascade generator

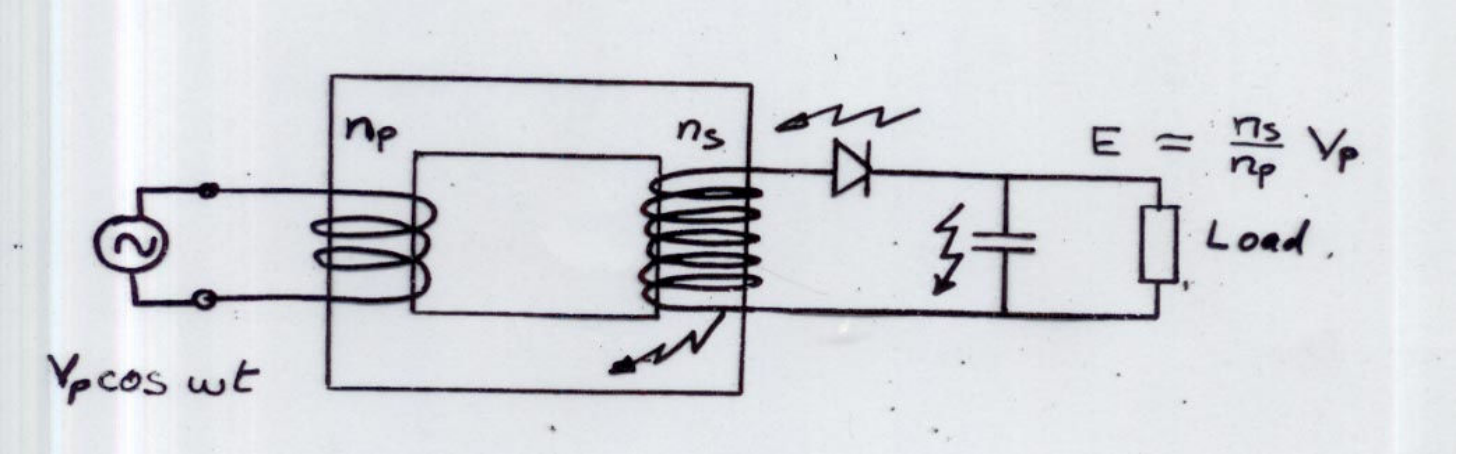


Parallel-driven circuit

Diagram of the Insulating Core Transformer (I.C.T.®)



TRANSFORMER – RECTIFIER
DC POWER SUPPLY



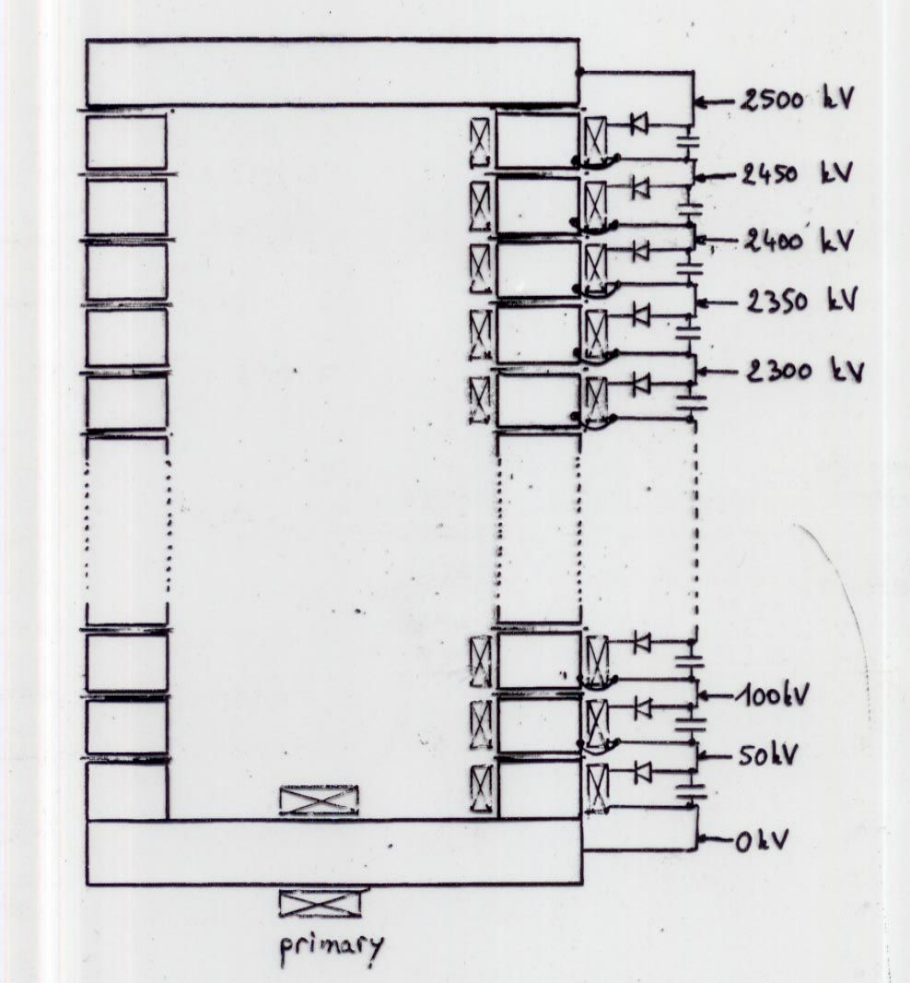
High efficiency

High power

Limited to low voltage (a few 100kw)

- secondary coil insulation
- components voltage limit

PRINCIPE OF ICT
(Insulated Core Transformer)

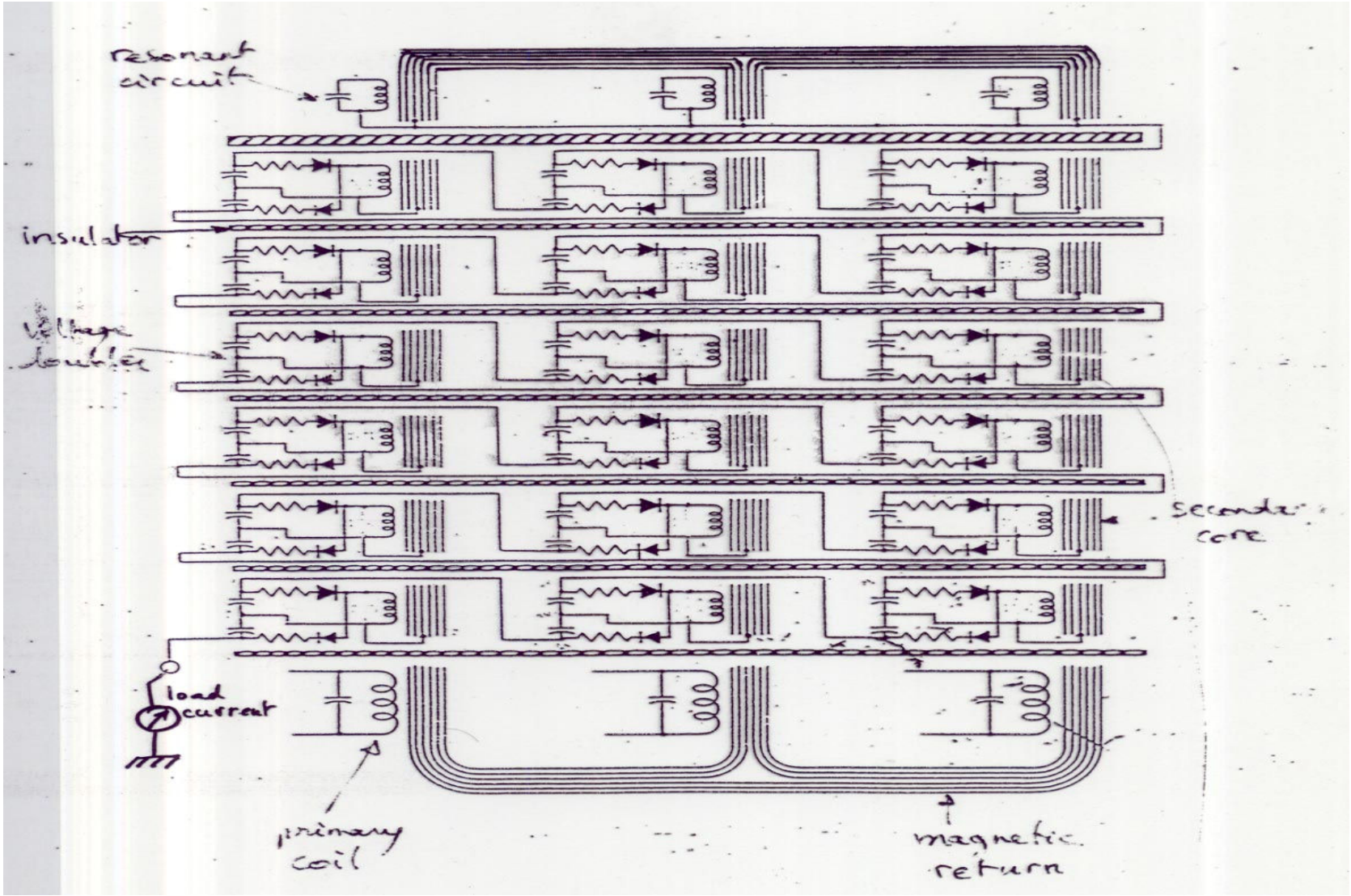


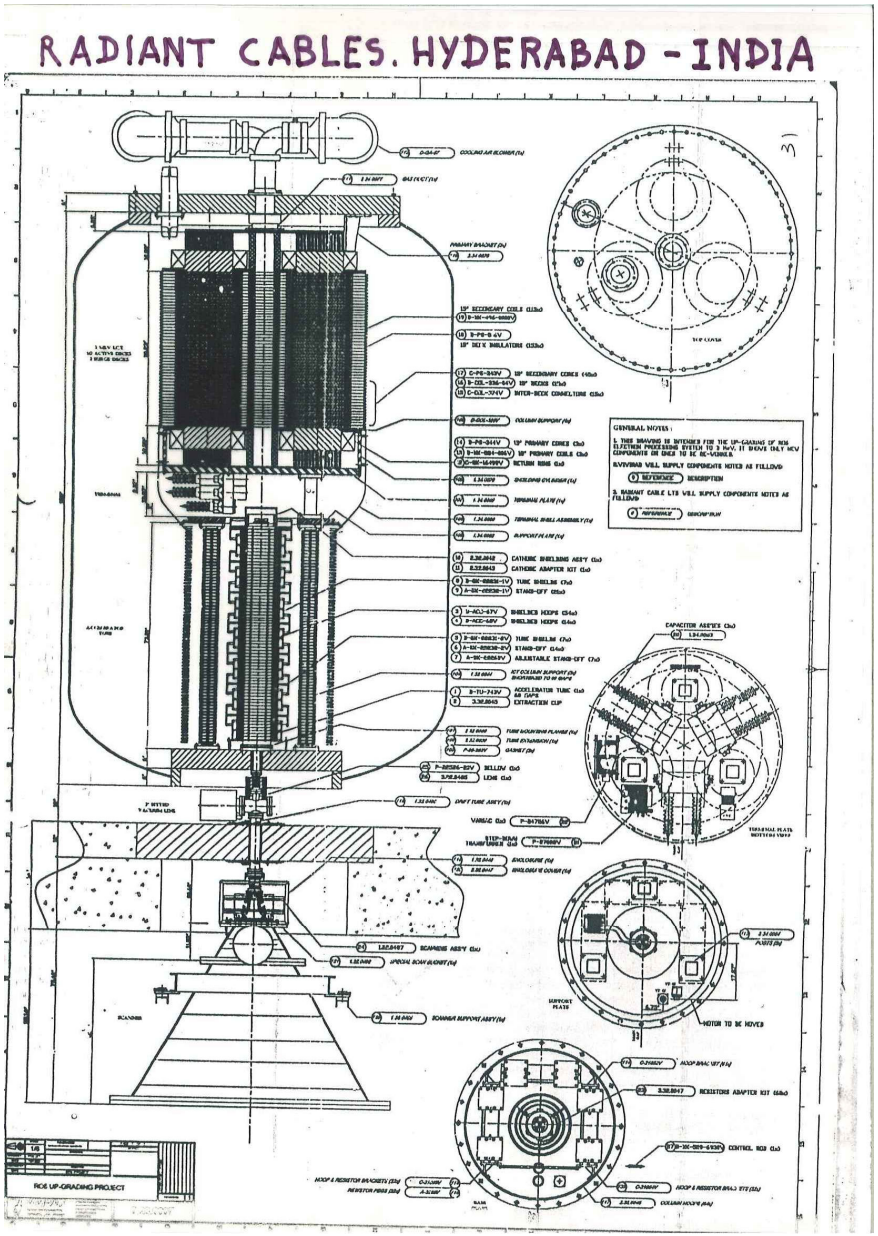
secondary core

insulator

secondary coil

3 PHASE ICT PRINCIPLE SCHEMATIC




RADIANT CABLES. HYDERABAD - INDIA
GENERAL NOTES :
1. THIS DRAWING IS INTENDED FOR THE UP-GRADING OF M/S ELECTRON PROCESSING SYSTEM TO 3 MeV. IT SHOWS ONLY M/V COMPONENTS OR ONES TO BE RE-VARIED.
2.VIVIRAD WILL SUPPLY COMPONENTS NOTED AS FILLED/B
REFERENCE
DESCRIPTION
3. RADIANT CABLE LTD WILL SUPPLY COMPONENTS NOTED AS FILLED/B
REFERENCE
DESCRIPTION
CAPACITOR ASSY'S (3a)
MOTOR TO BE MOVED
RCE UP-GRADING PROJECT

Applications industrielles des faisceaux d'électrons

INDUSTRIES	*PROCEDES*	*PRODUITS*
Chimie Pétrochimie	Réticulation - Dépolymérisation Greffage - Polymérisation	Polyéthylène, polypropylène, copolymères, Lubrifiants, alcool
Revêtements Adhésifs	Vulcanisation Greffage Polymérisation	Bandes adhésives, produits en papier couché, Panneaux en placqué, barrières thermiques, Composites bois-plastique et verre-plastique
Electricité	Réticulation Mémoire thermique Modification semi-conducteurs	Constructions, instruments, fils de téléphone Câbles de puissance, rubans isolants, épissures des câbles blindés, diodes Zener, IC, SCR, IGBT, ...
Alimentation	Désinfection - Pasteurisation Conservation - Stérilisation	Aliments pour animaux, grains, céréales, farine Légumes, fruits, volailles, viandes, poissons, Crustacés
Santé Pharmacie	Stérilisation Modification de polymères	Matériel à usage unique, poudres et onguents Médicaments, membranes
Plastiques Polymères	Réticulation Fabrication de mousses Mémoire thermique	Emballages alimentaires rétractables, appareils de gymnastique, tuyaux et gaines, emballages moulés Emballages flexibles en laminés
Environnement	Désinfection - Précipitation Détoxification organique Inhibition de fermentation DeSOx/DeNOx	Boues résiduaires pour l'épandage, émission de fumées, gaz, solvants, eaux et effluents divers, substances nutritives issues de boues ou de déchets
Pâte à papier Textiles	Dépolymérisation Greffage	Rayonne, calandrages sur textiles, traitement anti- tache, flocages et impressions
Caoutchouc	Vulcanisation, résistance accrue Vulcanisation contrôlée	Pneus, séparateurs de batterie Membranes d'étanchéité, joints

ELECTRON BEAM APPLICATIONS

	Usable Voltage Ranges				
	0.1 to 0.3 MV	0.3 to 0.8 MV	0.8 to 3 MV	3 to 5 MV	5 to 15 MeV
Wire and Cable					
Insulated Wire	*	*	*		
Multiconductor Cable			*	*	
Plastic Products					
Food Wrapping	*	*			
Electrical Tubing		*	*		
Shrinkable Tapes	*	*	*		
Molded Encapsulations			*	*	*
Irrigation tubing		*	*		
Plastic Foam		*	*		
Molded Gaskets			*		
Water Pipe			*	*	

ELECTRON BEAM APPLICATIONS

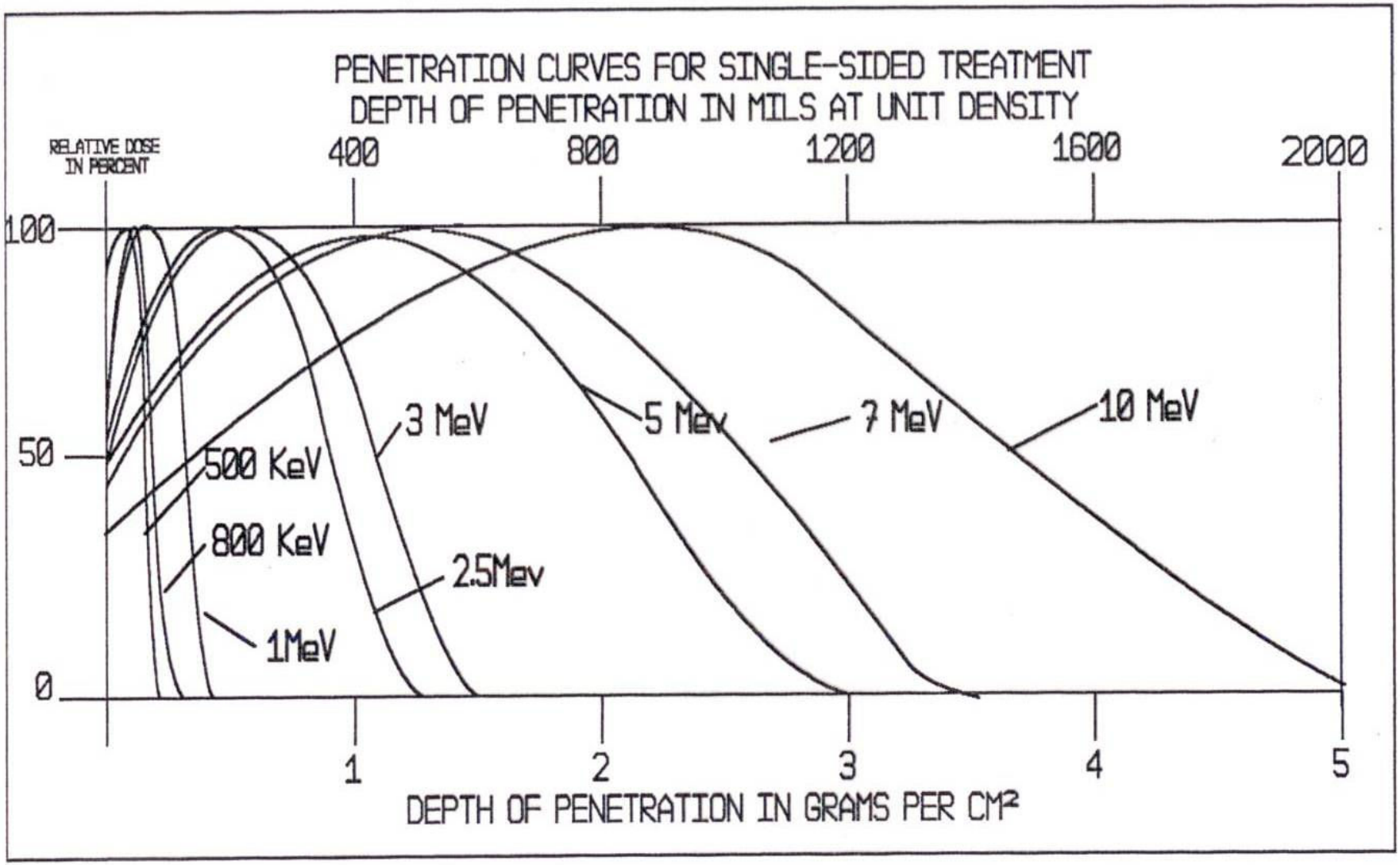
Solvent-Free Coatings	Usable Voltage Ranges				
	0.1 to 0.3 MV	0.3 to 0.8 MV	0.8 to 3 MV	3 to 5 MV	5 to 15 MeV
Metal Finishing	*				
Wood Finishing	*				
Textile Finishing	*	*			
Printable Surfaces	*				
Magnetic Tapes	*	*			
Adhesive Tapes	*				
Perselective Films	*	*			
Metalized Films	*	*			

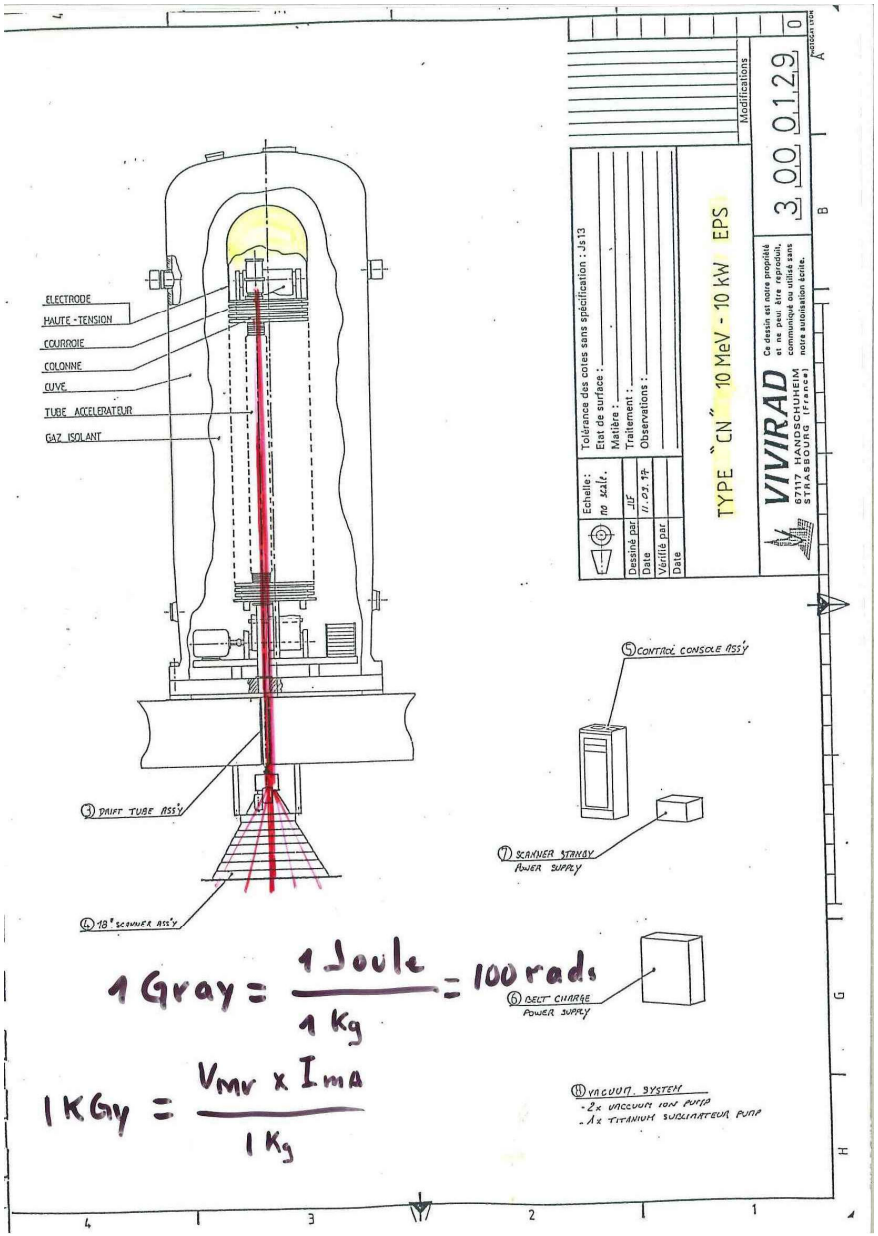
ELECTRON BEAM APPLICATIONS

Rubber Products	Usable Voltage Ranges 0.1 to 0.3 MV	0.3 to 0.8 MV	0.8 to 3 MV	3 to 5 MV	5 to 15 MeV
Automobile Tires		*	*	*	
Roofing Sheet		*	*		
Elastic Bands		*	*		
Conveyor Belts			*	*	
Industrial Hose			*	*	
P· ile Gaskets		*	*		
Rubberized Fabrics	*	*			
Weatherstripping			*	*	
Latex Products	*	*			

ELECTRON BEAM APPLICATIONS

Bulk Chemicals	Usable Voltage Ranges				
	0.1 to 0.3 MV	0.3 to 0.8 MV	0.8 to 3 MV	3 to 5 MV	5 to 15 MeV
Polyethylene Crosslinking		*	*	*	
Polypropylene Scission		*	*	*	
Teflon Degradation		*	*	*	
Rayon Pulp Aging	*	*	*		
Cellulose Hydrolysis		*	*	*	
Butyl Rubber Degradation		*	*	*	
Crude Oil Cracking		*	*		
High-Purity Polymers		*	*		
Reinforced Plastics	*	*	*	*	
Impregnated Wood		*	*	*	


PENETRATION CURVES FOR SINGLE-SIDED TREATMENT
DEPTH OF PENETRATION IN MILS AT UNIT DENSITY
RELATIVE DOSE IN PERCENT
400
800
1200
1600
2000
100
50
0
500 KeV
800 KeV
1MeV
3 MeV
2.5Mev
5 Mev
7 MeV
10 MeV
1
2
3
4
5
DEPTH OF PENETRATION IN GRAMS PER CM²


ELECTRODE
HAUTE - TENSION
COURROIE
COLONNE
CUVE
TUBE ACCELERATEUR
GAZ ISOLANT
3 DRIFT TUBE ASS'Y
4 18° SCANNER ASS'Y
5 CONTROL CONSOLE ASS'Y
7 SCANNER STANDY POWER SUPPLY
6 BEAM CHARGE POWER SUPPLY
10 VACUUM SYSTEM
- 2x VACCUUM ION PUMP
- 1x TITANIUM SUBLIMATEUR PUMP
1 Gray = 1 Joule / 1 Kg = 100 rads
1 KGy = Vmr x Ima / 1 Kg
Modifications
Tolérance des cotes sans spécification : Js13
Etat de surface :
Matière :
Traitement :
Observations :
Echelle : no scale.
Dessiné par JDF
Date 11.02.98
Vérifié par
Date
TYPE "CN" 10 MeV - 10 kW EPS
VIVIRAD
67117 HANDSCHUHEIM
STRASBOURG (France)
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3 00 0129
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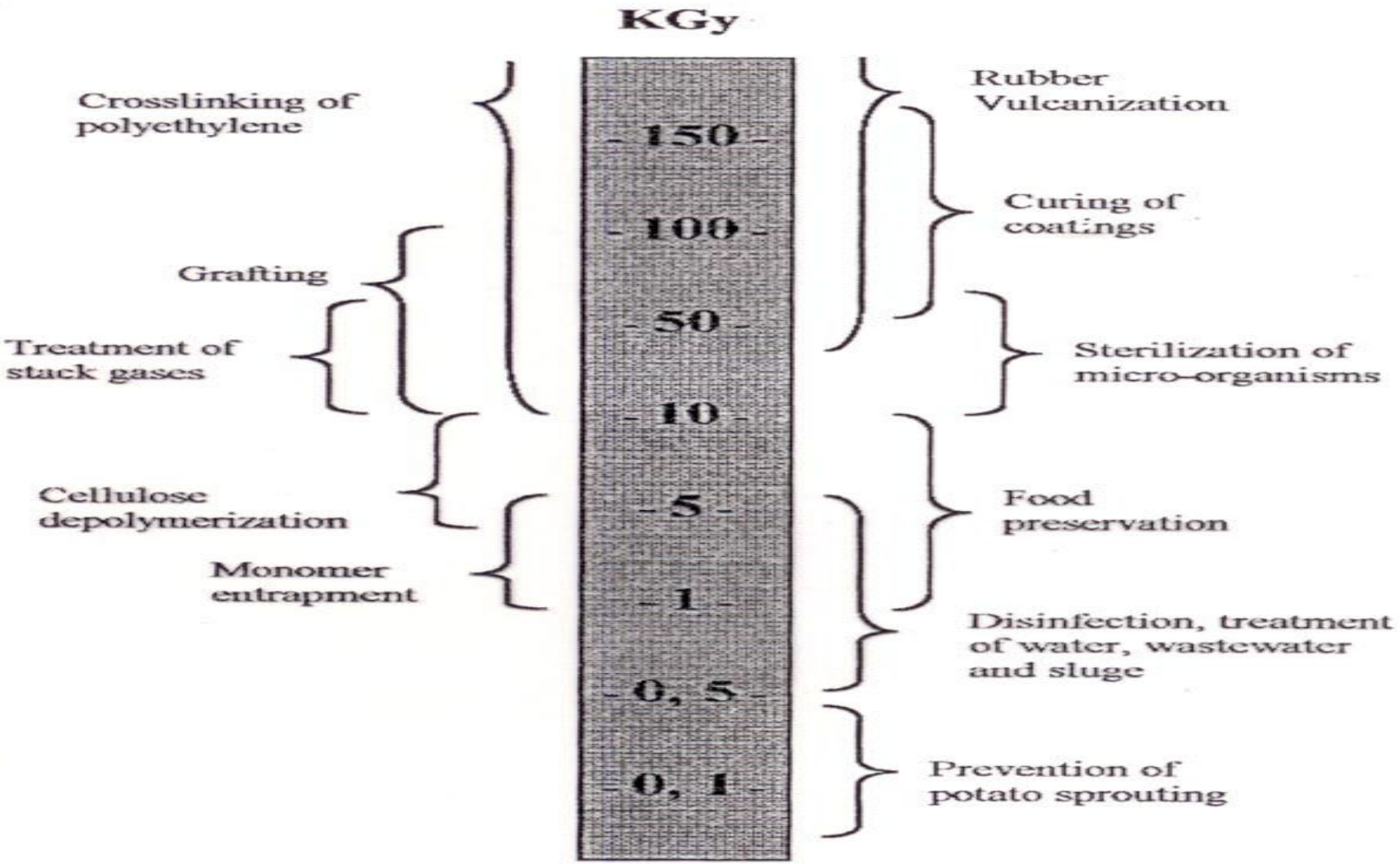
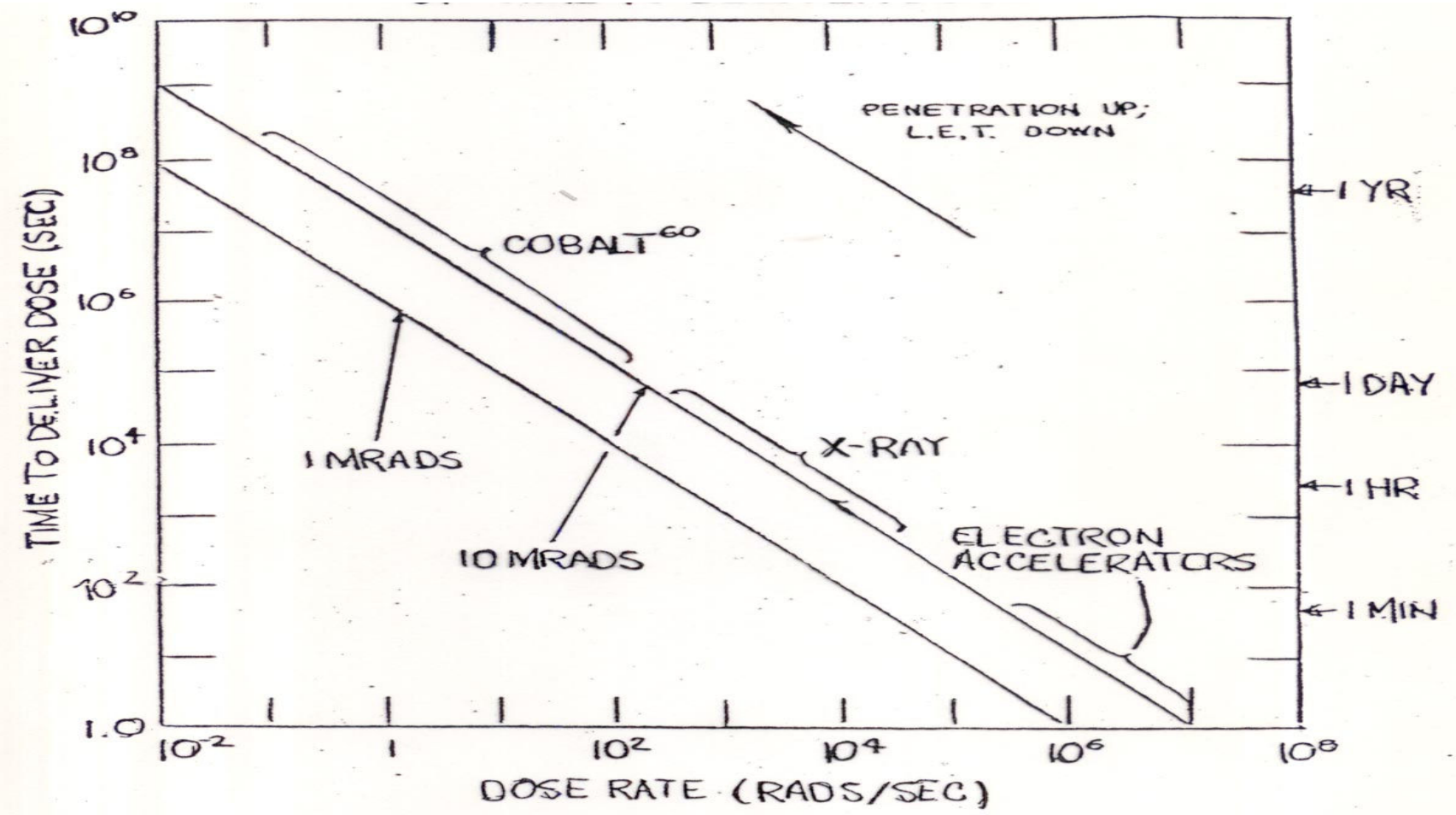
DOSE RANGES FOR VARIOUS APPLICATIONS



EFFECT OF DOSE RATE ON TIME TO DELIVER DOSE



ELECTRON PROCESSING SYSTEMS
VIVIRAD SA RANGE as of 01/01/2005

I.C.T. (Insulated Core Transformer)

CABLE CONNECTED ARRANGEMENT
500 keV to 800 keV

Energy	Beam Current
500 keV	25 mA
500 keV	50 mA
500 keV	100 mA / 2 x 50 mA
750 keV	25 mA
750 keV	100 mA / 2 x 50 mA
800 keV	25 mA
800 keV	100 mA / 2 x 50 mA

X-RAY GENERATOR
Conversion of 5 MV electrons

5 MeV – 80 mA, direct electrons & X-ray emission simultaneously available in separated vaults.
X-Ray treatment capacity : 3 MCi Co^{60} equivalent

INTEGRAL TANK
650 keV to 5 MeV

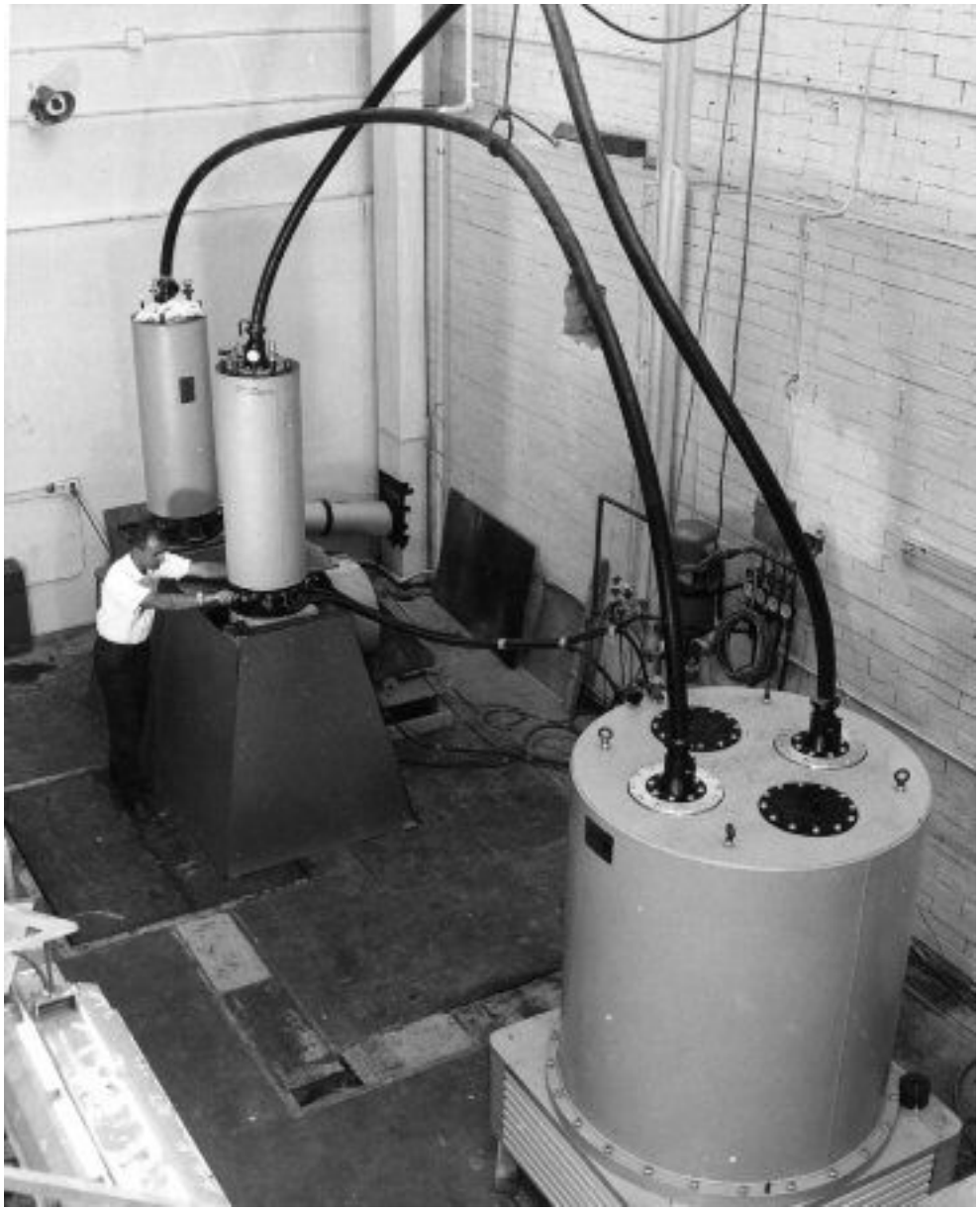
Energy	Beam Current
650 keV	50 mA
800 keV	25 mA
800 keV	50 mA
800 keV	100 mA / 2 x 50 mA
1 MeV	100 mA / 2 x 50 mA
1,5 MeV	65 mA
1,5 MeV	100 mA / 2 x 50 mA
2 MeV	50 mA
2 MeV	100 mA / 2 x 50 mA
2,5 MeV	40 mA
2,5 MeV	80 mA / 2 x 40 mA
3 MeV	35 mA
3 MeV	70 mA / 2 x 35 mA
5 MeV	100 mA / 2 x 50 mA

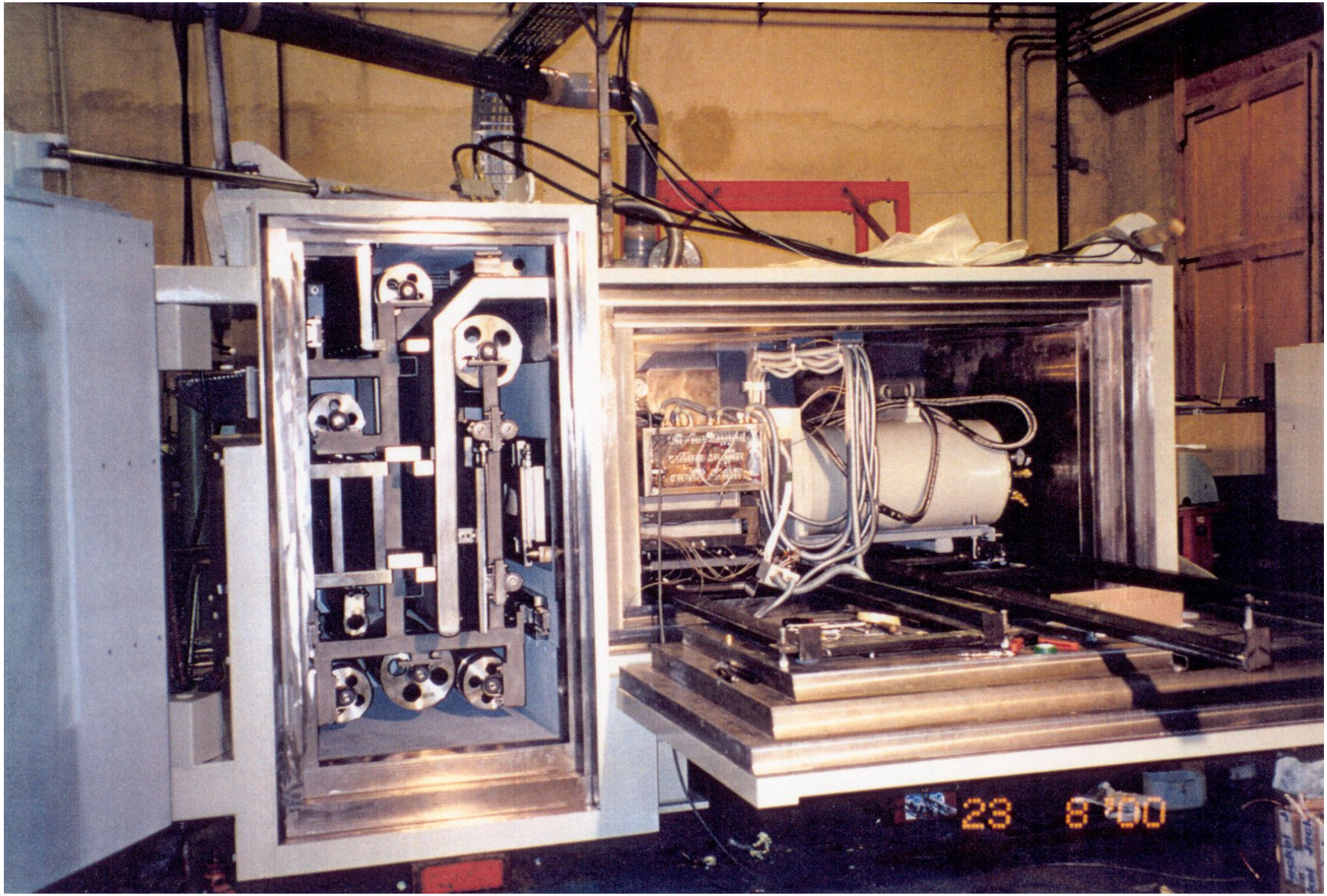
SELF-SHIELDED SYSTEMS

Energy	Beam Current	Energy	Beam Current
550 keV	60 mA	650 keV	50 mA / 2 x 25 mA
600 keV	50 mA / 2 x 25 mA	750 keV	100 mA / 2 x 50 mA

All VIVIRAD accelerators are adjustable in voltage and in current. They can be delivered with all peripheral equipments to meet the application. Scanner sizes are available from 24" to 144" (60 cm to 365 cm).

Positive or negative D.C. High Voltage Power Supplies and Isolating Power Transformers with characteristics similar to the Electron Beam Equipment are available.

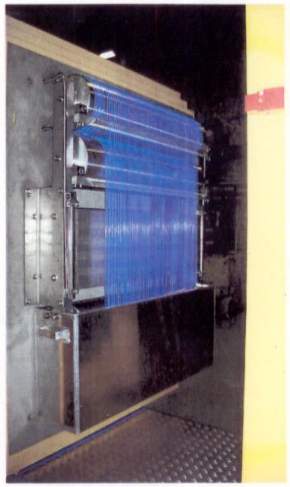



23 8 00

IN-LINE AUTOMOTIVE WIRE SELF-SHIELDED ELECTRON BEAM CROSSLINKING UNIT

SELF-SHIELDED CONVENTIONAL IN-LINE CROSSLINKING OF SMALL Ø WIRES AND JACKETS

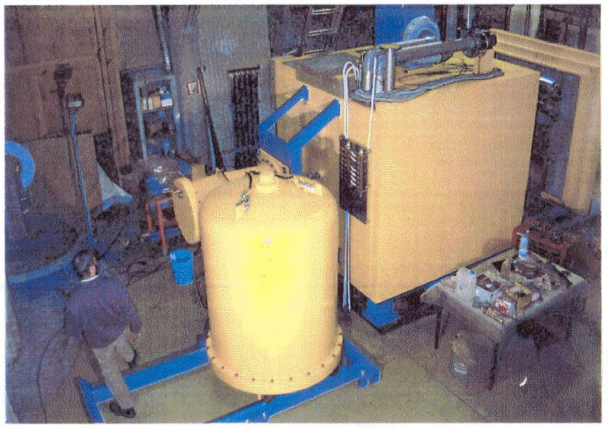
650 keV – 50 mA in-line crosslinking unit



Water cooled under beam handling system

VIVIRAD

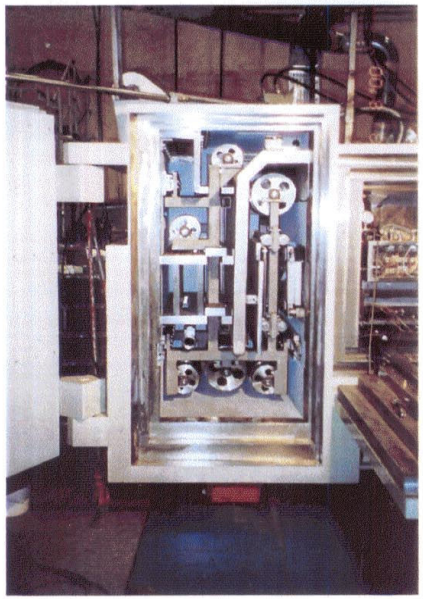
SELF-SHIELDED CONVENTIONAL IN-LINE CROSSLINKING OF SMALL Ø WIRES AND JACKETS



650 keV – 50 mA in-line crosslinking unit

Water cooled under beam handling system

Self-shielded units for crosslinking of wires
From 0,22 mm² to 12 mm²
Processing speed up to 1000 m/min.



550 keV – 50 mA in-line self-shielded crosslinking unit

- > Turn-key solutions up to 800 keV
- > Low space requirement (20 to 30 m²)
- > Water cooled beam processing
- > Multi-line capability from one system
- > Customized systems upon processing requirements
- > Fully automated controls, enslaved to the master process
- > Stainless steel and graphite UBHS
- > Operation and maintenance friendly
- >"Public Zone"radiation protection design
- > CE - ISO or US standards

For more information, please contact us :

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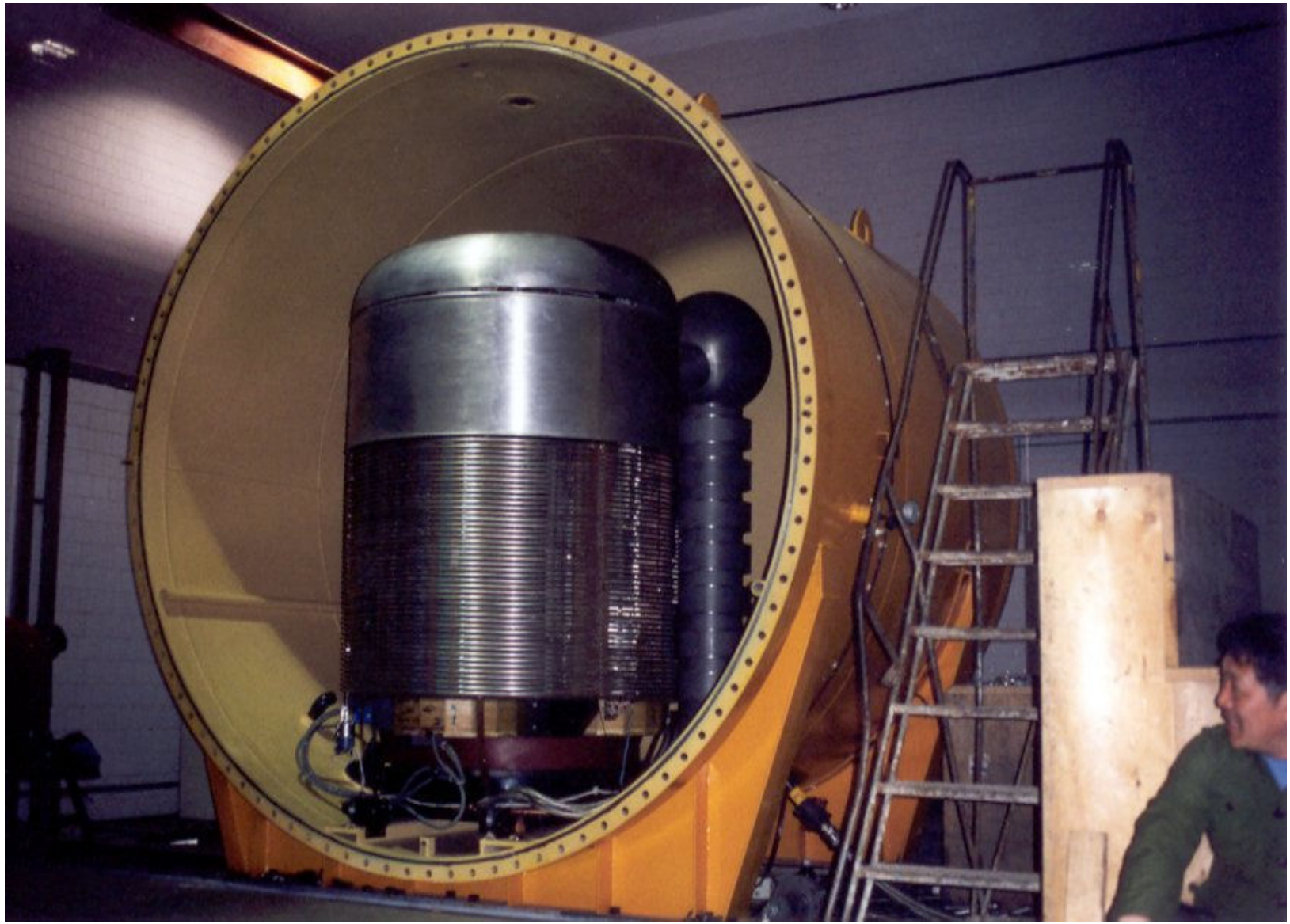
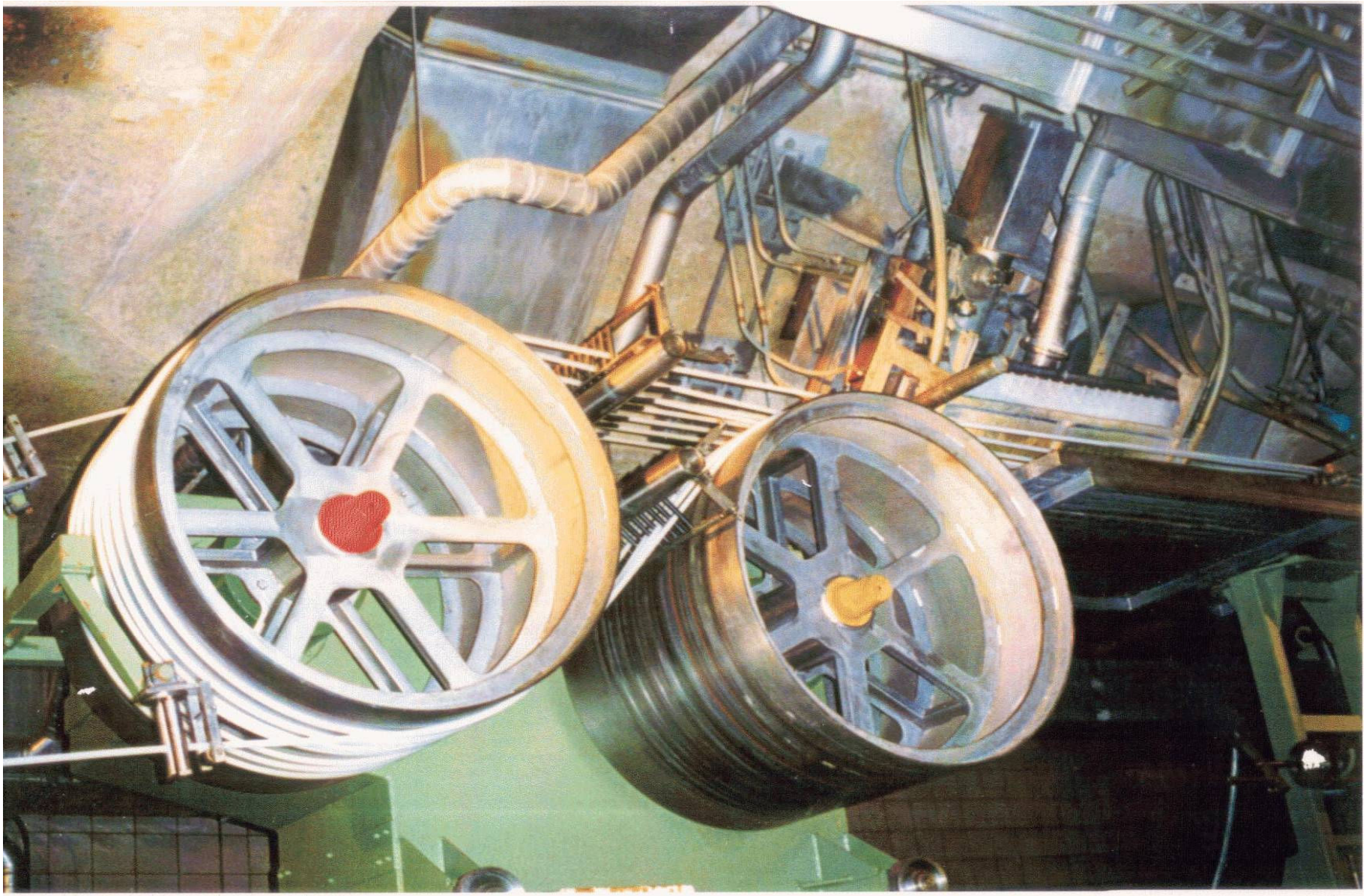
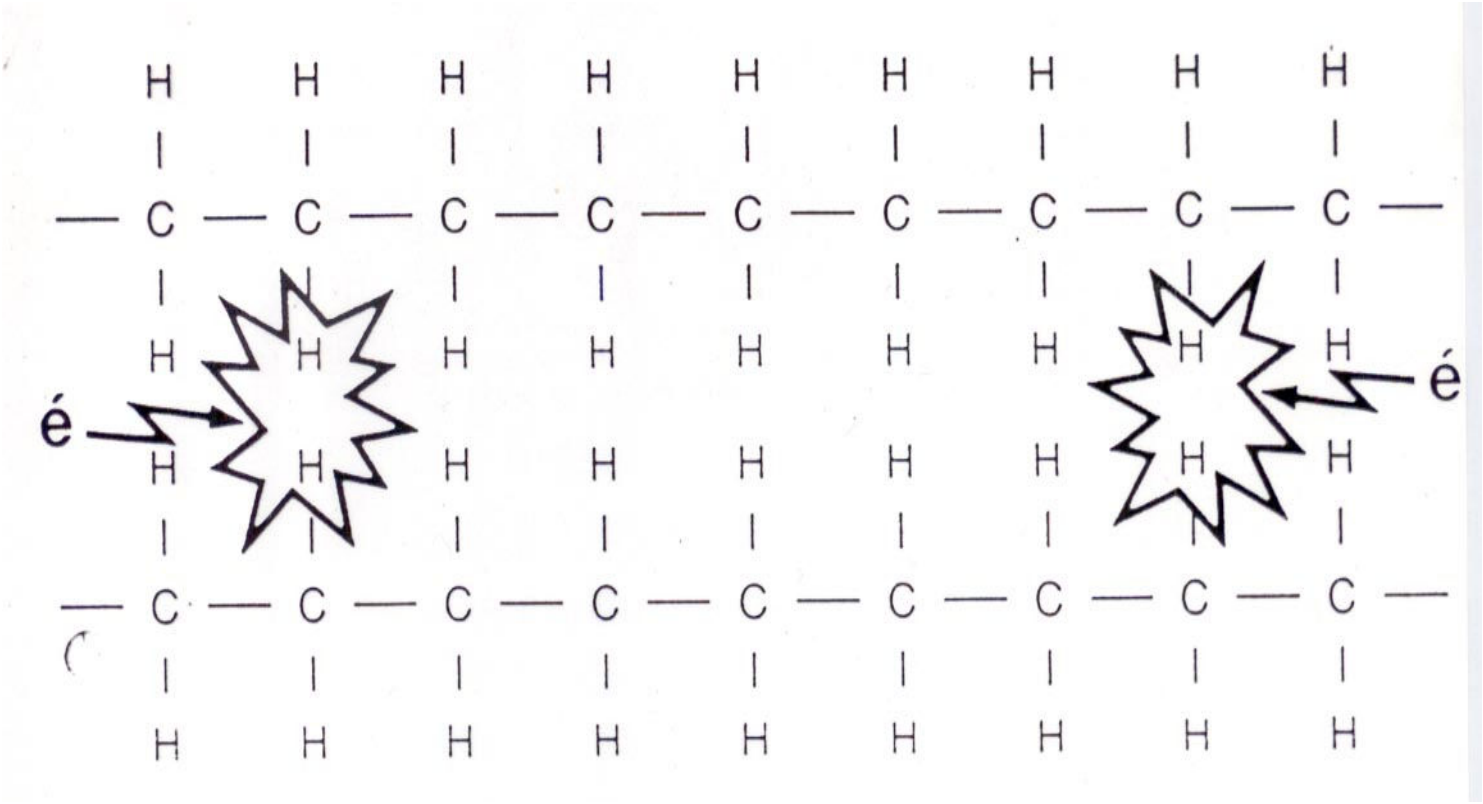
23, rue Principale
F-67117 Handschuheim - France
Tel : +33 3 88 69 13 25
Fax : +33 3 88 69 16 18
e-mail : vivirad@aol.com
web site : www.vivirad.com

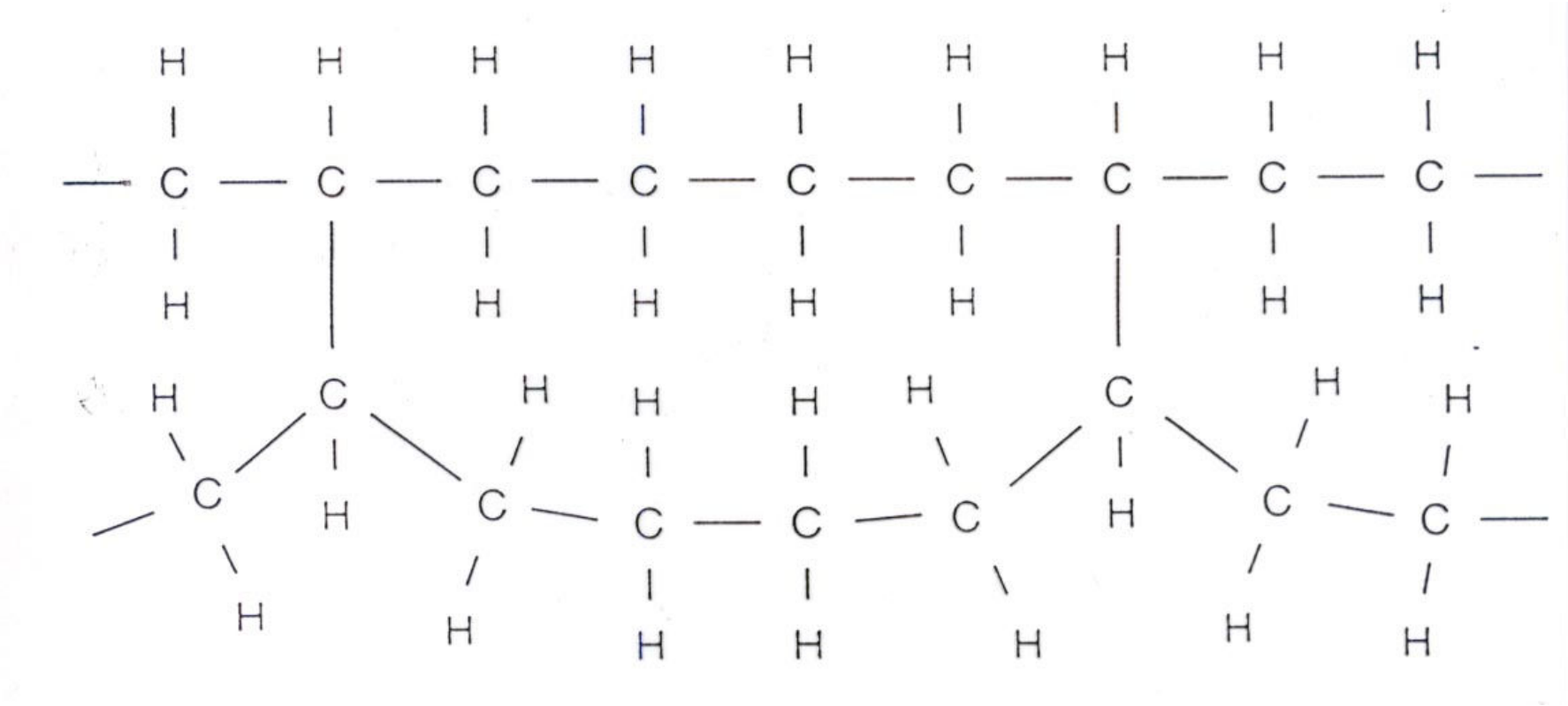




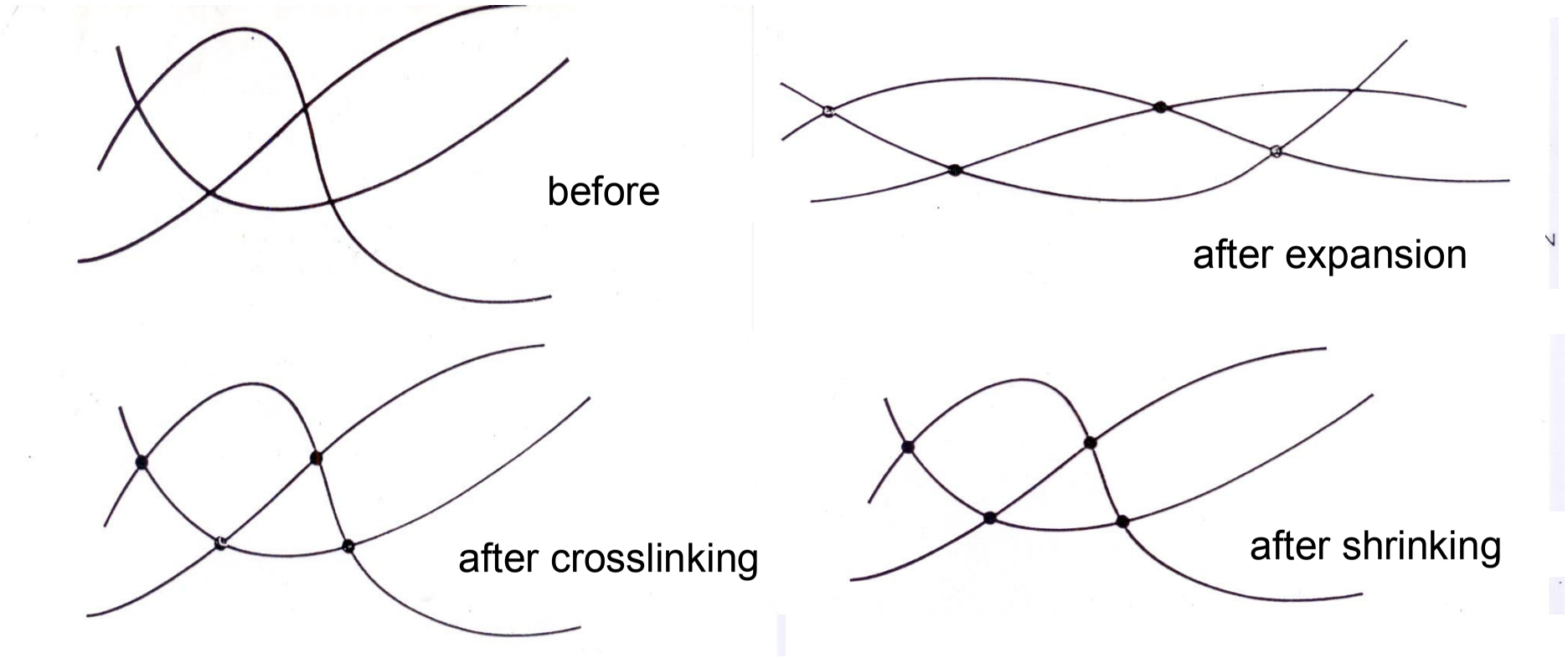
CROSSLINKING

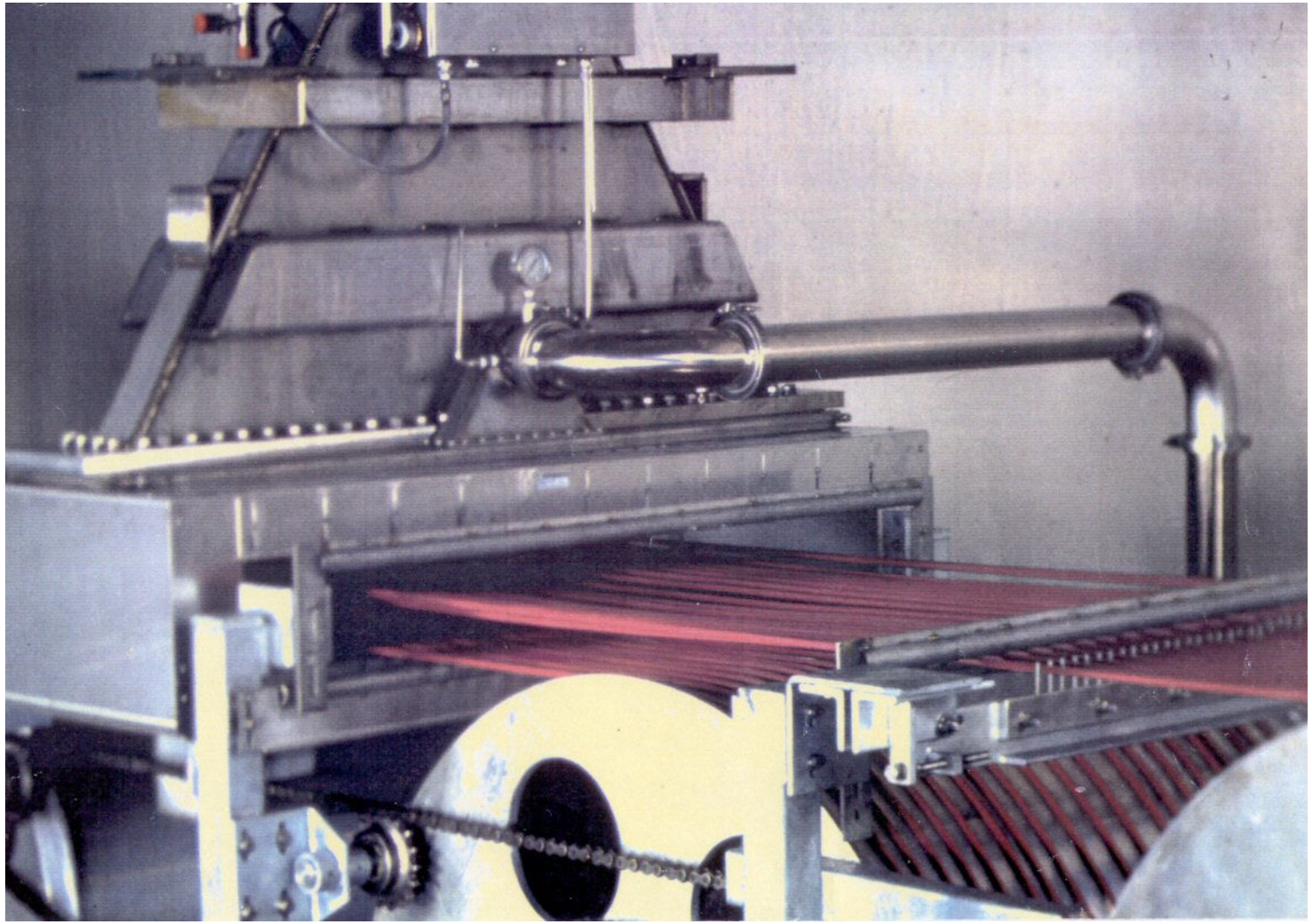


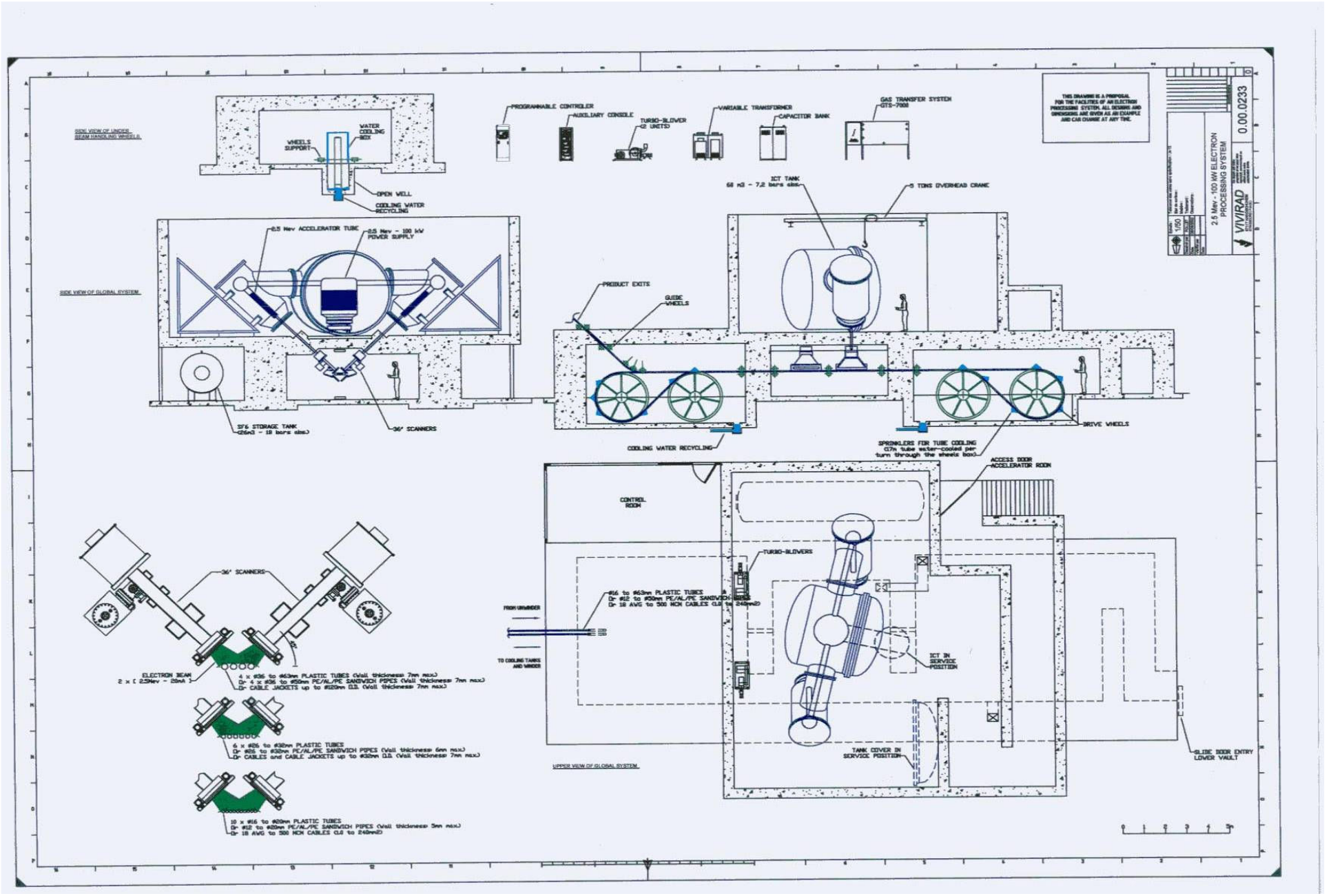
CROSSLINKING

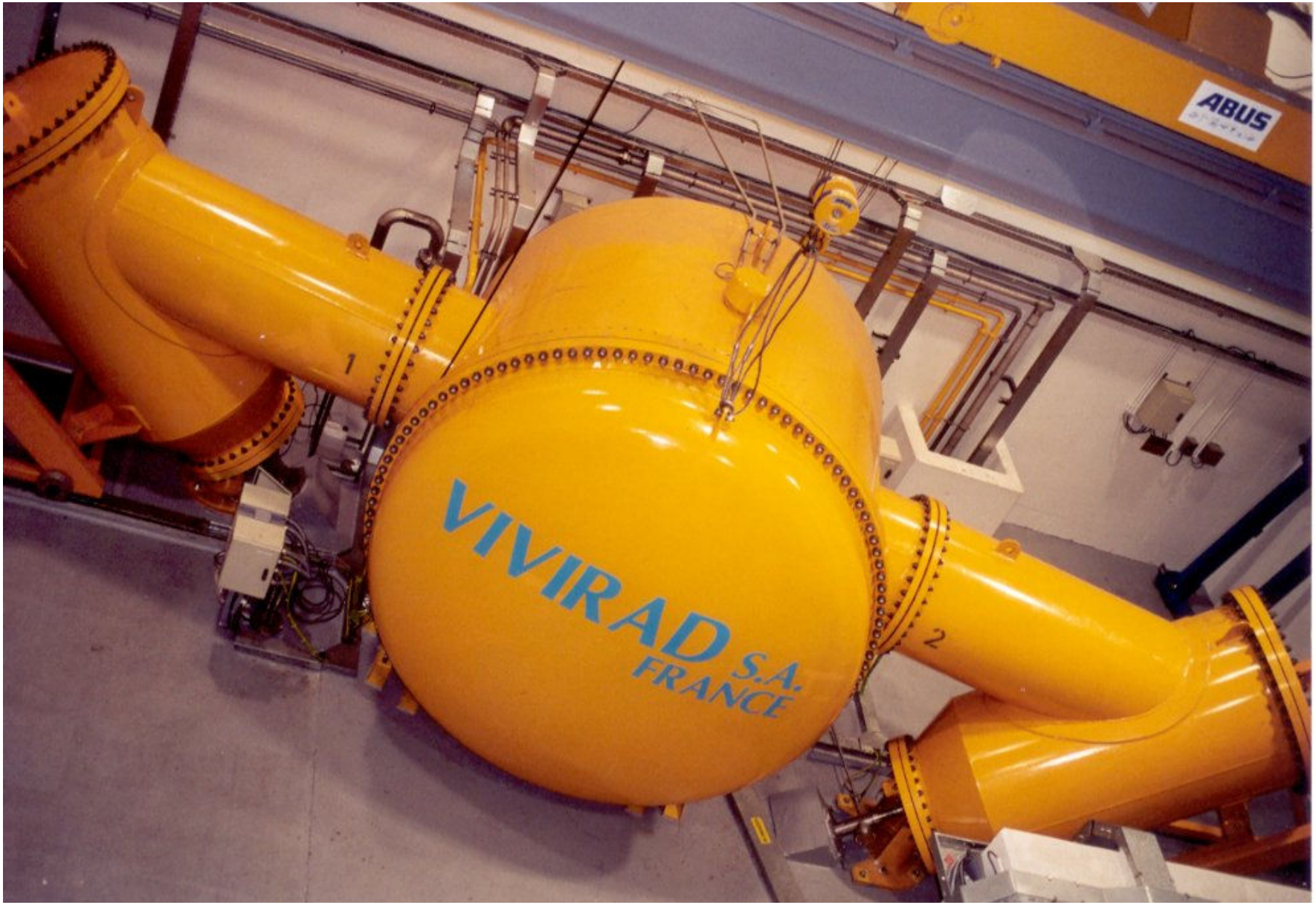


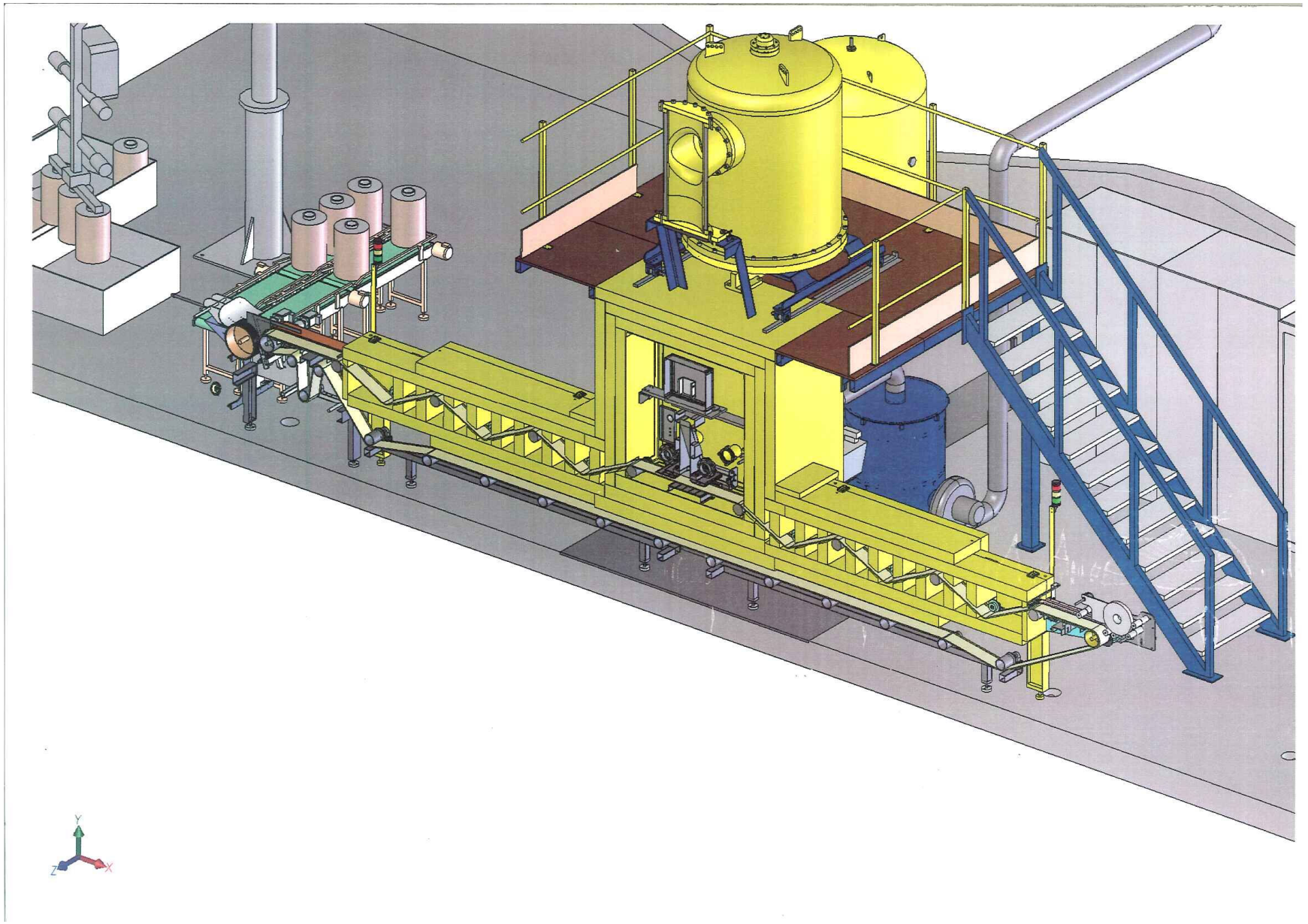
HEATSHRINKABLE MATERIAL

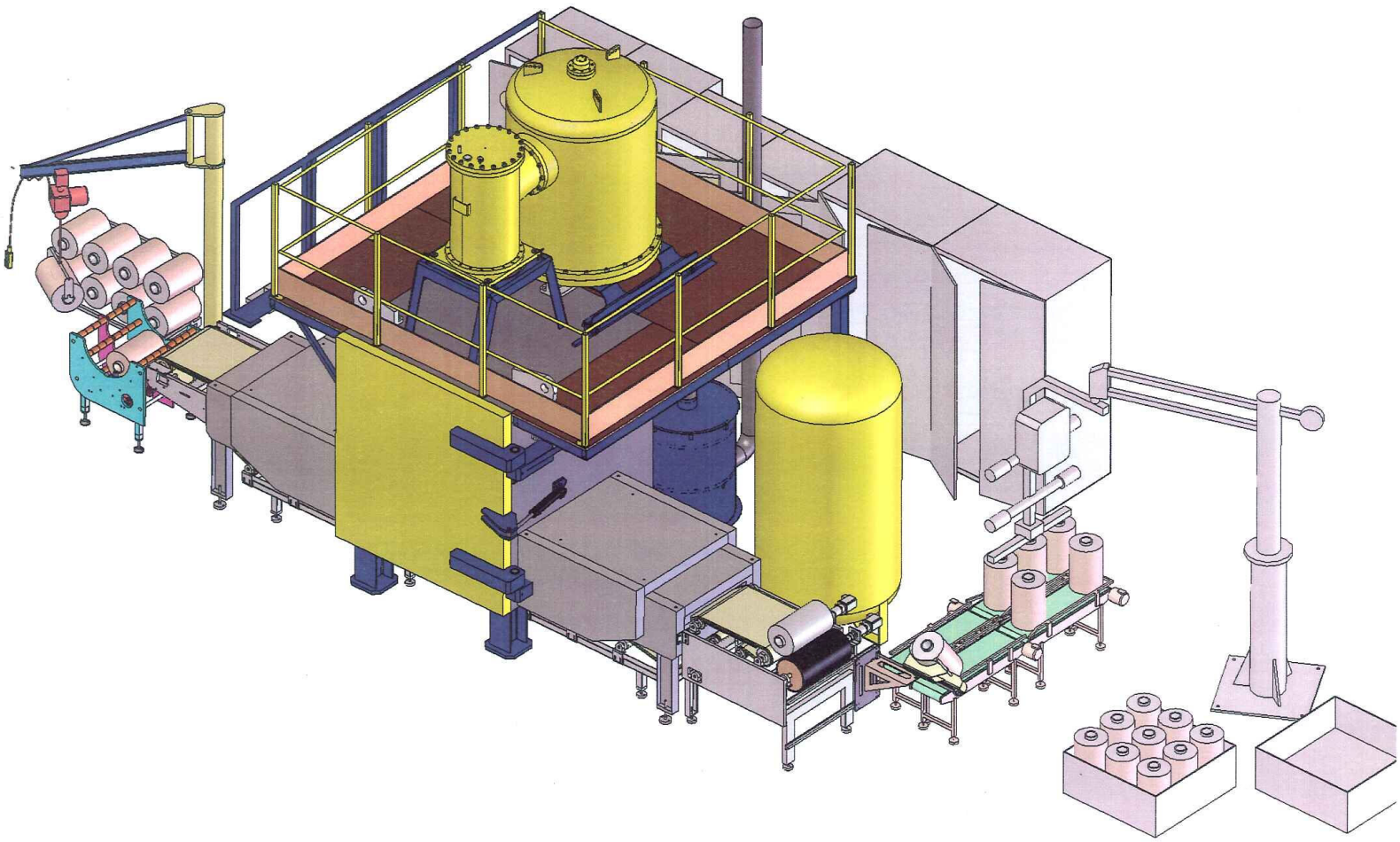




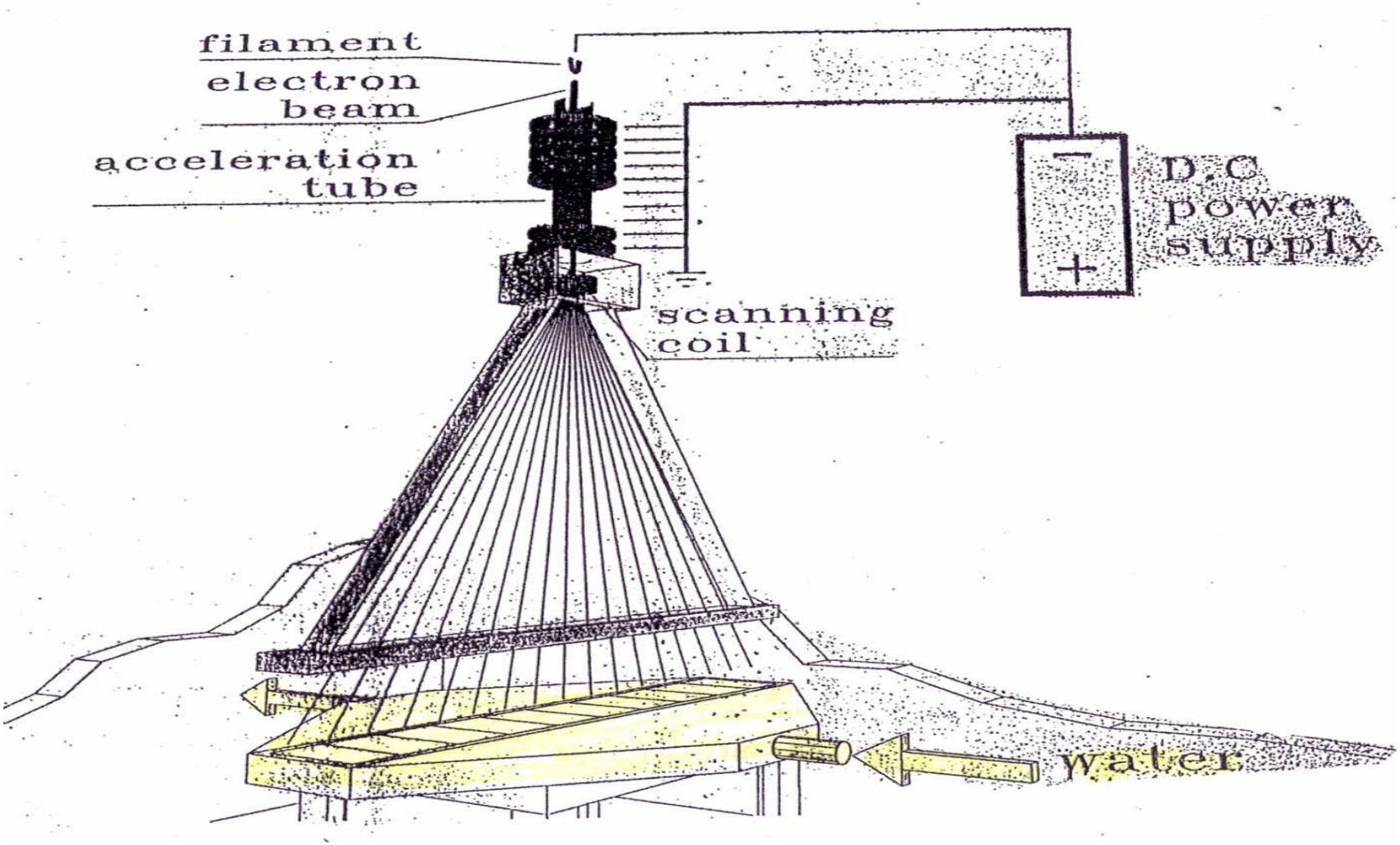

SIDE VIEW OF UNDER BEAM HANDLING WHEELS
WHEELS SUPPORT
WATER COOLING BOX
OPEN WELL
COOLING WATER RECYCLING
PROGRAMMABLE CONTROLER
AUXILIARY CONSOLE
TURBO-BLOWER (2 UNITS)
VARIABLE TRANSFORMER
CAPACITOR BANK
GAS TRANSFER SYSTEM GTS-7000
THIS DRAWING IS A PROPOSAL FOR THE FACILITIES OF AN ELECTRON PROCESSING SYSTEM. ALL DESIGNS AND DIMENSIONS ARE GIVEN AS AN EXAMPLE AND CAN CHANGE AT ANY TIME.
0.00.0233
2.5 Mev - 100 kW ELECTRON PROCESSING SYSTEM
VIVIRAD
SIDE VIEW OF GLOBAL SYSTEM
0.5 Mev ACCELERATOR TUBE
0.5 Mev - 100 kW POWER SUPPLY
ICT TANK
68 m3 - 7,2 bars abs.
5 TONS OVERHEAD CRANE
PRODUCT EXITS
GUIDE WHEELS
SF6 STORAGE TANK (26m3 - 18 bars abs.)
36° SCANNERS
COOLING WATER RECYCLING
SPRINKLERS FOR TUBE COOLING (17m tube water-cooled per turn through the wheels box)
DRIVE WHEELS
ACCESS DOOR ACCELERATOR ROOM
CONTROL ROOM
TURBO-BLOWERS
FROM UNWINDER
TO COOLING TANKS AND WINDER
ICT IN SERVICE POSITION
TANK COVER IN SERVICE POSITION
SLIDE DOOR ENTRY LOWER VAULT
UPPER VIEW OF GLOBAL SYSTEM
ELECTRON BEAM
2 x (2.5Mev - 20mA)
4 x Ø36 to Ø63mm PLASTIC TUBES (Wall thickness 7mm max.)
Or 4 x Ø36 to Ø50mm PE/AL/PE SANDWICH PIPES (Wall thickness 7mm max.)
Or CABLE JACKETS up to Ø120mm O.D. (Wall thickness 7mm max.)
6 x Ø26 to Ø32mm PLASTIC TUBES
Or Ø26 to Ø32mm PE/AL/PE SANDWICH PIPES (Wall thickness 6mm max.)
Or CABLES and CABLE JACKETS up to Ø32mm O.D. (Wall thickness 7mm max.)
10 x Ø16 to Ø20mm PLASTIC TUBES
Or Ø12 to Ø20mm PE/AL/PE SANDWICH PIPES (Wall thickness 5mm max.)
Or 18 AWG to 500 MCM CABLES O.D to 240mmØ


ABUS
VIVIRAD S.A.
FRANCE



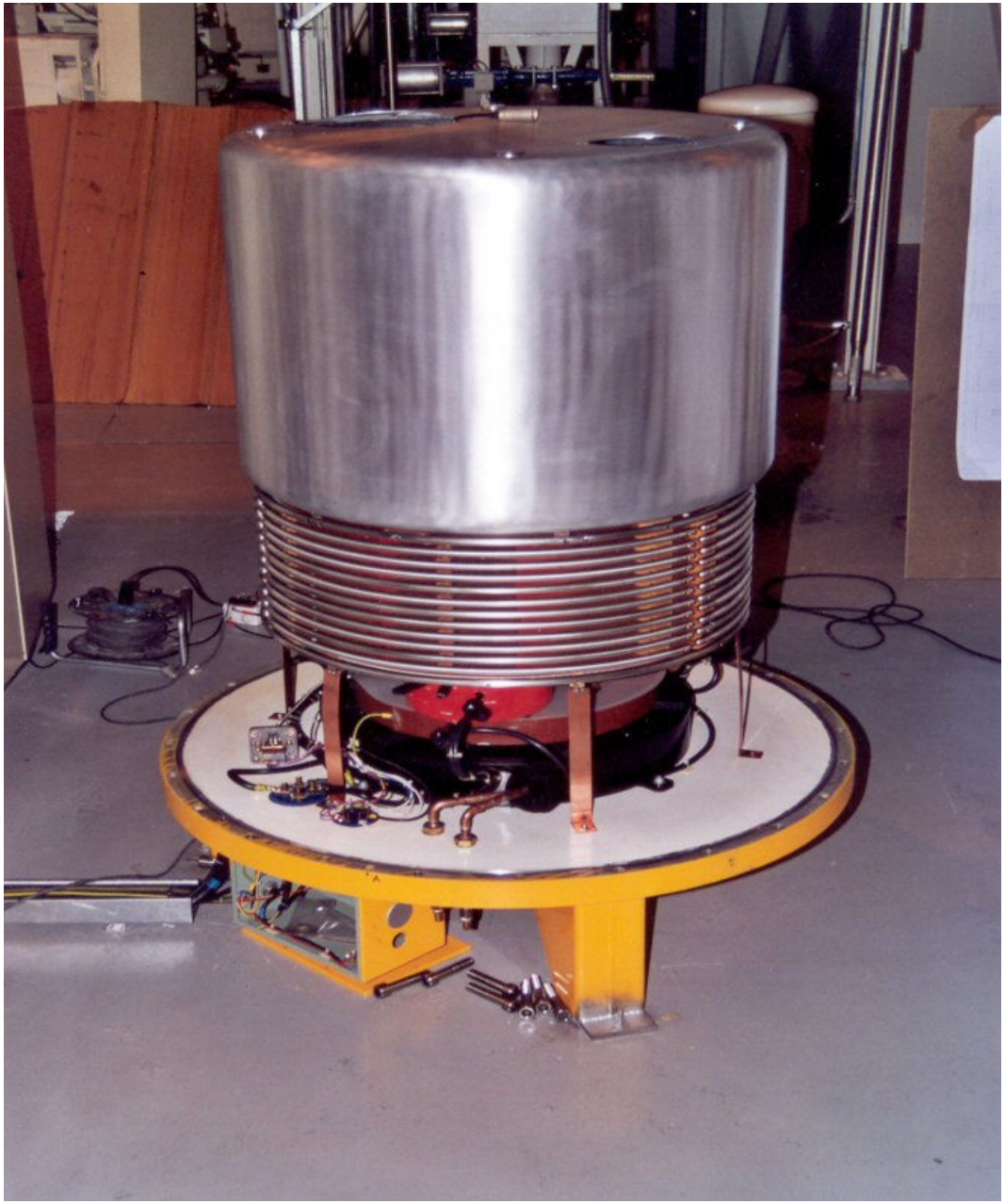


Beaming Process Principle

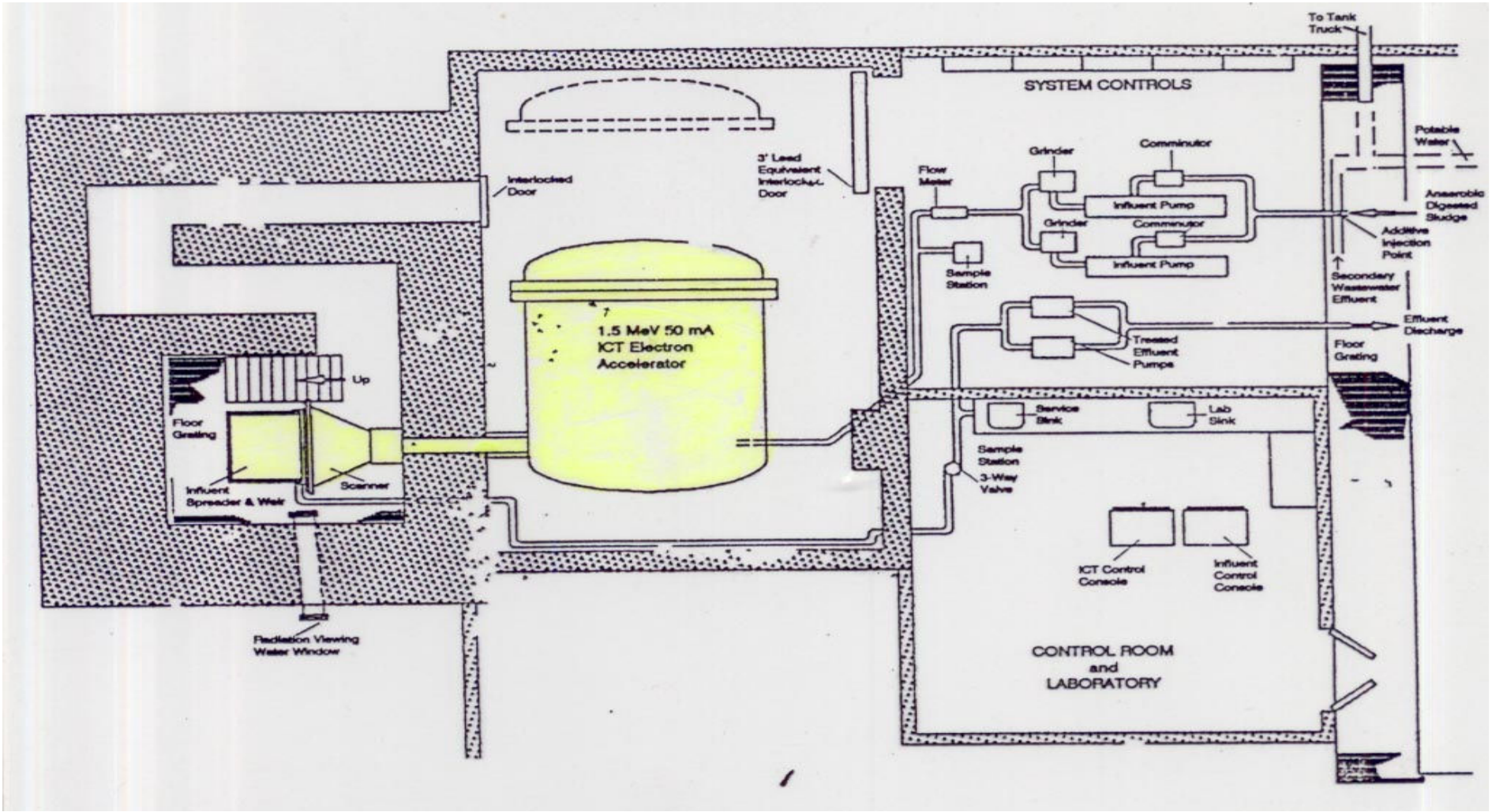



DANGER
HIGH
VOLTAGE

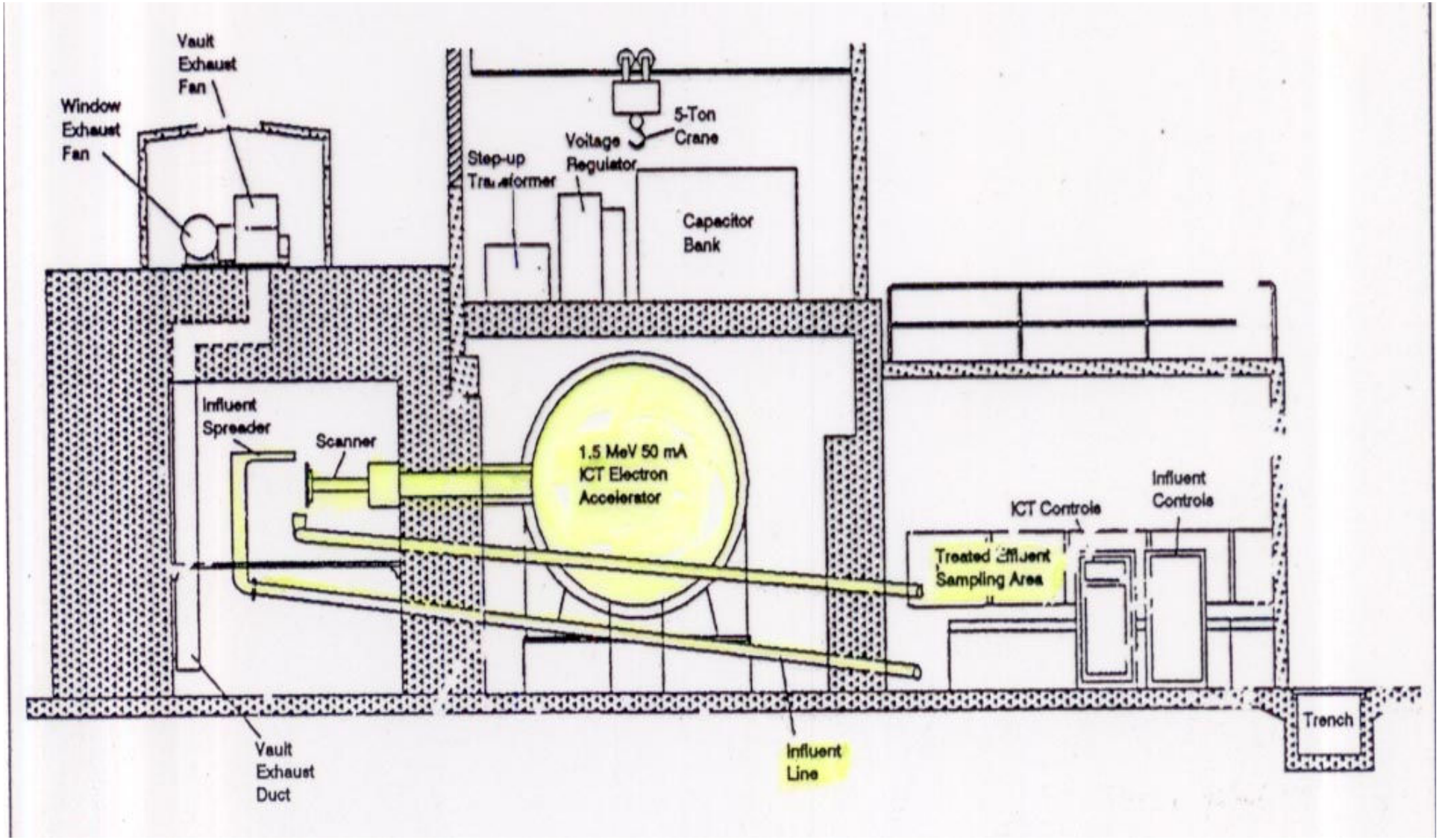
Mobile E-Beam Unit for Water remediation

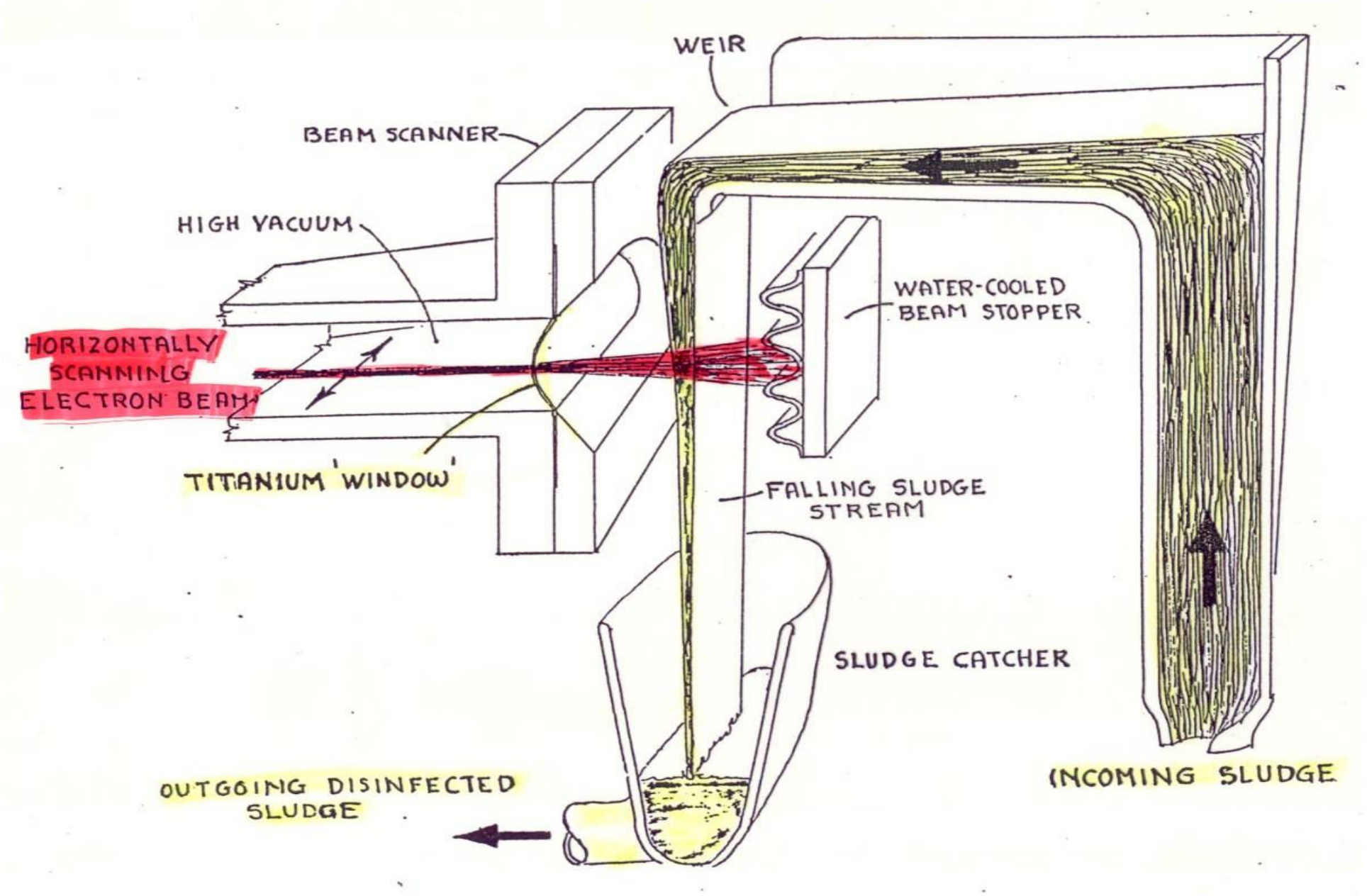


Electron Beam Research Facility
Miami, Florida



SIDE VIEW


Vault
Exhaust
Fan
Window
Exhaust
Fan
5-Ton
Crane
Voltage
Regulator
Step-up
Transformer
Capacitor
Bank
Influent
Spreader
Scanner
1.5 MeV 50 mA
ICT Electron
Accelerator
ICT Controls
Influent
Controls
Treated Effluent
Sampling Area
Trench
Vault
Exhaust
Duct
Influent
Line


WEIR
BEAM SCANNER
HIGH VACUUM
WATER-COOLED
BEAM STOPPER
HORIZONTALLY
SCANNING
ELECTRON BEAM
TITANIUM 'WINDOW'
FALLING SLUDGE
STREAM
SLUDGE CATCHER
OUTGOING DISINFECTED
SLUDGE
INCOMING SLUDGE

SUMMARY OF PERCENT REMOVAL OF VARIOUS ORGANIC COMPOUNDS BY TREATMENT APPLICATION AREA

	Percent Removal	Required Dose (Krads)
Drinking Water		
Chloroform	83%	650
Bromodichloromethane	>99	80
Dibromochloromethane	>99	80
Bromoform	>99	80
Wastewater/Groundwater Treatment		
Carbon tetrachloride	>99	50
Trichloroethylene (TCE)	>99	500
Tetrachlorethylene (PCE)	>99	500
trans-1,2-dichloroethene	93	800
cis-1,2-dichloroethene	98	800
1,1-dichloroethene	>99	800
1,2-dichloroethane	60	800
hexachloroethane	>99	800
1,1,1-trichloroethane	89	650
1,1,2,2-tetrachloroethane	88	650
hexachloro-1,3-butadiene	98	800
Methylene chloride	77	800
Groundwater Treatment		
Benzene	>99	650
Toluene	97	650
Chlorobenzene	97	650
Ethylbenzene	92	650
1,2-Dichlorobenzene	88	650
1,3-Dichlorobenzene	86	650
1,4-Dichlorobenzene	84	650
m-Xylene	91	650
o-Xylene	92	650
Dieldrin	>99	800
Total phenol	88	800

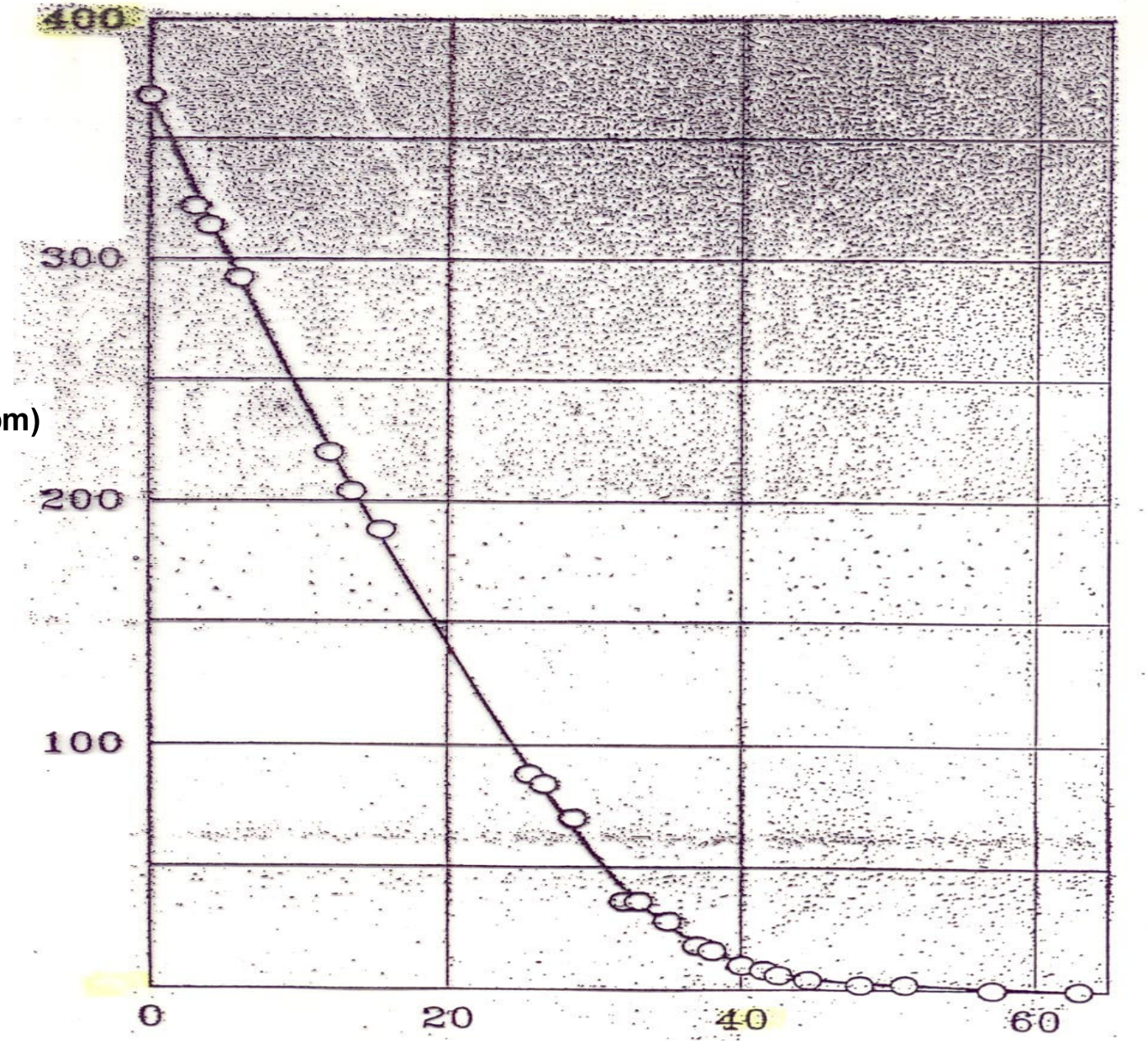
FUNDAMENTALS

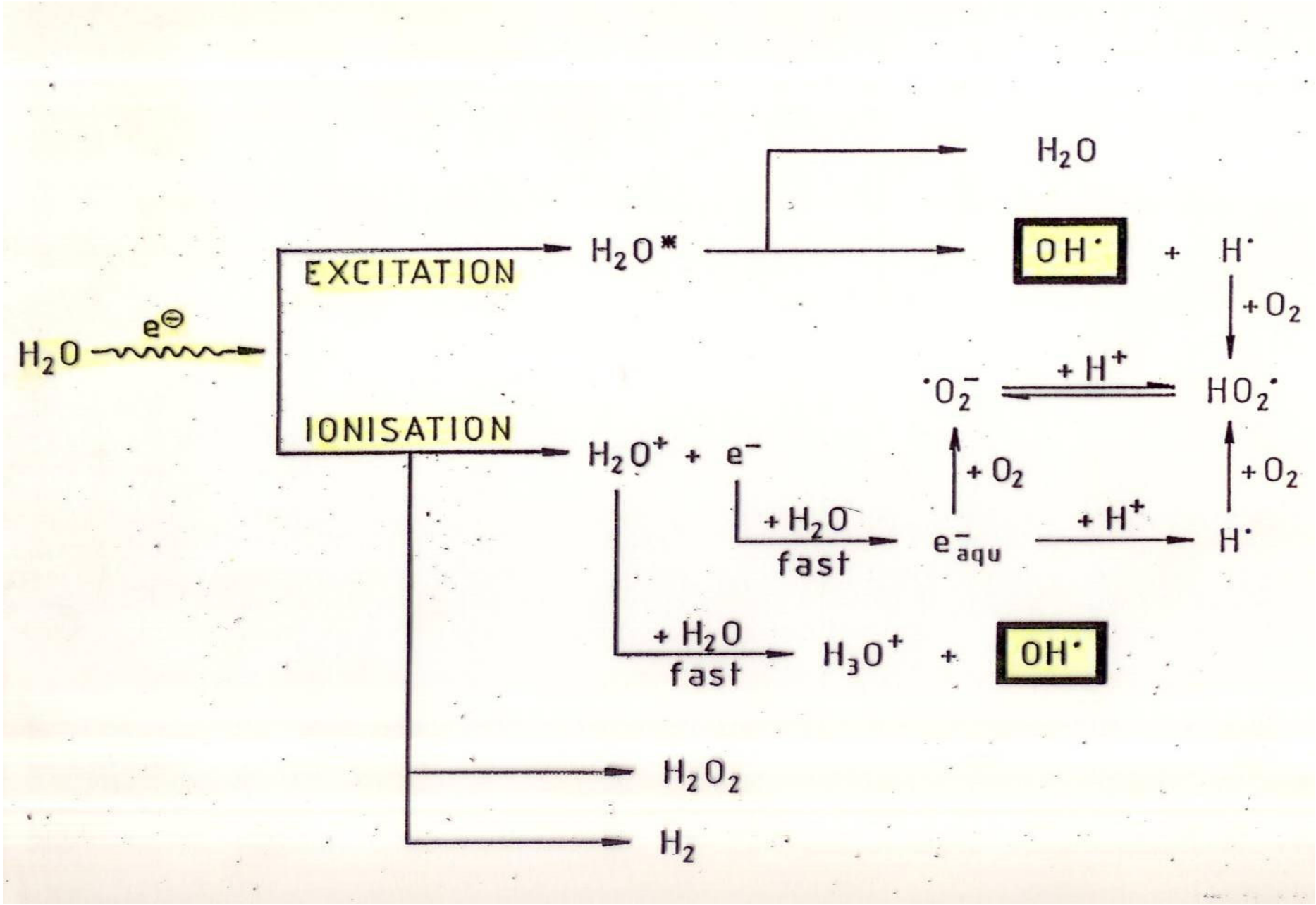
- Energy of the radiation sources 300 keV up to several MeV
- Energy necessary to ionize a molecule : between 10 and 20 keV

THAT MEANS :

- All molecules have, independent of their chemical structure, the same active cross-section
- The interaction between molecules and radiation is proportional only to their concentration in the system
- The pollutants exists in trace amounts only
- The direct interaction of the radiation onto the pollutants may be neglected usually

THE ACTION OF RADIATION WITH REGARD TO POLLUTANT DECOMPOSITION TAKES PLACE INDIRECTLY BY RADIOLYSIS PRODUCTS OF THE MAIN COMPONENTS IN THE SYSTEME


400
300
200
100
0
20
40
60
TRICHLOROETHANE (ppm)
DOSE (kGy)


H_2O
$e^{\ominus}$
EXCITATION
IONISATION
H_2O^*
$H_2O^+ + e^-$
H_2O
OH· + H·
$+O_2$
$^{\cdot}O_2^-$
$+H^+$
$HO_2^{\cdot}$
$+O_2$
$+O_2$
$+H_2O$
fast
e^-_{aqu}
$+H^+$
H·
$+H_2O$
fast
H_3O^+ + OH·
H_2O_2
H_2

SCHEMATIC VIEW OF THE PROTOTYPE FOR CONTINUOUS OZONE-ELECTRON BEAM IRRADIATION TREATMENT OF WATER IN SEIBERSDORF

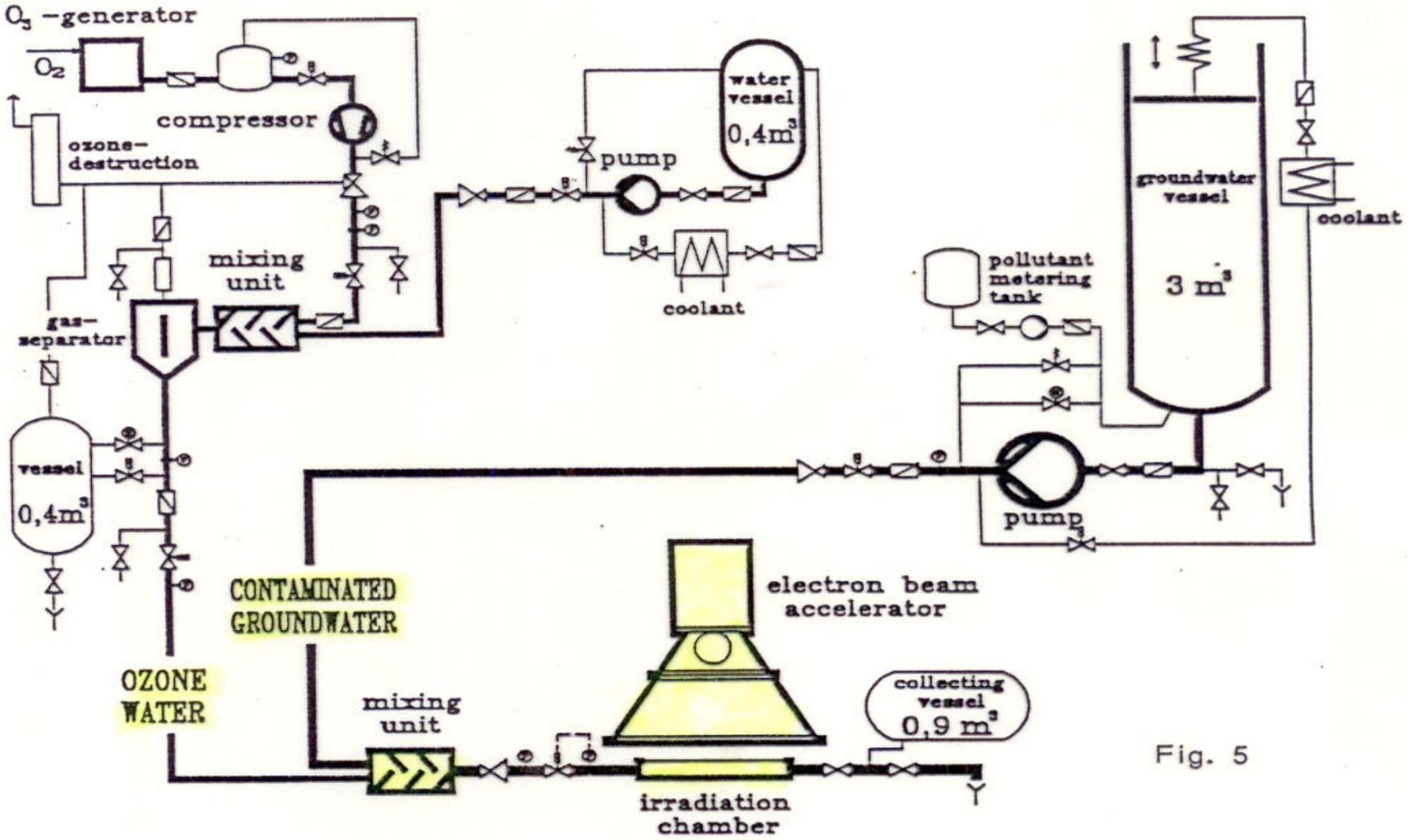
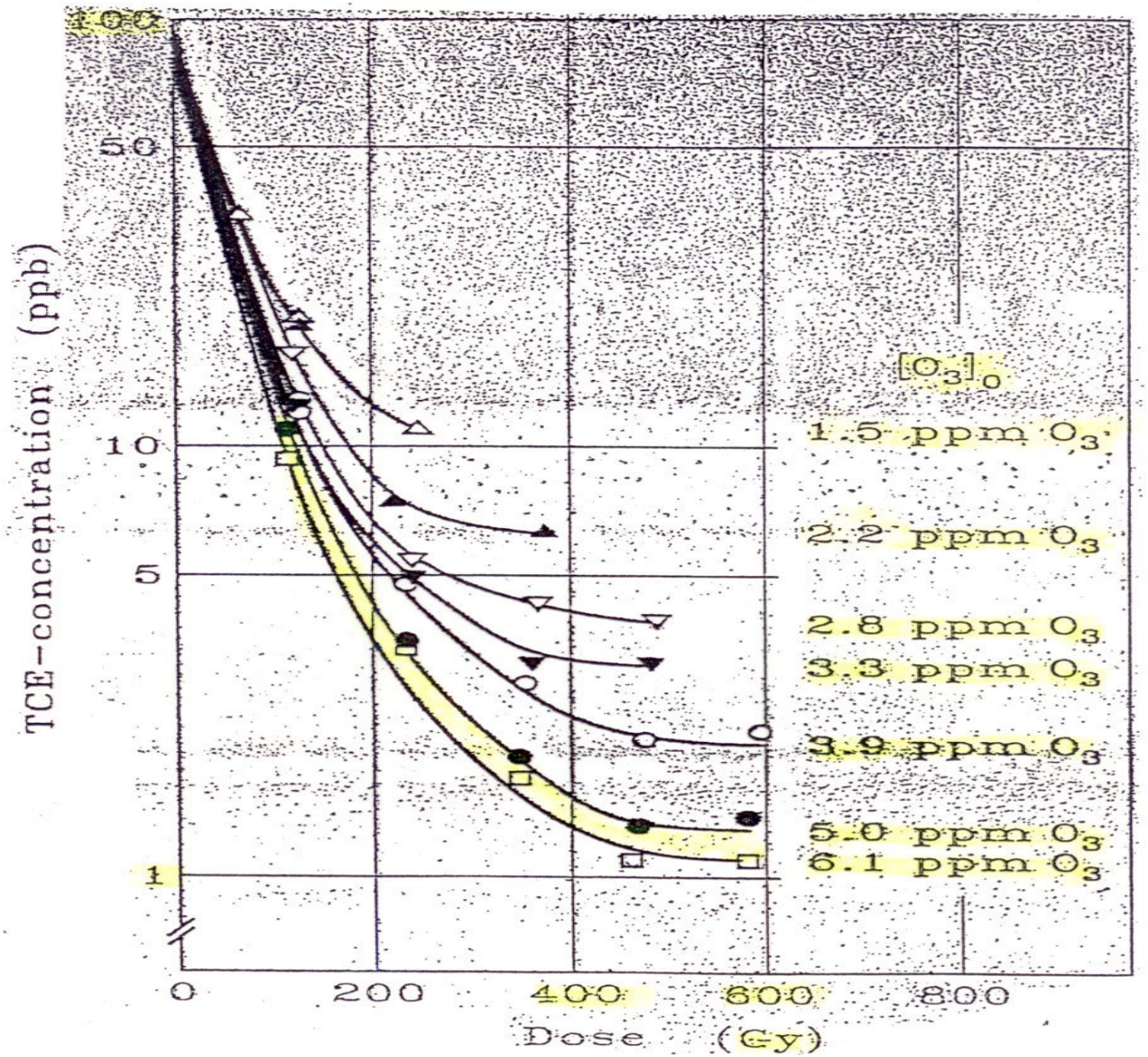


Fig. 5

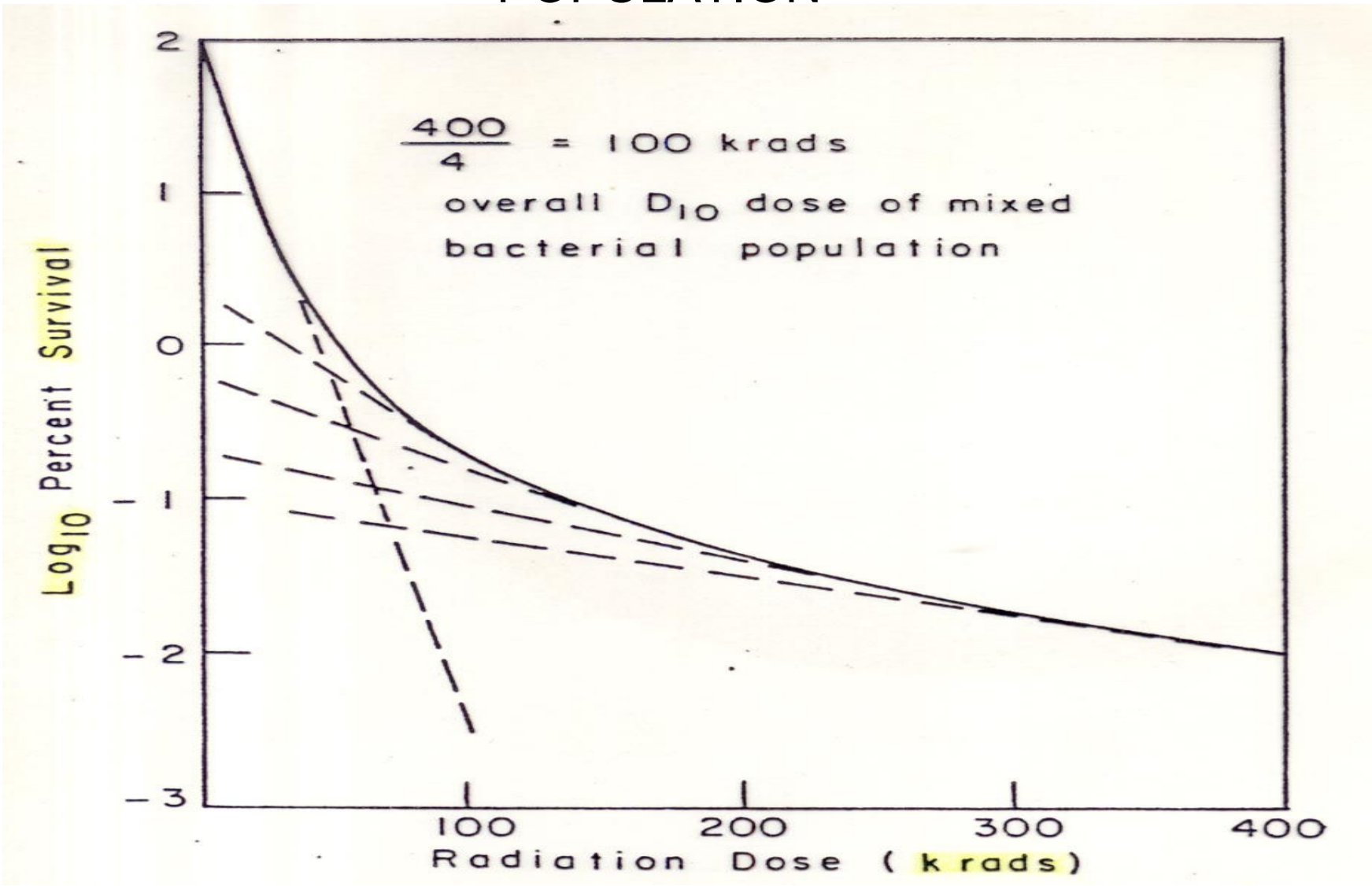
VIVIRAD SA - FRANCE

PROF. GERHINGER

DECOMPOSITION OF TCE



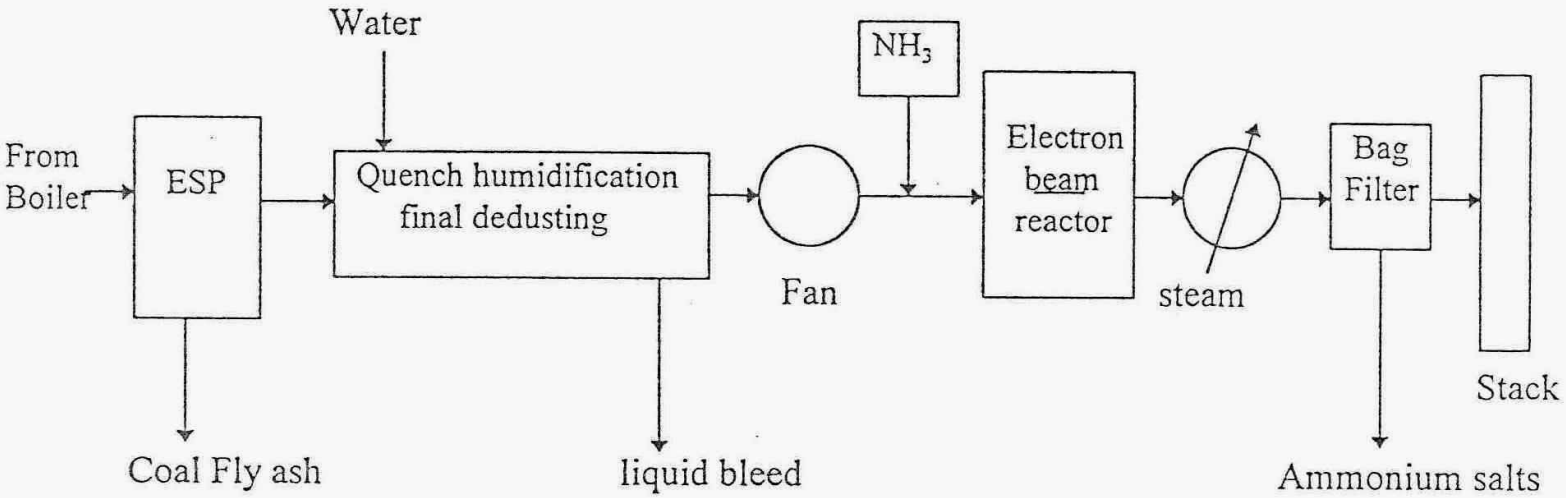
SURVIVAL CURVES OF MIXED BACTERIAL POPULATION



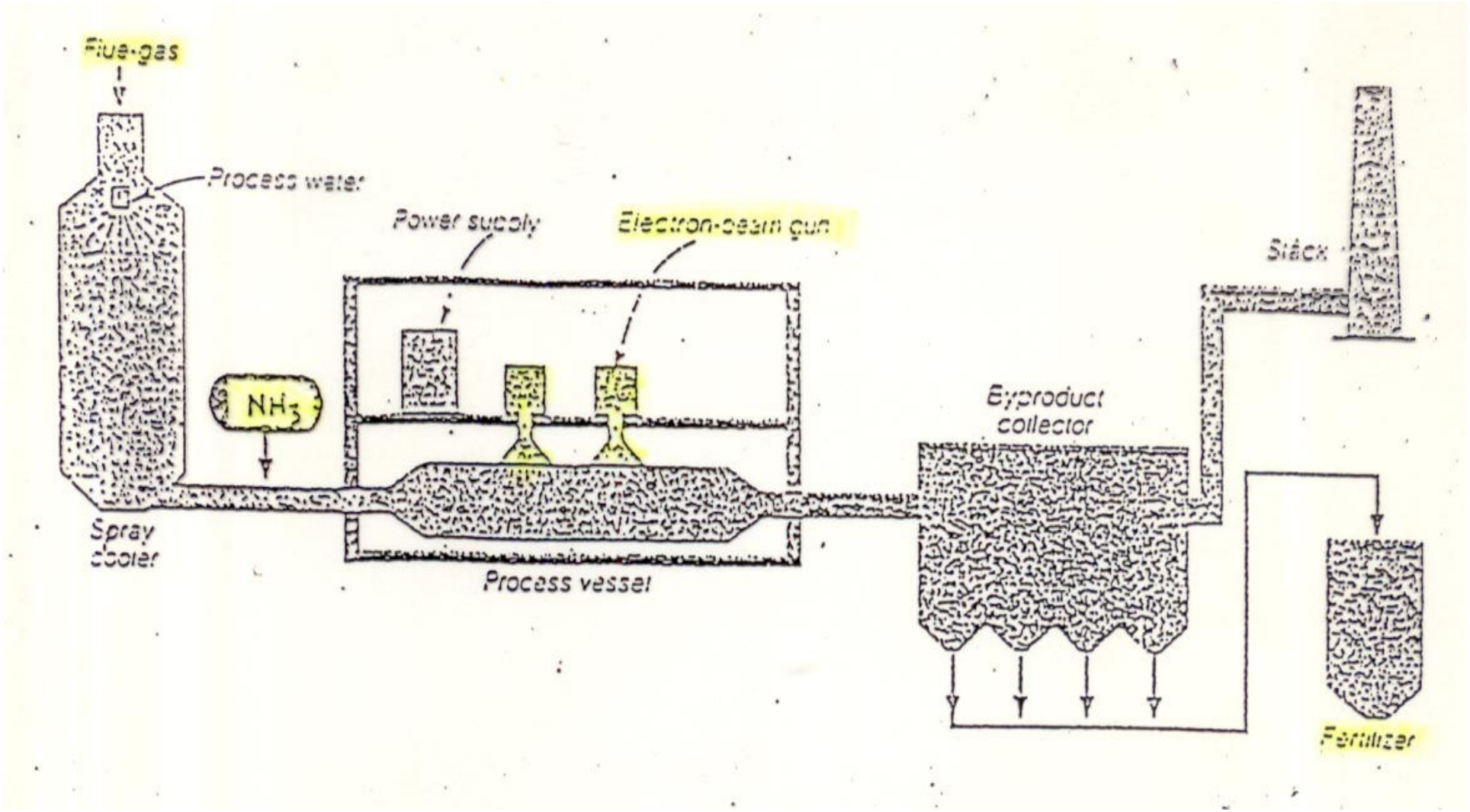
RADIATION CHEMISTRY METHODS FOR SOLVING ENVIRONMENTAL PROBLEMS

- Conversion of NOx and SO_2/SO_3 in combustion into fertilizer in the presence of ammonia
- CO_2 and CO utilization – formation of valuable products
- Disinfection as well as decomposition of pollutants in drinking water
- Degradation of biologically resistant harmful substances in wastewaters from industry etc.
- Disinfection of sludge and conversion into fertilizer
- Disinfection of hospital wastes
- Recycling of biologically undegradable plastics and rubbler waste

Basic principle



PRINCIPLE OF PROCESS



FLUE GAS TREATMENT BY ELECTRON IRRADIATION

1. Generations of free radicals

$$N_2, O_2, H_2O \xrightarrow{e^{\ominus}} OH^{\cdot}, O^{\cdot}, HO_2^{\cdot}, N^{\cdot}$$

$$N_2^+ + O_2 \longrightarrow O_2^+$$

$$O_2^+ + 2\,H_2O \longrightarrow OH^{\cdot} + H_3O^+ + O_2$$

2. Oxidation of SO_2 and formation of H_2SO_4

$$SO_2 \xrightarrow{+OH^{\cdot}} HSO_3^{\cdot} \xrightarrow{+OH^{\cdot}} H_2SO_4$$

3. Oxidation of NO_x and formation of HNO_3

$$NO \xrightarrow{+O^{\cdot}} NO_2$$

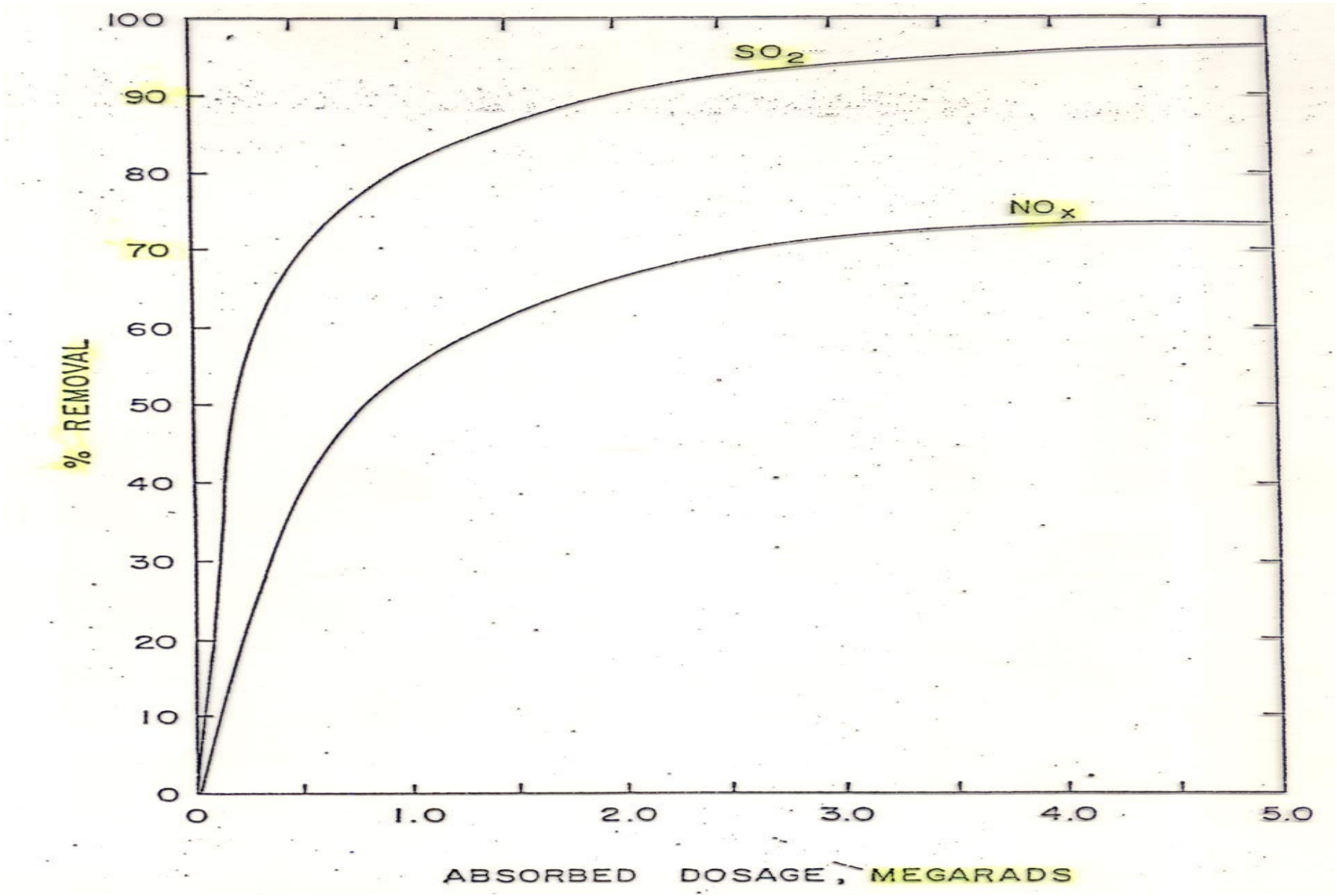
$$NO \xrightarrow{+HO_2^{\cdot}} NO_2 + OH^{\cdot}$$

$$NO_2 \xrightarrow{+OH^{\cdot}} HNO_3$$

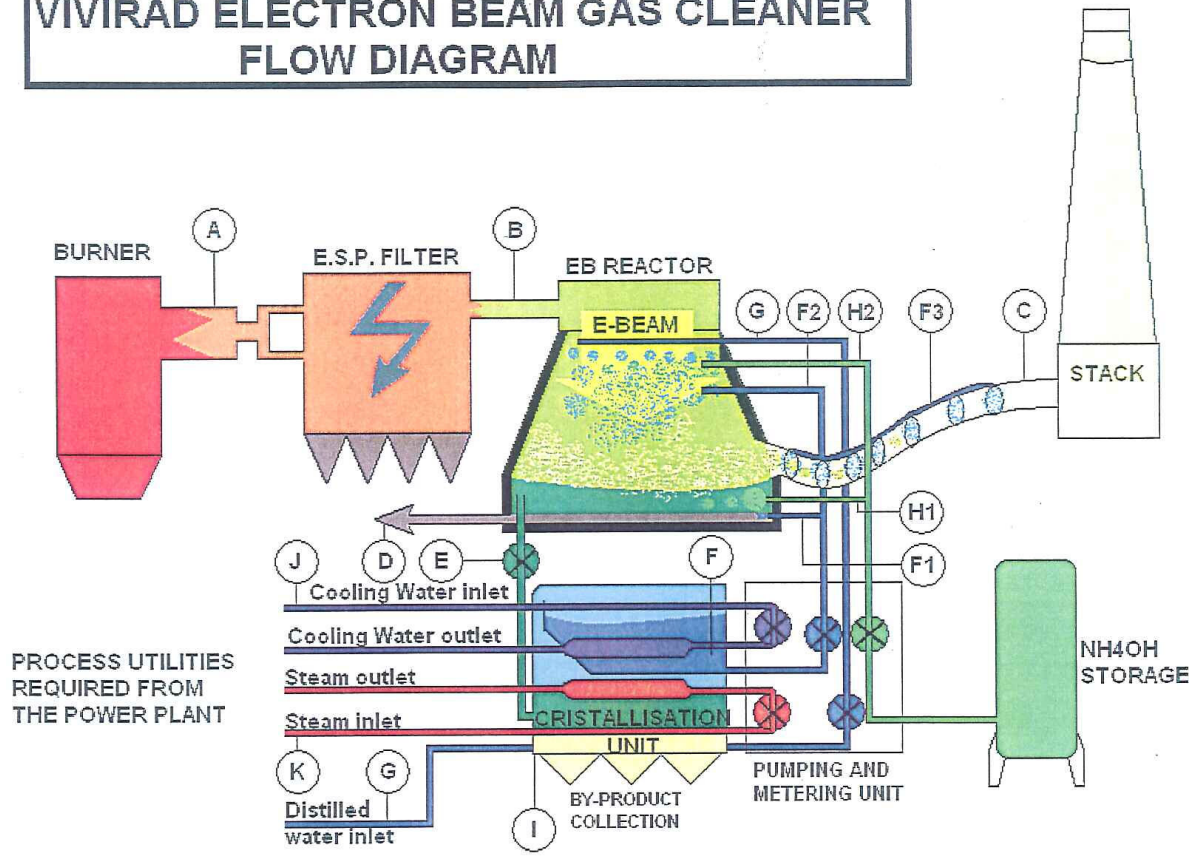
4. Reaction of the acids to solid products

$$H_2SO_4 \xrightarrow{+2\,NH_3} (NH_4)_2SO_4$$

$$HNO_3 \xrightarrow{+NH_3} NH_4NO_3$$


100
90
80
70
60
50
40
30
20
10
0
% REMOVAL
SO_2
NO_x
0
1.0
2.0
3.0
4.0
5.0
ABSORBED DOSAGE, MEGARADS

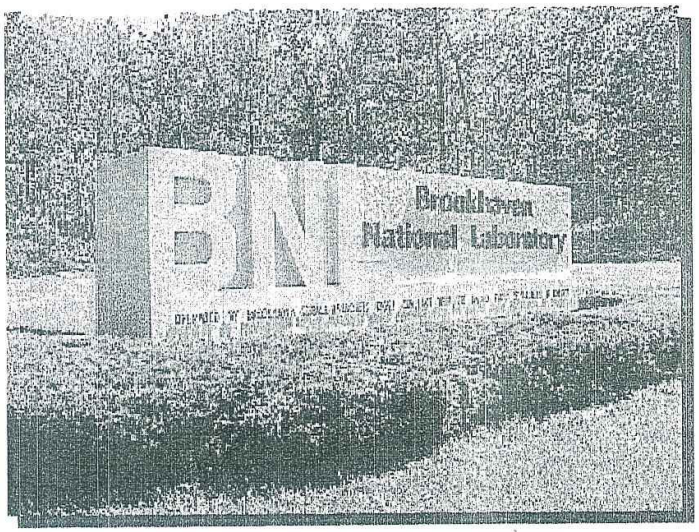
VIVIRAD ELECTRON BEAM GAS CLEANER FLOW DIAGRAM

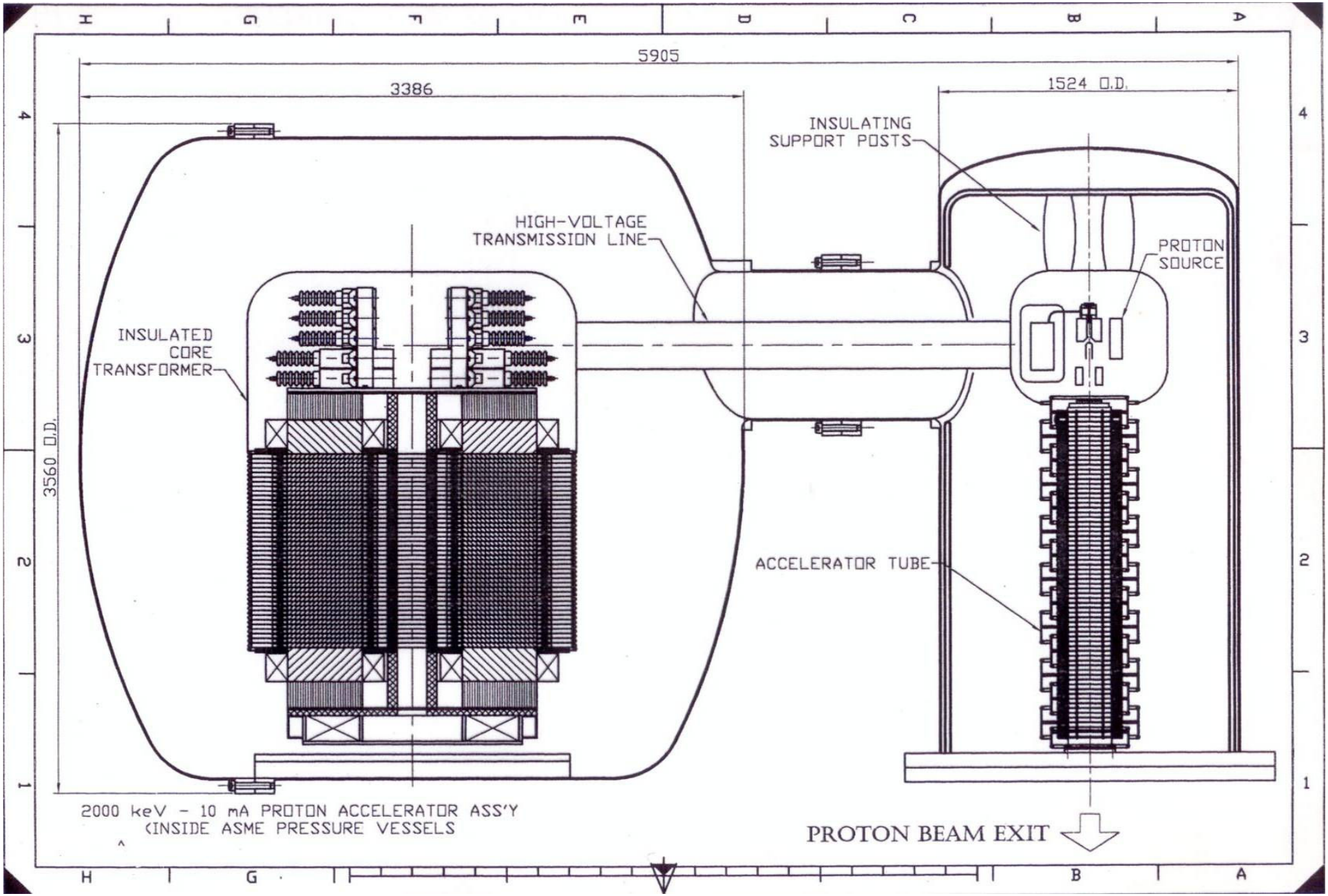


GAMMA RESONANCE TECHNOLOGY FOR LARGE CARGO CONTAINERS AND VEHICLE INSPECTION

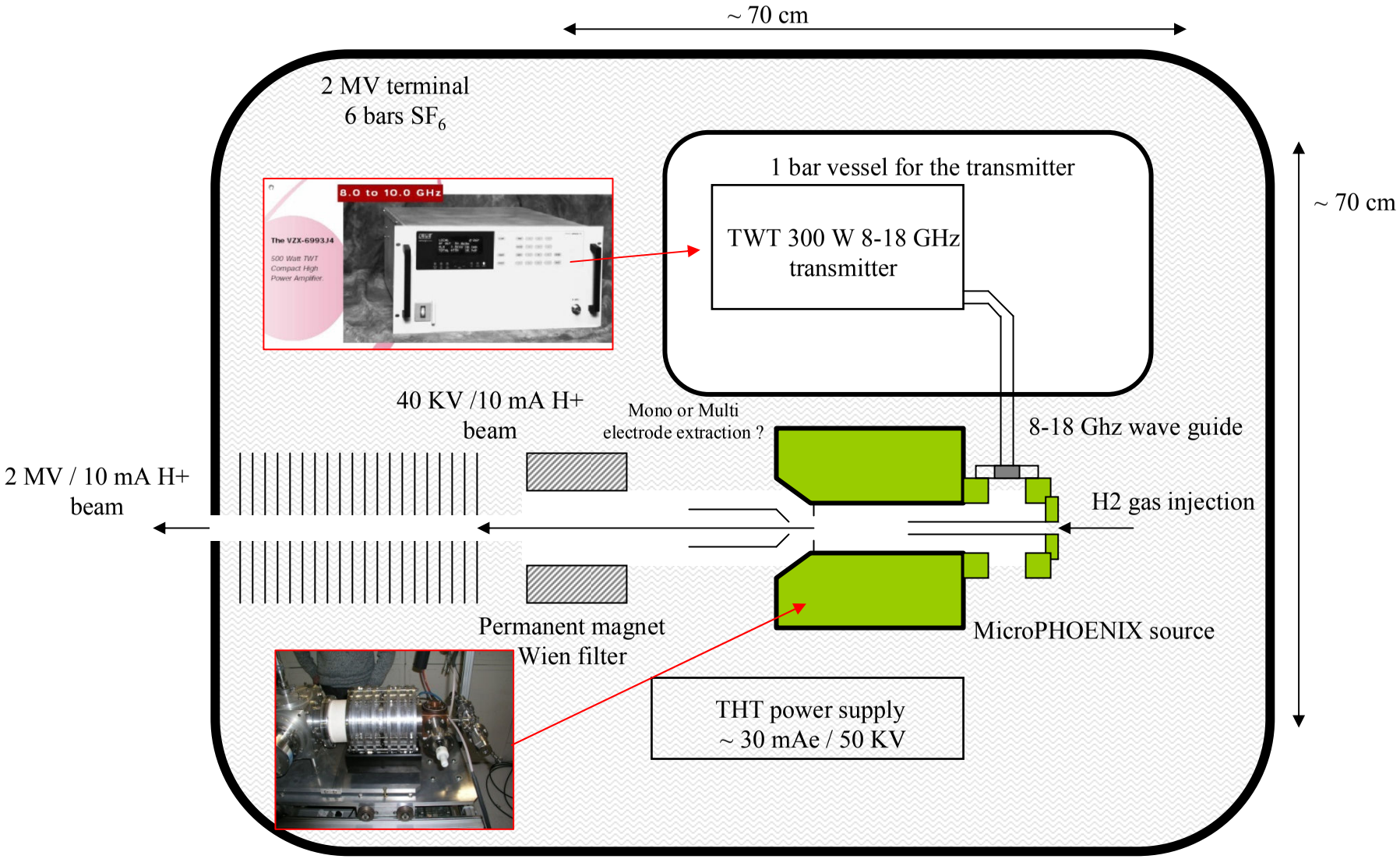
$^{13}C(p,\gamma)N^{14}$

Brookhaven National Laboratory
Lucian Wielopolski, Ph.D.
Peter Thieberger, Ph.D.
Scientific Innovations Inc.
Joseph Brondo, CEO




5905
3386
1524 O.D.
3560 O.D.
INSULATING
SUPPORT POSTS
HIGH-VOLTAGE
TRANSMISSION LINE
PROTON
SOURCE
INSULATED
CORE
TRANSFORMER
ACCELERATOR TUBE
2000 keV - 10 mA PROTON ACCELERATOR ASS'Y
(INSIDE ASME PRESSURE VESSELS
PROTON BEAM EXIT

MicroPHOENIX system inside a 2 MV terminal

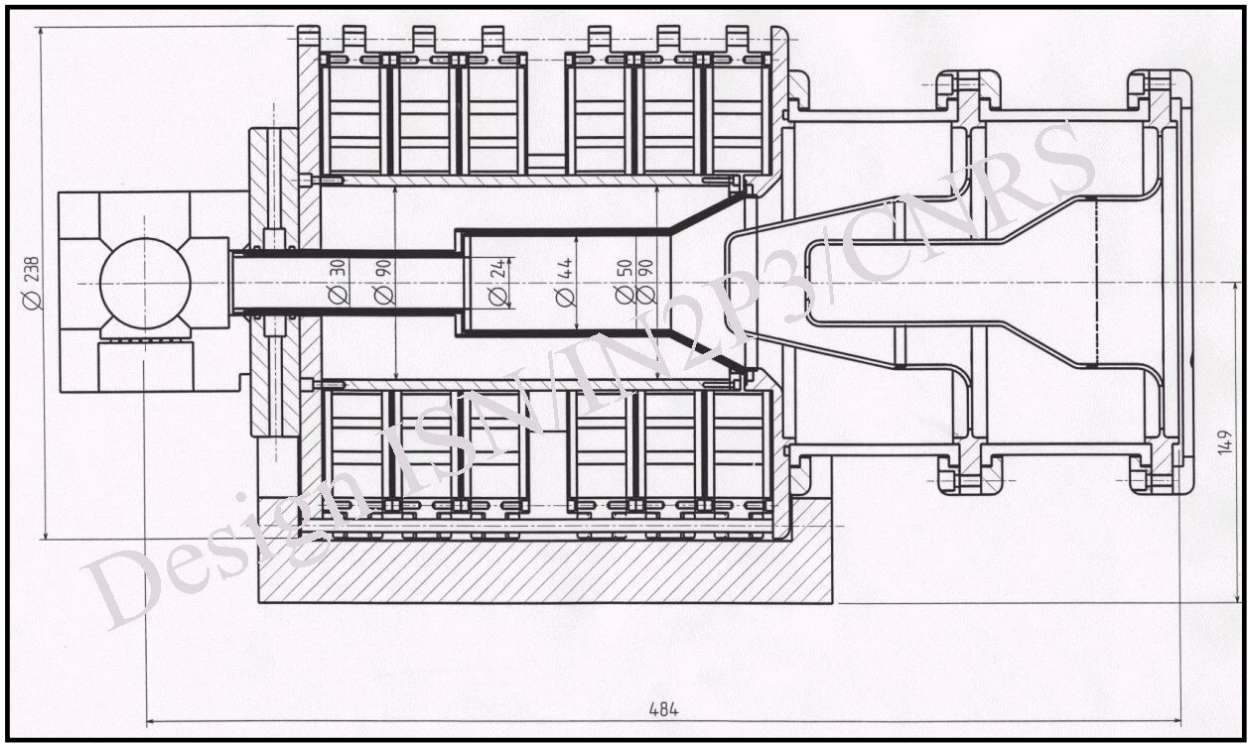


ECRIS and production of the 10 mAe H+ beam

High brightness development program

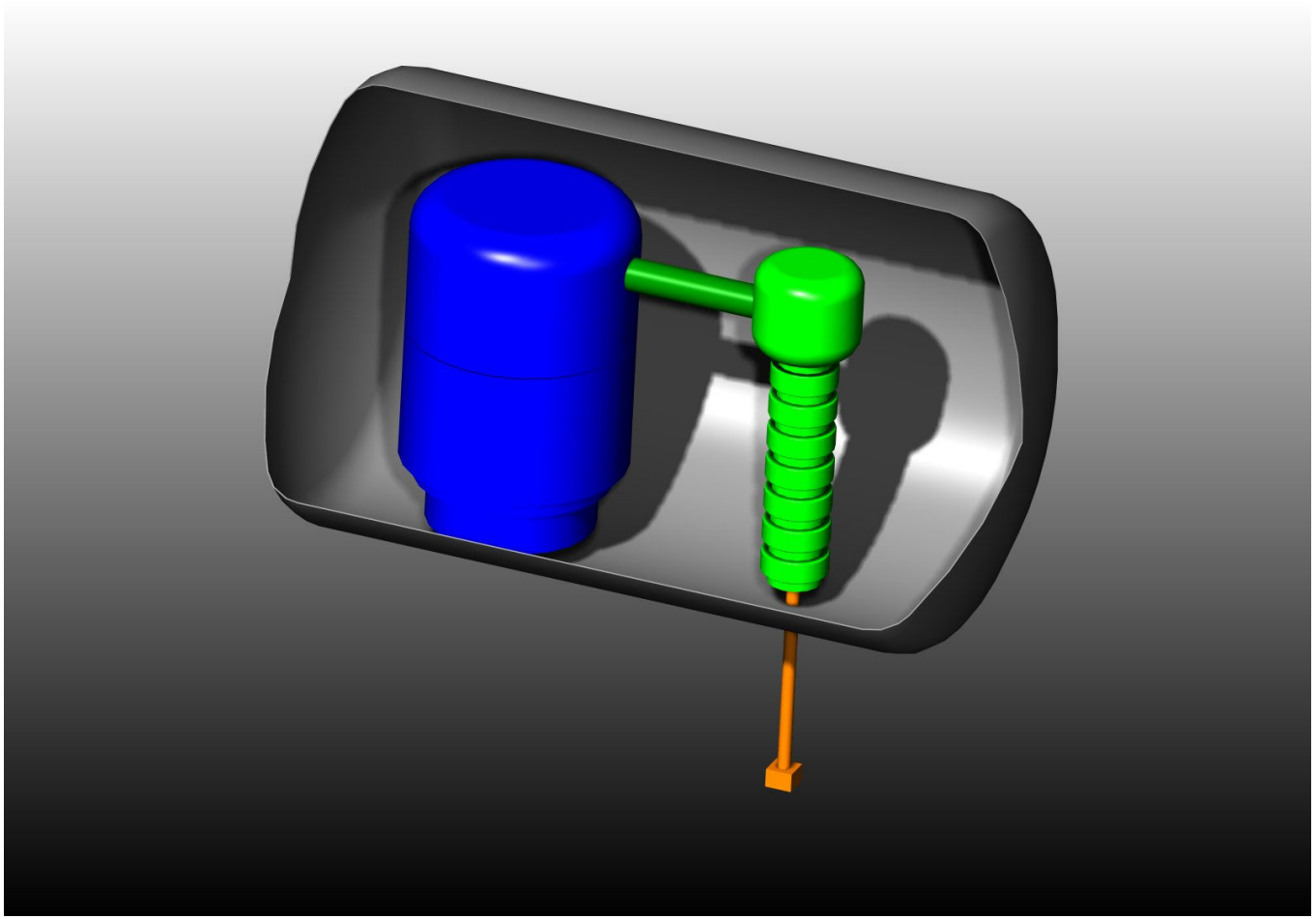
How can we build the best emittance 10mA / 40 KV H+ beam ?

Optimization of : **Extraction hole 1-2-3 mm / Extractor geometry / Magnetic field / Current density 50 –500 mA/mm²**



MicroPHOENIX : 8-18 GHz / 0-80 KV extractor

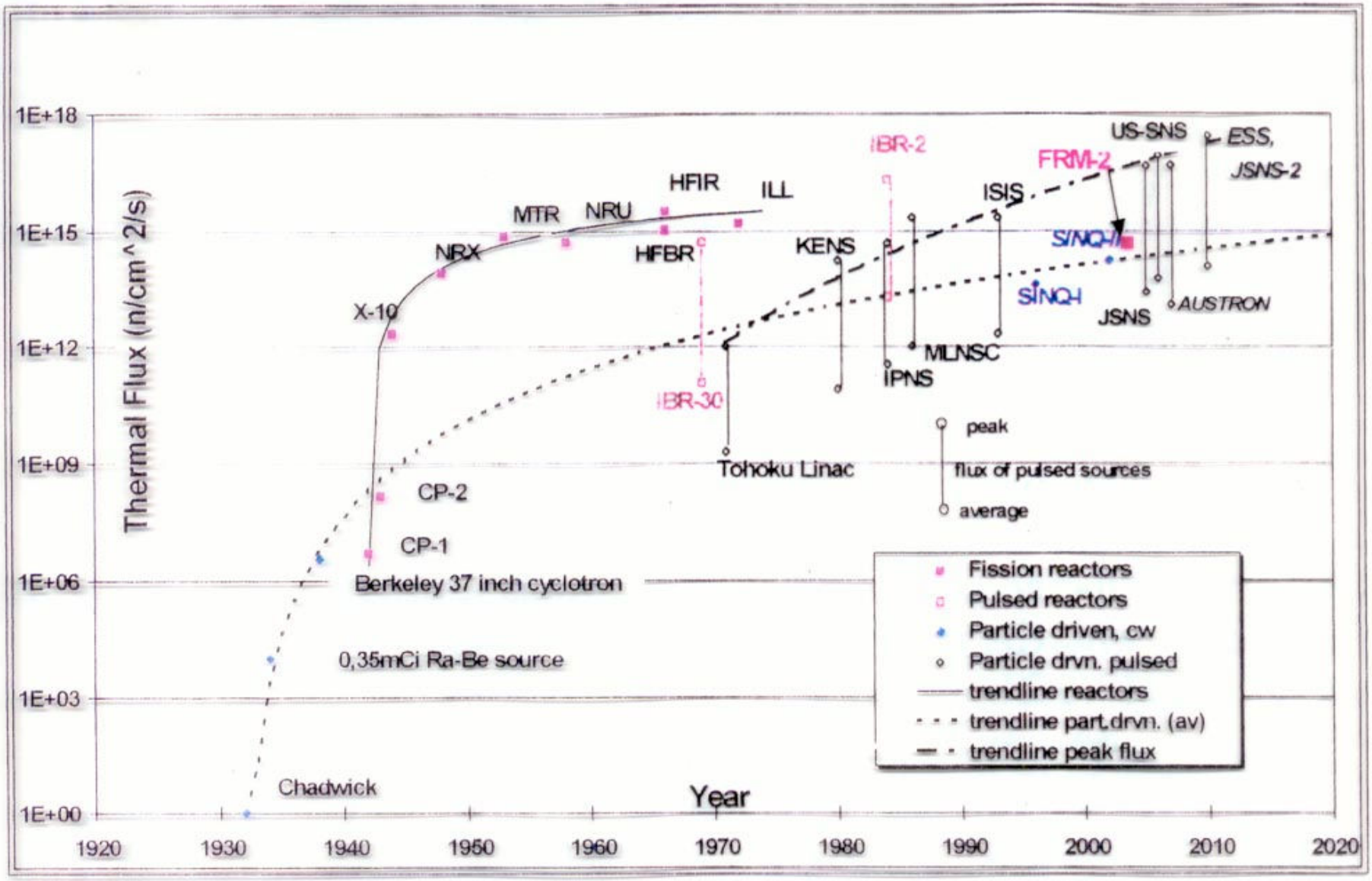
Cut view of a 3 MV beam system



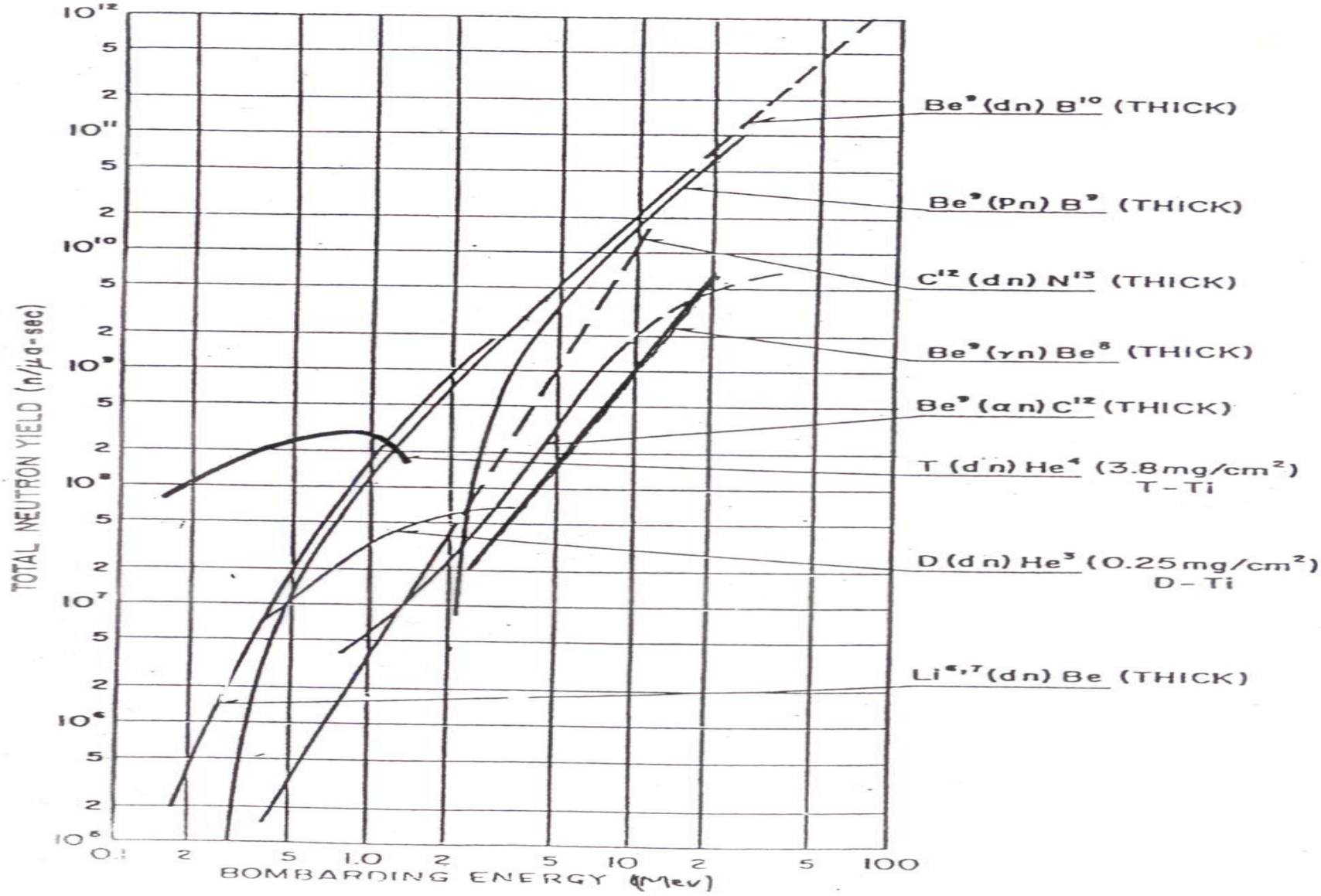
ACCELERATOR DRIVEN NEUTRON SOURCES

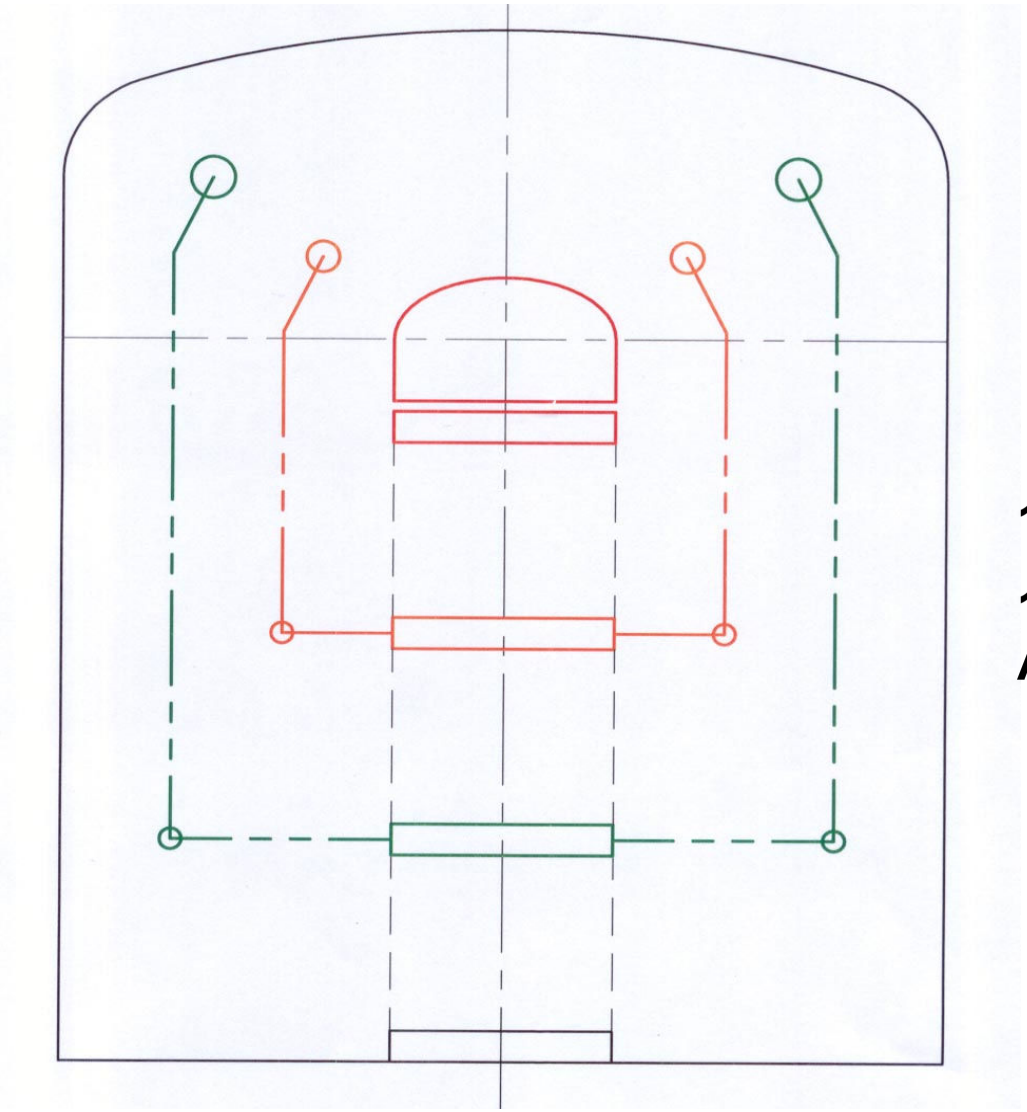
Introducing **ADNS** facilities in developing nations will be greatly facilitated through the formation of networks (among developing nations and more developed ones). Forming such a network will require a number of actions:

- Identification of possible stakeholders in developing and developed countries
- Analysis of the stakeholders' research goals and priorities relevant to ADNS
- Training of scientists and engineers on existing facilities («Awareness of needs» and deployment of skills)
- Selection of a source concept based on the stakeholders' needs
- Support for interested parties on the scientific and technical level
- Supporting the building of a suitable infrastructure and facility management culture
- Planning of « baseline » suite of research opportunities
- Setting up funding agreements and site selection
- Construction of « network nodes », if possible anchored to existing facilities
- Expansion of the network



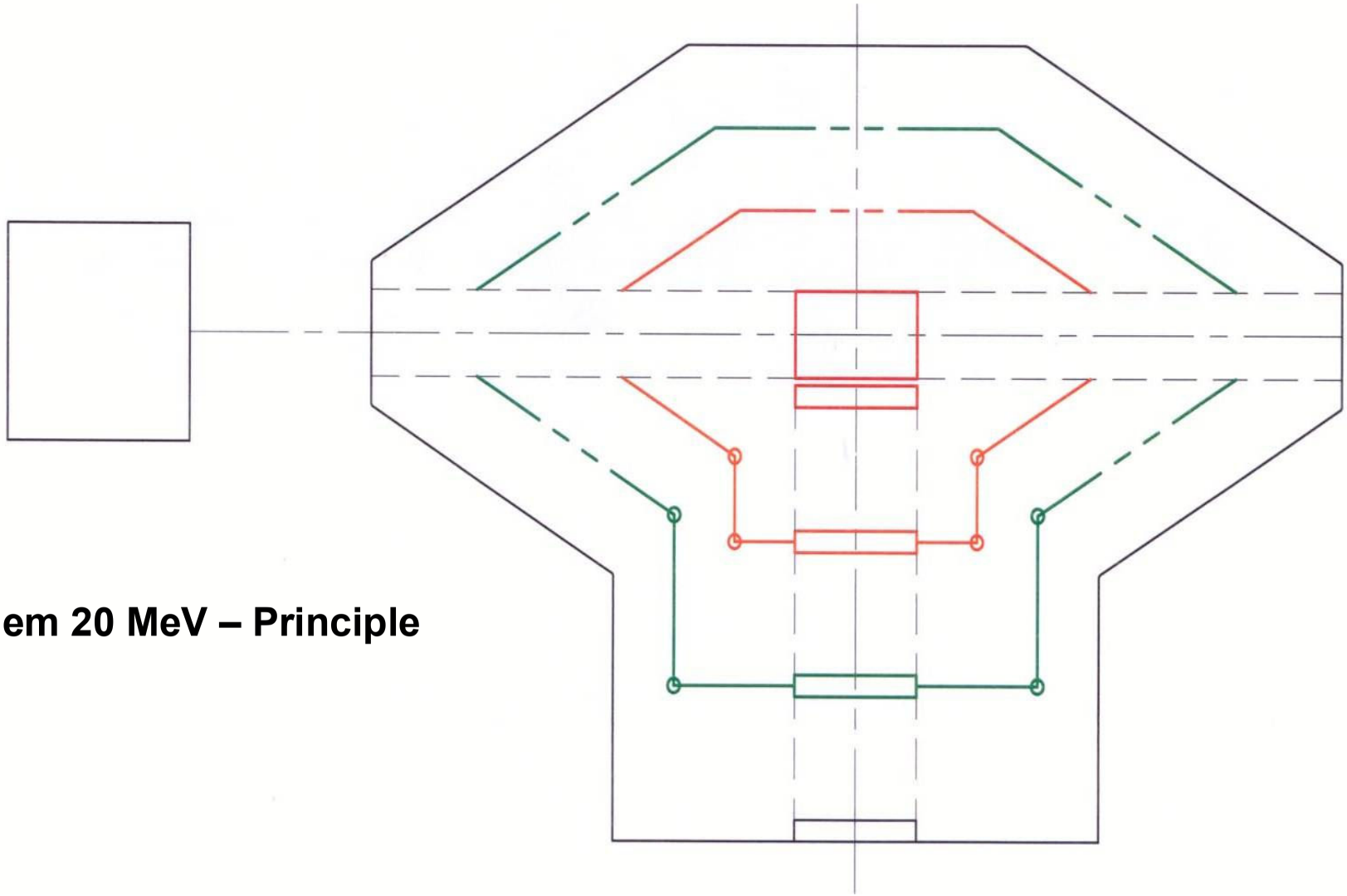
Thermal neutron flux available at various neutron sources.


TOTAL NEUTRON YIELD (n/μa-sec)
BOMBARDING ENERGY (Mev)
Be⁹(dn)B¹⁰ (THICK)
Be⁹(Pn)B⁹ (THICK)
C¹²(dn)N¹³ (THICK)
Be⁹(γn)Be⁸ (THICK)
Be⁹(αn)C¹² (THICK)
T(dn)He⁴ (3.8mg/cm²) T-Ti
D(dn)He³ (0.25mg/cm²) D-Ti
Li⁶,⁷(dn)Be (THICK)



10mA

10 MeV – 100 kW
Accelerator Principle



2mA

Tandem 20 MeV – Principle

NEUTRON FLUX

ACCELERATOR	YIELD n/μA-sec	(P,d) Beam mA	TOTAL
-Single stage 10 MeV (10mA.p)	2.10^{10} x 10.10^{3}		2.0 10^{14} n/sec
-Tandem 20 MeV (2mA.p)	7.10^{10} x 2.10^{3}		1.4 10^{14}n/sec

ION SOURCES

POSITIVE	-ECR	Grenoble Spiral II (Sortais) Pantechnik (Bieth) Berkeley Brown
	- Other	Berkeley Brown
NEGATIVE	-Multicusp	Pantechnik Berkeley
	- H.F	Triumf Berkeley
	- Sputtering	

MISCELLEANOUS

- Beam Optics :

  - Space charge → accelerating tubes :
    - Genepi
    - Grenoble – Cadarache

- Tandem :
  - High flux with less beam
  - Numerous negative ion sources. Open air
  - HV injection. Platform (~350 KV) easy to define emittance
  - Stripping (Culham, Cadarache) NET

Alternative Neutron Producing Reactions

Nuclear process	Example	Neutron yield	Heat release (MeV/n)
D-T in solid target	400 keV deuterons on T in Ti	$4*10^{-5}$ n/d	10 000
Deuteron stripping	40 MeV deuterons on liquid Li	$7*10^{-2}$ n/d	3 500
Nuclear photo effect from e^--bremsstrahlung	100 MeV e^- on ^{238}U	$5*10^{-2}$ n/e^-	2 000
^{9}Be (d,n) ^{10}Be	15 MeV d on Be	1 n/d	1 000
^{9}Be (p,n;p,pn)	11 MeV p on Be	$5*10^{-3}$ n/p	2 000
Nuclear fission	fission of ^{235}U by thermal neutrons	1n/fission	180
Nuclear evaporation (spallation)	800 MeV p+ on ^{238}U on Pb	27 n/p 17 n/p	55 30

Alternative Neutron Producing Reactions

Reaction	Beam Energy (MeV)	Beam Power (kW)	Neutron Production Rate (n/s)
$T(d,n)^4He$	~0.3	0.05	10^9
Be(d,n)	1	0.12	10^{10}
Be(p,n)	11	11	10^{13}
Be(p,n)	13	30	10^{14}
Li(d,n)	20-30	100	10^{15}
Spallation	400-1000	100	10^{16}

Neutron Spectra from different reactions