Logistics of a Movable, Scanning Electron Beam

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Movable, Scanning Electron Beam

PRESENTATION OUTLINE

- INTRODUCTION
- EB APPLICATIONS
- TECHNICAL ASPECTS
- RHODOTRON ACCELERATORS
- ELECTRON BEAM FACILITIES
- CURING OF COMPOSITES
- CONCLUSION

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INTRODUCTION

- Many Electron Beam Facilities
- A Variety of EB Applications
- Most Accelerators Less Than 5 MeV
- New EB Technology Above 5 MeV
- High-Energy Applications Increasing

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ELECTRON BEAM APPLICATIONS

- Crosslinking Plastic and Rubber Products
- Sterilizing Single-Use Medical Devices
- Disinfesting and Pasteurizing Foods
- Protecting the Environment
- Modifying Semiconductors and Gemstones
- Curing Composite Structures

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TECHNICAL ASPECTS

- Temperature Rise vs Absorbed Dose
- Product Penetration vs Electron Energy
- Area Throughput vs Electron Beam Current
- Mass Throughput vs Electron Beam Power

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TEMPERATURE RISE VS ABSORBED DOSE

- $\Delta T = 0.239\ D / c$
- ΔT = Temperature Rise in Degrees Celsius
- D= Absorbed Dose in kGy
- c = Thermal Capacity in cal/g degree celsius
- A dose of 10 kGy increases the temperature of water about 2.4 degrees C and plastics about 5 degrees C.

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PENETRATION VS ELECTRON ENERGY

- Treatment from One Side
- Equal Entrance and Exit Doses
- E = Electron Energy in MeV
- Z = Thickness x Density in g/sq cm
- $Z = 0.37 (E - 0.20)$
- Z = 3.6 cm of Water at 10 MeV

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AREA THROUGHPUT VS BEAM CURRENT

- Unity Rule for High-Energy Electrons
- A beam current of 1 mA delivers a surface dose of about 1 Mrad (10 kGy) to water-like material which moves with an area throughput rate of 1 sq m/min.
- For example: a 10 MeV, 150 kW, 15 mA beam can deliver a surface dose of about 15 Mrad (150 kGy) with an area throughput rate of 1 sq m/min.

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MASS THROUGHPUT VS BEAM POWER

- Unity Rule for High-Energy Electrons
- An absorbed beam power of 1 kW delivers an average dose of 1 kGy (0.1 Mrad) to material which moves with a mass throughput rate of 1 kg/see.
- The absorbed beam power is usually in the range of 25% to 50% of the incident beam power. This factor depends on the configuration of the material.

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RHODOTRON ACCELERATORS

- Operating Concepts
- Photographs
- Performance Specifications
- Special Features

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RHODOTRON ACCELERATORS

Performance Specifications

● Model	TT1OO	TT200	TT300
● Energy (MeV)	3-10	1-10	1-10
● Power (kW)	0-35	0-80	0-150
● MeV/Pass	0.83	1.0	1.0
● No. of Passes	12	10	10

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RHODOTRON ACCELERATORS

Special Features

- High Electrical Efficiency
- Wide Temperature Range
- Short Start-up and Restart Cycles
- Convenient Programmable Logic Controls
- Versatile Beam Transport and Scanning Systems

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ELECTRON BEAM FACILITIES

- Accelerators can be oriented in any direction.
- Beam direction is usually horizontal or vertical.
- Beam direction can be changed with magnets.
- High-energy EB facilities need thick shielding walls.
- Entrance can be through labyrinths or heavy doors.
- Ventilation is needed to remove ozone gas.

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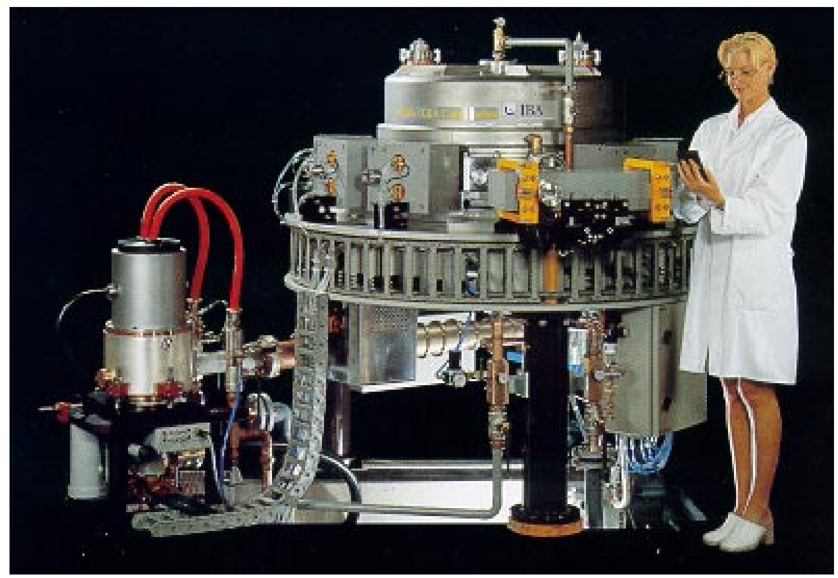
CURING OF COMPOSITE STRUCTURES

Rhodotron Capabilities

- Divergent Beam Scanning
- Parallel Beam Scanning
- Offset Beam Scanning
- Variable Scanning Direction
- Moving Accelerator Platform

Movable Rhodotron

- The Rhodotron can be mounted on a movable platform.
- Platform should hold the following Rhodotron elements in a fixed "relative" position.
  - Rhodotron cavity
  - Scan horn
  - Tetrode assembly
- Tetrode assembly can be relocated.



ION BEAM APPLICATIONS

Movable Rhodotron - Range

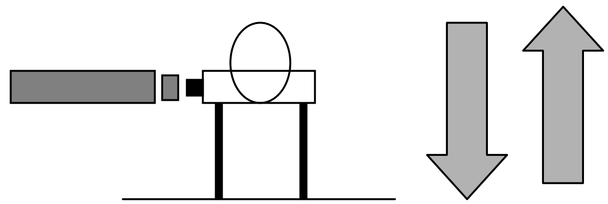
- RF signal line
  - unrestricted distance from main PS and controls.
  - estimated 25% per 100 m power loss in the RF coax signal line to tetrode is easily compensated.
  - signal line bending radius of 1 meter.
  - rotating coupler at interface of signal line and platform.
- Cooling lines
  - limited distance to reservoir and heat exchanger or mount them on the platform.

Movable Rhodotron - Shielding

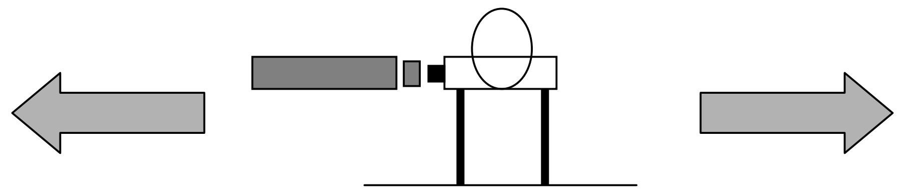
- Rhodotron should be housed in a metallic box.
  - positive air pressure within box to protect against ozone.
  - metallic, to shield against the influence of the earth's magnetic field in different orientations.
  - metallic, to act as an RF shield, if located near an airfield.
- X-Ray shielding of Rhodotron is not necessary.
  - enhanced inspection and maintenance program for vulnerable components.

Movable Rhodotron - Orientation

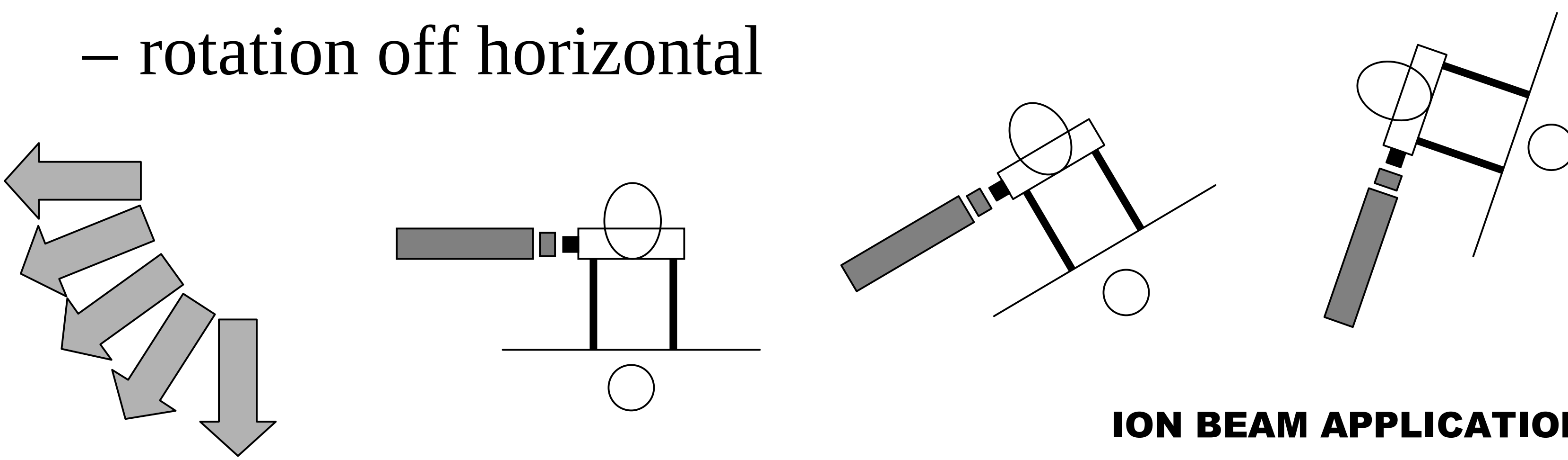
- Degrees of Freedom
  - vertical



  - horizontal

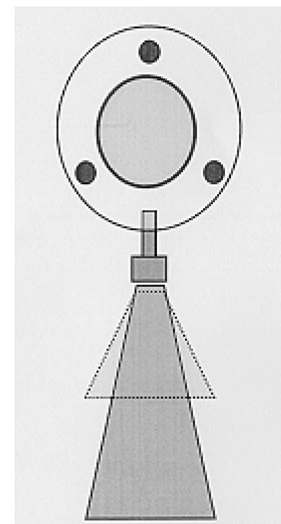


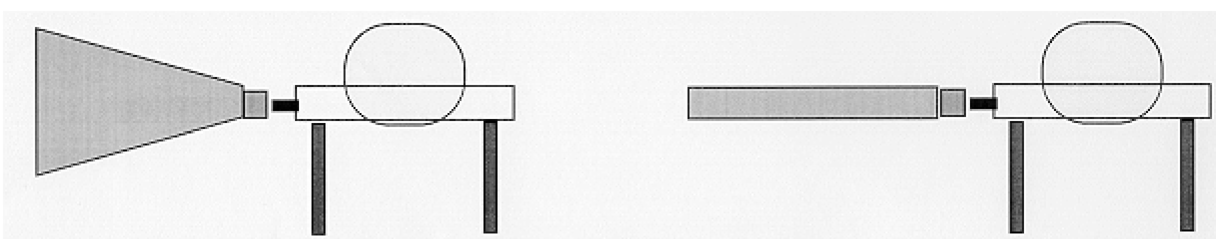
  - rotation off horizontal



Movable Rhodotron - Scan Horn

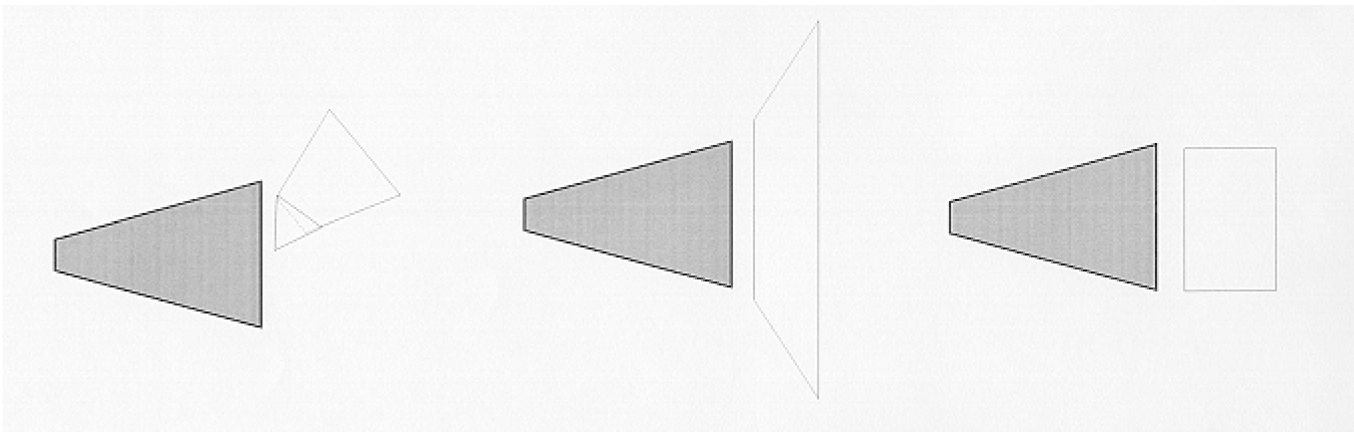
- Horn can be made with wider scan angle.
- Horn axis can be made rotatable.





Movable Rhodotron - Scanning

- Scan offset, divergence, and sweep functions can be used in creative combinations.



Parallel beam

Parallel beam magnets reversed

Parrallel beam magnets reversed, with scan offset and modified sweep

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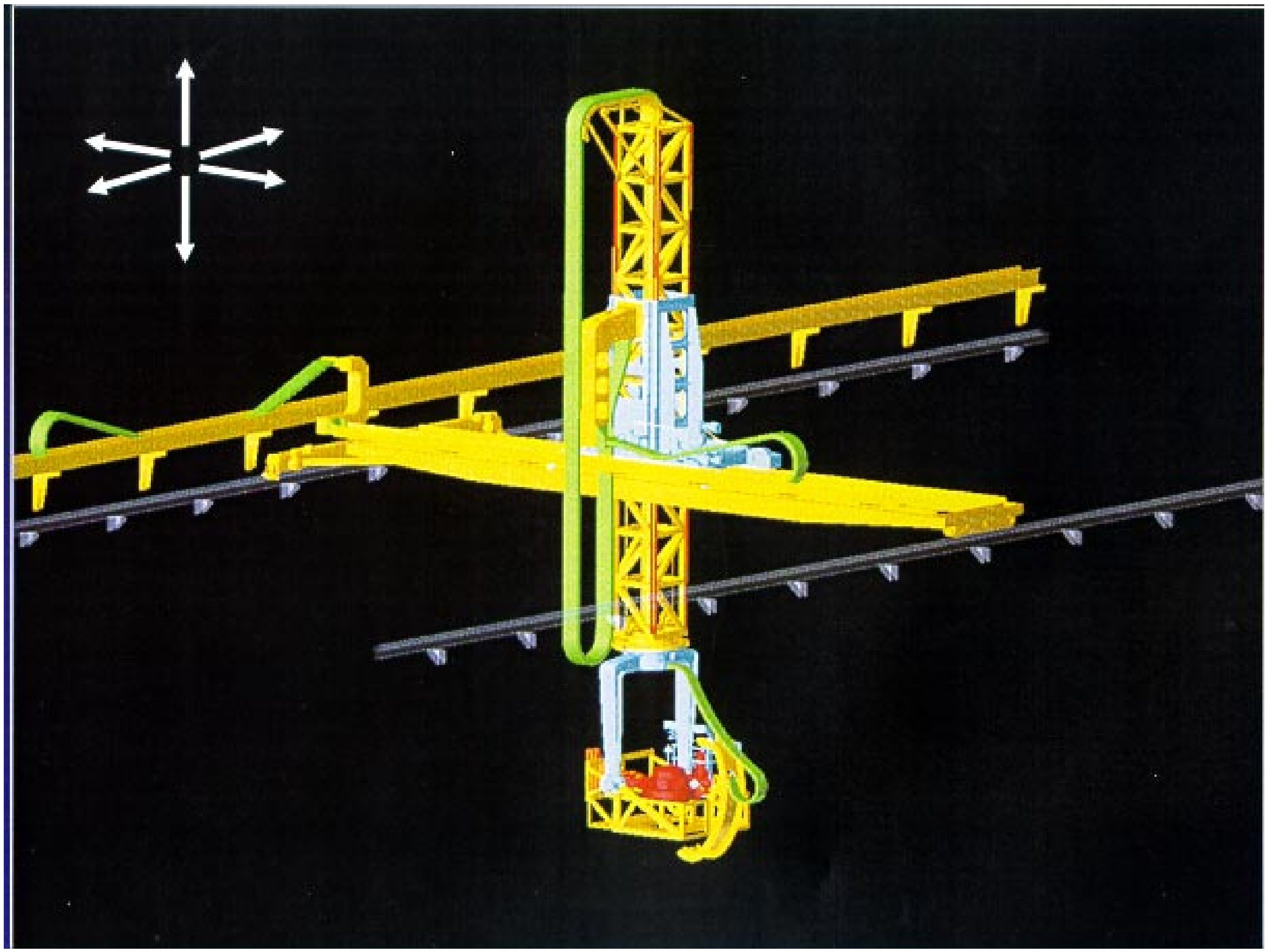
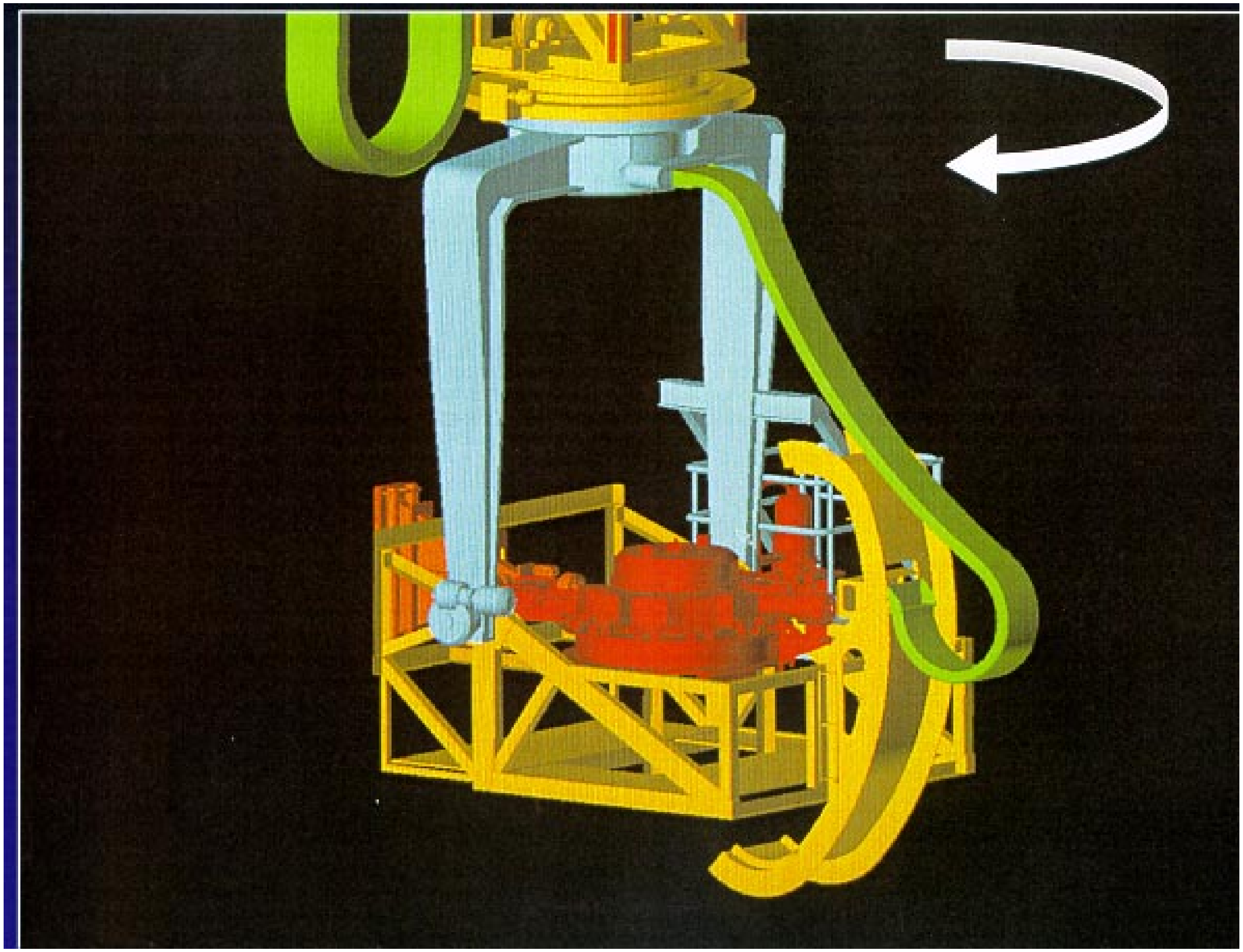
CONCLUSION

Impact of High-Power, High-Energy Accelerators

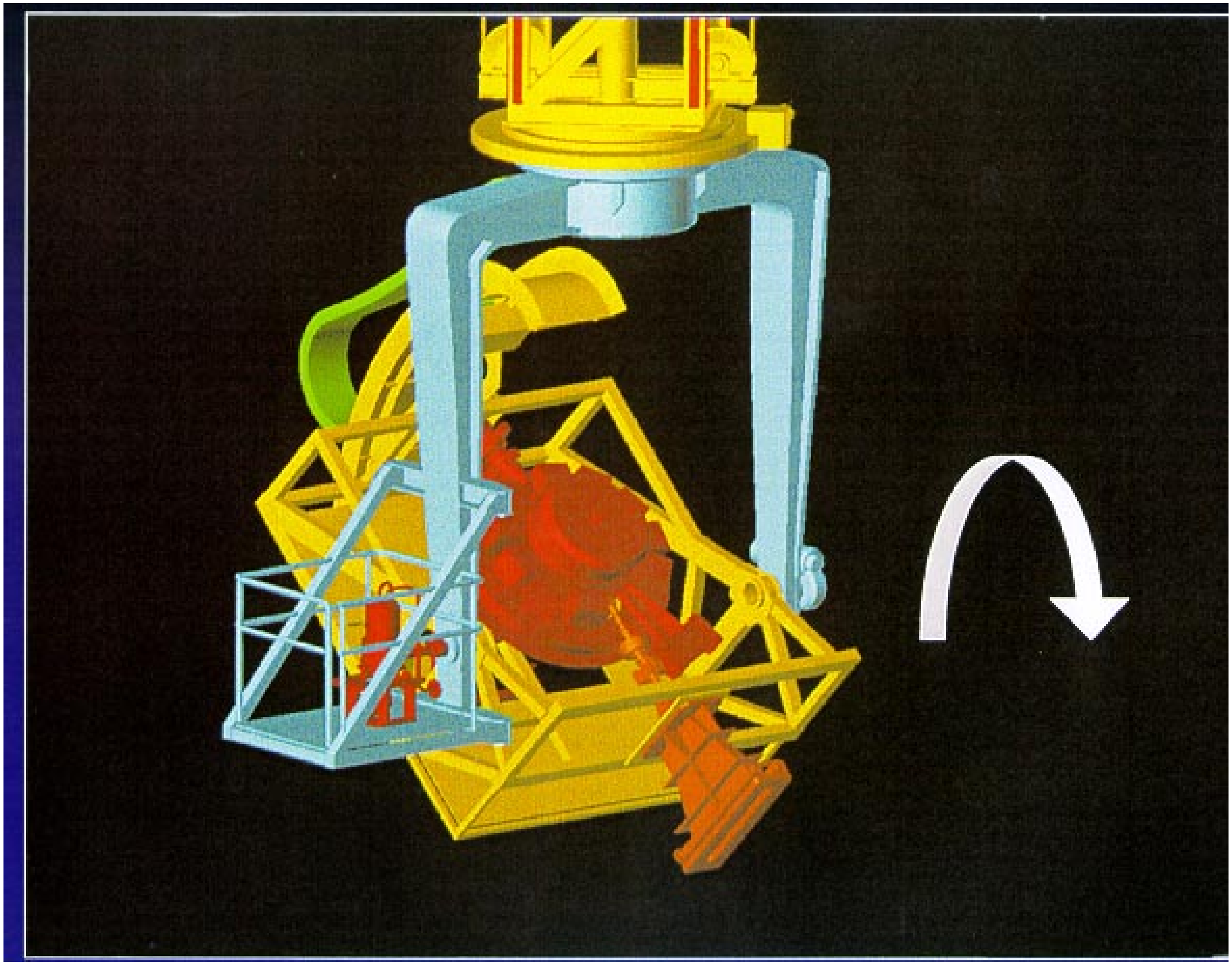
- Greater Variety of Applications
- Especially Suitable for Curing Composites
- Treatment of Thicker, More Complex Products
- More Uniform Dose Distributions
- Shorter Treatment Times



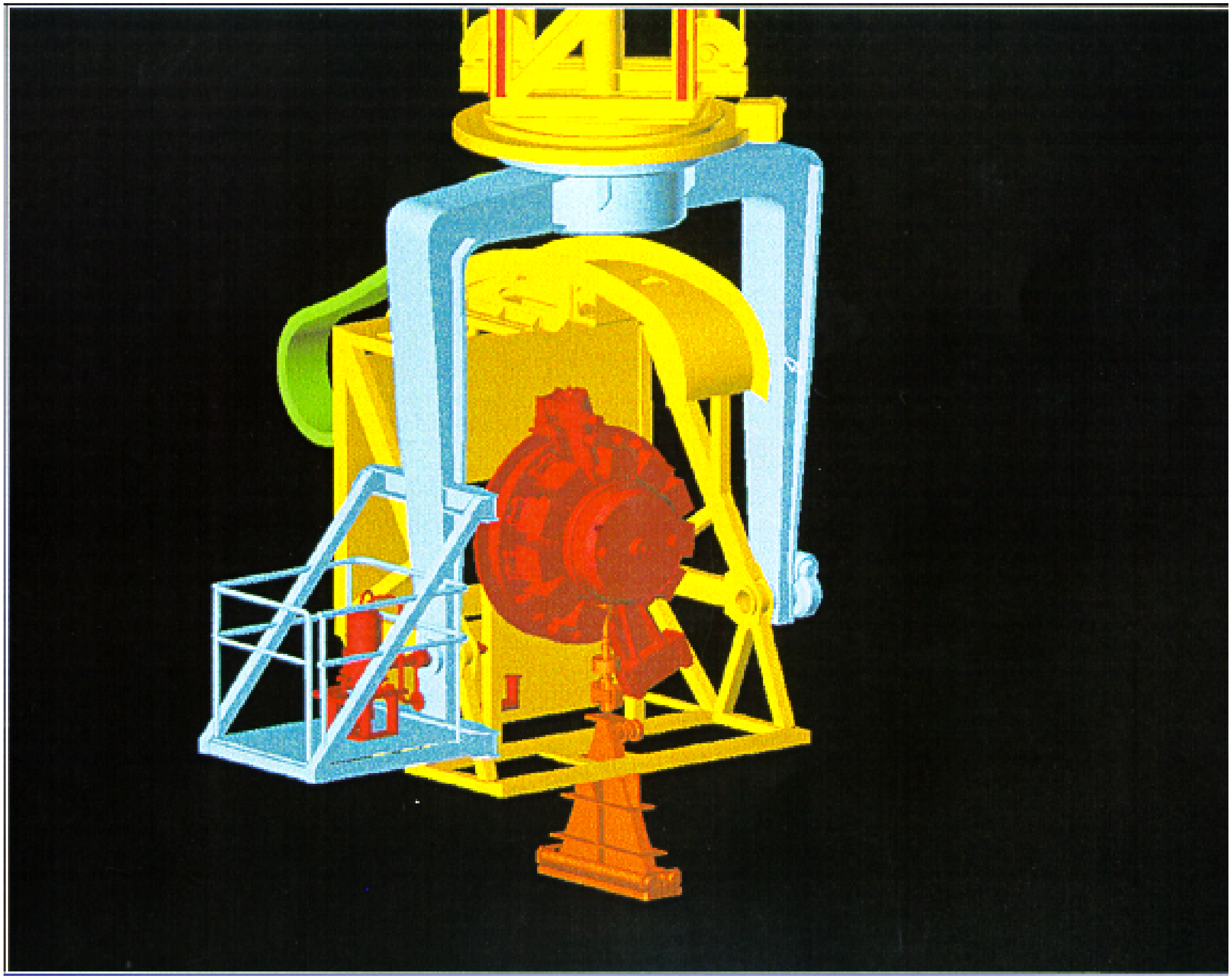
ION BEAM APPLICATIONS



ION BEAM APPLICATIONS



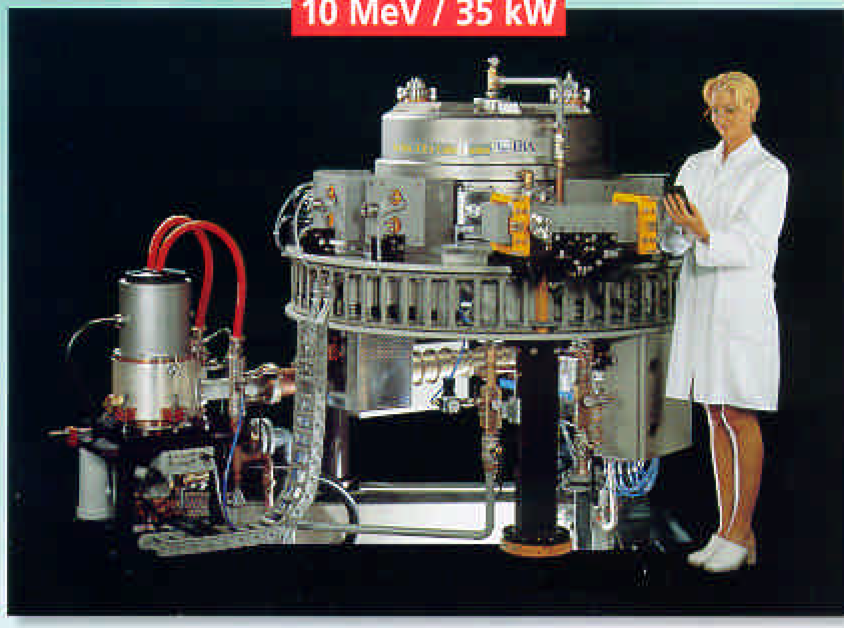
ION BEAM APPLICATIONS



ION BEAM APPLICATIONS

RHODOTRON® TT 100

10 MeV / 35 kW



Key Technical Features	User Benefits
• Up to 10 MeV Electron Beam Energy	• Deep product penetration
• 10 to 35 kW Beam Power	• Lowest unit costs for medical device sterilization
• Advanced Scanning Options (parallel scan, scan offset)	• Highest throughput, improved max/min ratios, less ozone production
• Exceptional Parameter Control (energy, current, scan width)	• Precise, flexible, even and highly reproducible product exposures
• State-of-the-Art Control System	• Easy to validate, operate, maintain, and troubleshoot
• High Electrical Efficiency	• Low operating cost
• Simple and Robust Design	• Proven commercial reliability, low maintenance requirements

IBA

BEAM

Beam energy:	standard	10 MeV
	optional 2nd output	2.5-9.2 MeV
Beam power at 10 MeV:	guaranteed	35 kW
Scanning range:	standard	30 to 100 cm custom configurations available
Beam orientation:	vertical or horizontal	

POWER CONSUMPTION

Stand-by:	<10 kW
At 35 kW beam power:	<210 kW

RF SYSTEM

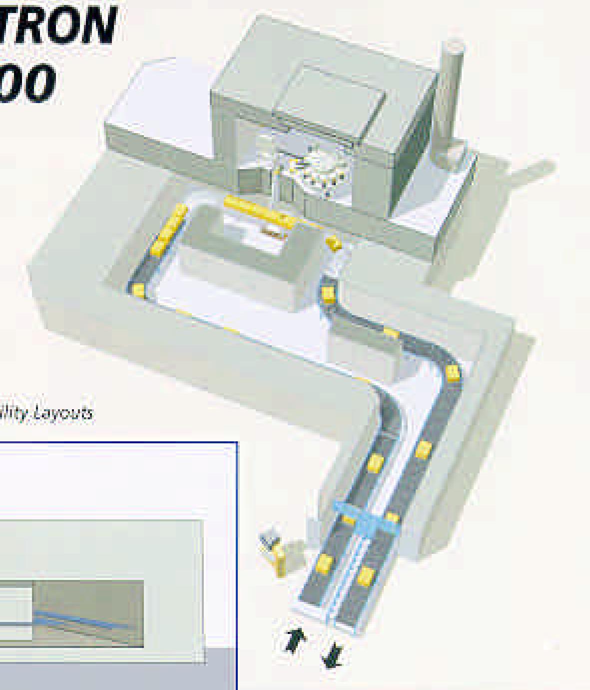
Mode:	Continuous Wave (CW)
Frequency:	215 MHz
Tetrode type:	Thomson TH 781

DIMENSIONS

Cavity outer diameter:	1.05 meters
Cavity height:	0.75 meters
Total diameter:	1.60 meters
Total height:	1.75 meters
Weight:	2.5 metric tons

RHODOTRON TT 100

The compact and versatile Rhodotron TT100 can be configured in many ways including either a vertical scan horn in a two level layout (pictured right) or a horizontal scan horn in a single level layout (pictured below)



Typical Rhodotron TT100 Facility Layouts

IBA

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RHODOTRON® TT 200

10 MeV / 80 kW

Key Technical Features	User Benefits
• Up to 10 MeV Electron Beam Energy	• Deep product penetration
• Up to 80 kW Beam Power	• Highest throughput and lowest unit processing cost
• Advanced Scanning Options (parallel scan, scan offset)	• Highest throughput, improved max/min ratios, less ozone production
• Exceptional Parameter Control (energy, current, scan width)	• Precise, flexible, even and highly reproducible product exposures
• State-of-the-Art Control System	• Easy to validate, operate, maintain, and troubleshoot
• High Electrical Efficiency	• Low operating cost
• Simple and Robust Design	• Proven commercial reliability, low maintenance requirements

IBA

BEAM

Beam energy:	standard optional 2nd output	10 MeV 1-9 MeV
Beam power at 10 MeV:	guaranteed	80 kW upgradable to a TT300
Scanning range:	standard	30 to 100 cm custom configurations available
Beam orientation:	vertical or horizontal	

POWER CONSUMPTION

Stand-by:	<15 kW
At 80 kW beam power:	<260 kW

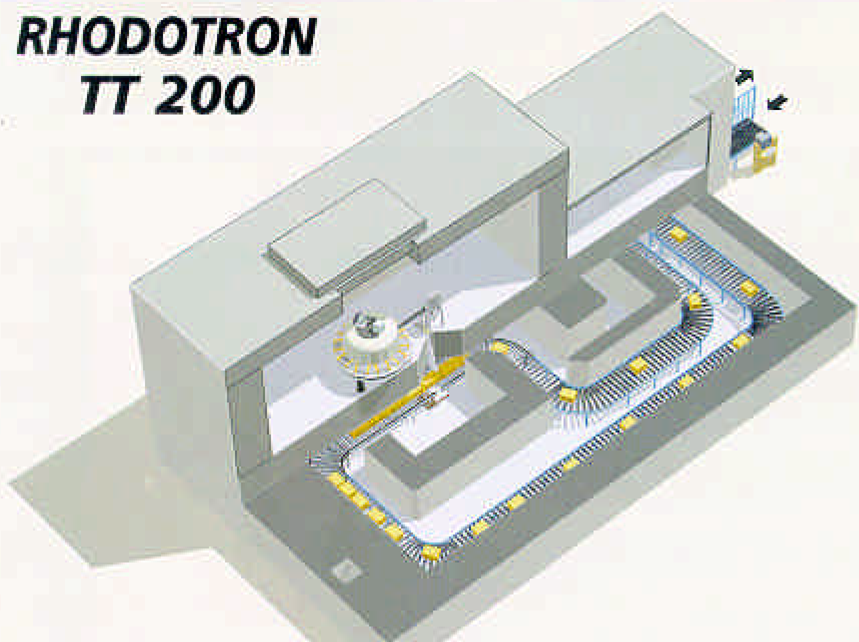
RF SYSTEM

Mode:	Continuous Wave (CW)
Frequency:	107.5 MHz
Tetrode type:	Thomson TH 681

DIMENSIONS

Cavity outer diameter:	2.0 meters
Cavity height:	1.8 meters
Total diameter:	3.0 meters
Total height:	2.4 meters
Weight:	11 metric tons

RHODOTRON TT 200



Typical Rhodotron TT200 Facility Layout

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RHODOTRON® TT 300

10 MeV / 150 kW

Key Technical Features	User Benefits
• Up to 10 MeV Electron Beam Energy	• Deep product penetration
• Up to 150 kW Beam Power	• Highest throughput and lowest unit processing cost
• Advanced Scanning Options (parallel scan, scan offset)	• Highest throughput, improved max/min ratios, less ozone production
• Exceptional Parameter Control (energy, current, scan width)	• Precise, flexible, even and highly reproducible product exposures
• State-of-the-Art Control System	• Easy to validate, operate, maintain, and troubleshoot
• High Electrical Efficiency	• Low operating cost
• Simple and Robust Design	• Proven commercial reliability, low maintenance requirements

IBA

BEAM

Beam energy:	standard	10 MeV
	optional 2nd output	1-9 MeV
Beam power at 10 MeV:	guaranteed	150 kW higher guaranteed ratings available
Scanning range:	standard	30 to 100 cm custom configurations available
Beam orientation:	vertical or horizontal	

POWER CONSUMPTION

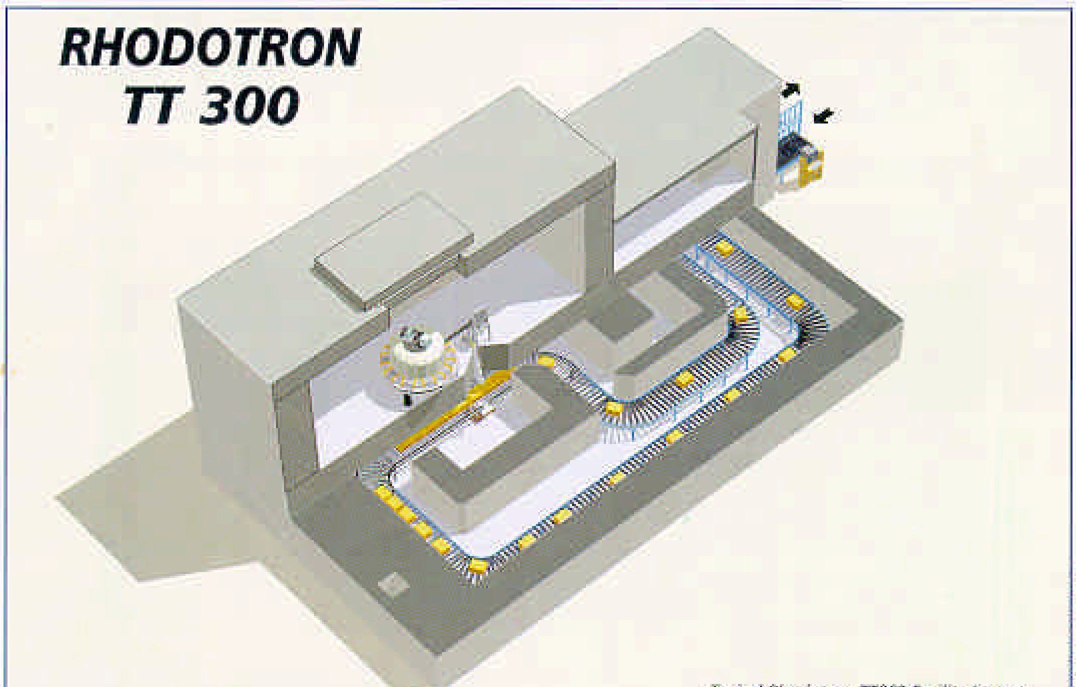
Stand-by:	<15 kW
At 150 kW beam power:	<370 kW

RF SYSTEM

Mode:	Continuous Wave (CW)
Frequency:	107.5 MHz
Tetrode type:	Thomson TH 781

DIMENSIONS

Cavity outer diameter:	2.0 meters
Cavity height:	1.8 meters
Total diameter:	3.0 meters
Total height:	2.4 meters
Weight:	11 metric tons



Typical Rhodotron TT300 Facility Layout

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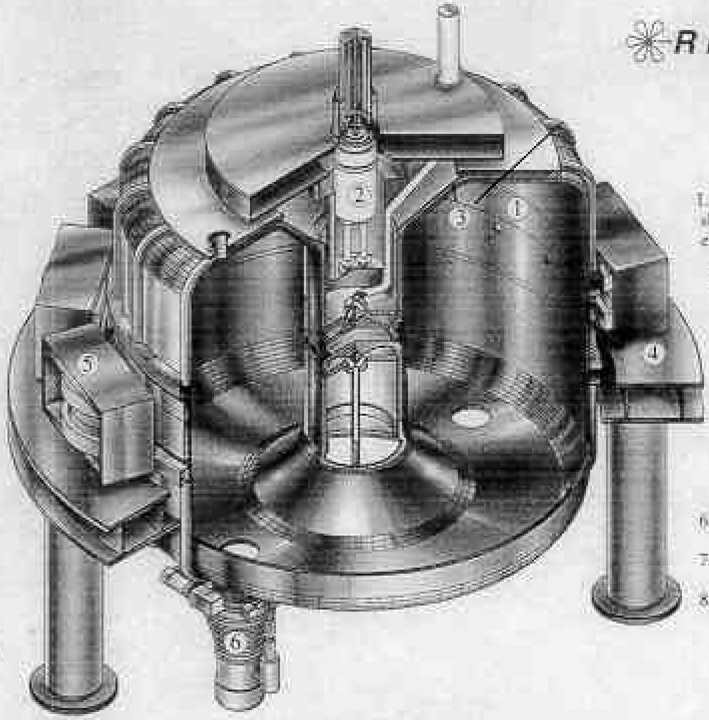
RHODOTRON®



1. Coaxial cavity, made of rolled, shaped and welded plates of steel, electrochemically copper-plated

2. RF amplifier

3. Cooling system composed of a water jacket placed on the inner conductor and end flanges, and of discrete water channels on the outer diameter

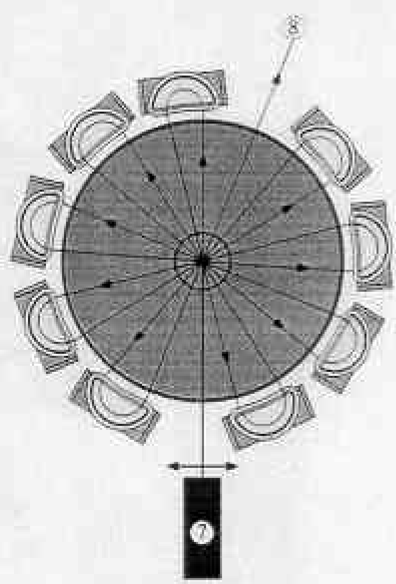
4. Supporting ring

5. Deflecting magnets

6. Vacuum system

7. Electron gun

8. 10 MeV beam exit



Operating Principle

The Rhodotron repetitively accelerates electrons across a coaxial cavity. The electrons undergo a first acceleration when fired from an external electron gun through openings in the outer cavity towards the inner conductor. As they emerge on the other side of the inner conductor, the radial electric field is reversed, giving them a second acceleration. The beam leaves the cavity, then is bent by a small external magnet, sending the electrons back towards the inner conductor. The rose-shaped pattern described by the acceleration paths gives rise to the name Rhodotron : "rhodos" in Greek means rose.