REMOTE AFTERLOADER SYSTEMS

-from commissioning to treatment-

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SCOPE

From receiving a remote afterloading system to the safe treatment of patients

Objectives

- Key components to commission a remote afterloading system
- Guidance to facilitate establishing a program
- Estimate the effort/resources required

HDR AFTERLOADERS

GammaMed Plus

MicroSelectron Classic

MicroSelectron HDR

Varian VariSource

Gammamed Treatment Unit - Back

General Features of an HDR Remote Afterloader

- More control than manually loaded sources
- Potential for Conformance to the target volume
- Afterloading adds flexibility to the treatment
- Very high activity source → Shorter Tx times
- Staff protection affords better patient care
- Typically more fractions than LDR

MORE FLEXIBILITY

MORE COMPLEXITY

REQUIRES AN ELABORATE QA PROGRAM

Planning, installation and survey

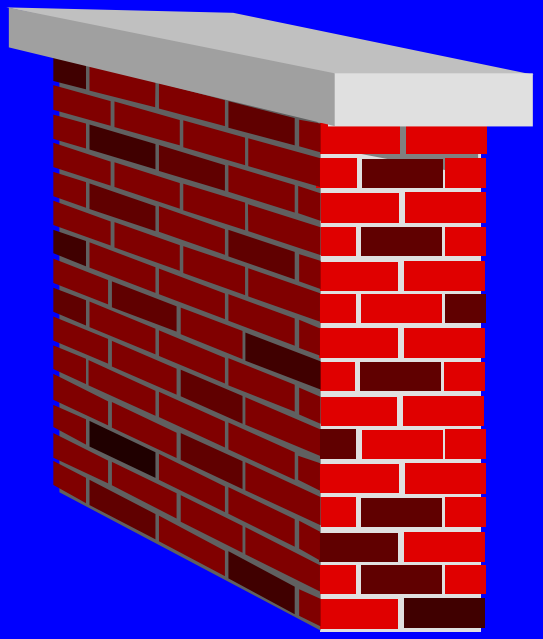
The vault

Safety elements

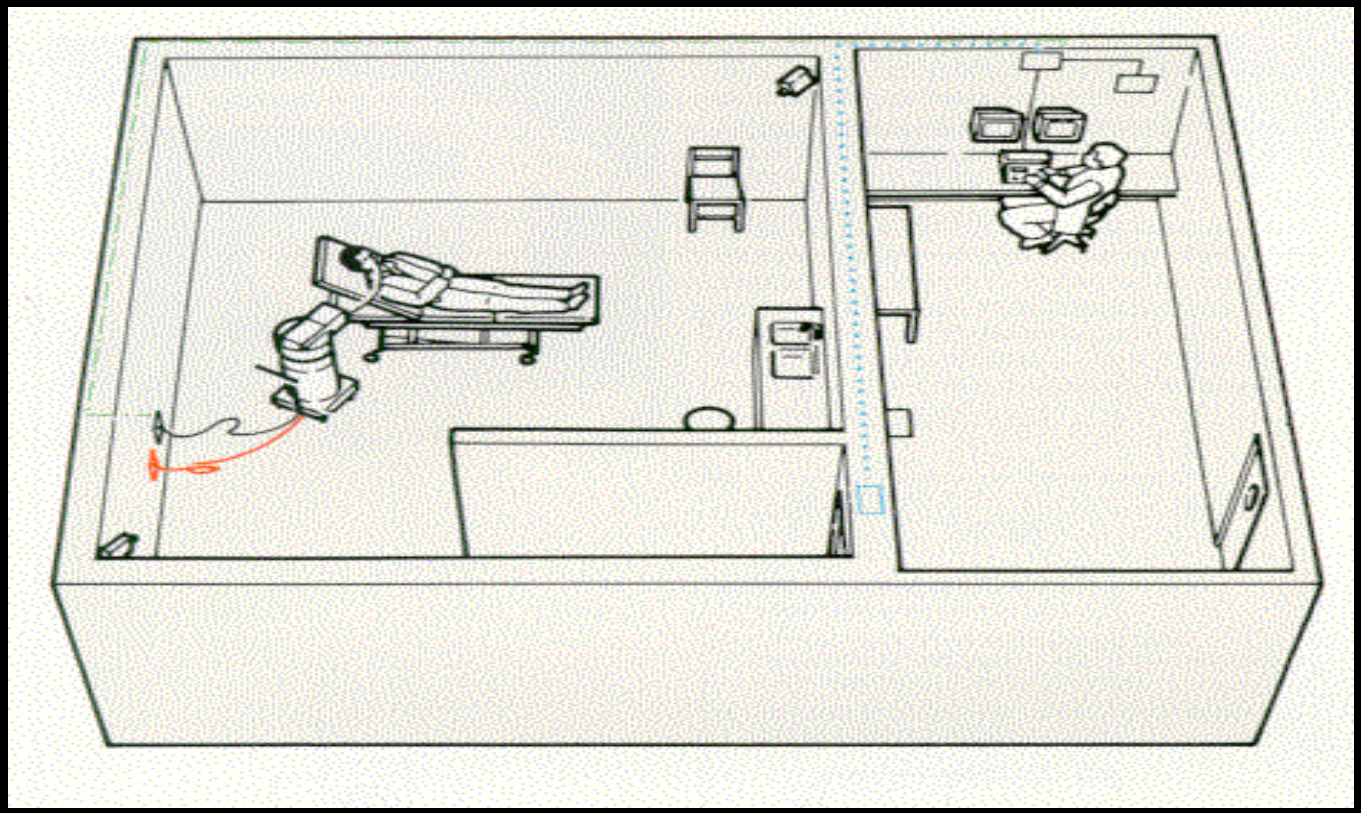
System interfaces

RADIATION PROTECTION

- Shielding plans
- Room survey
- Emergency OFF
- Emergency Procedure
- Independent Monitor
- Patient survey



HDR in a dedicated vault



Better utilization of unit

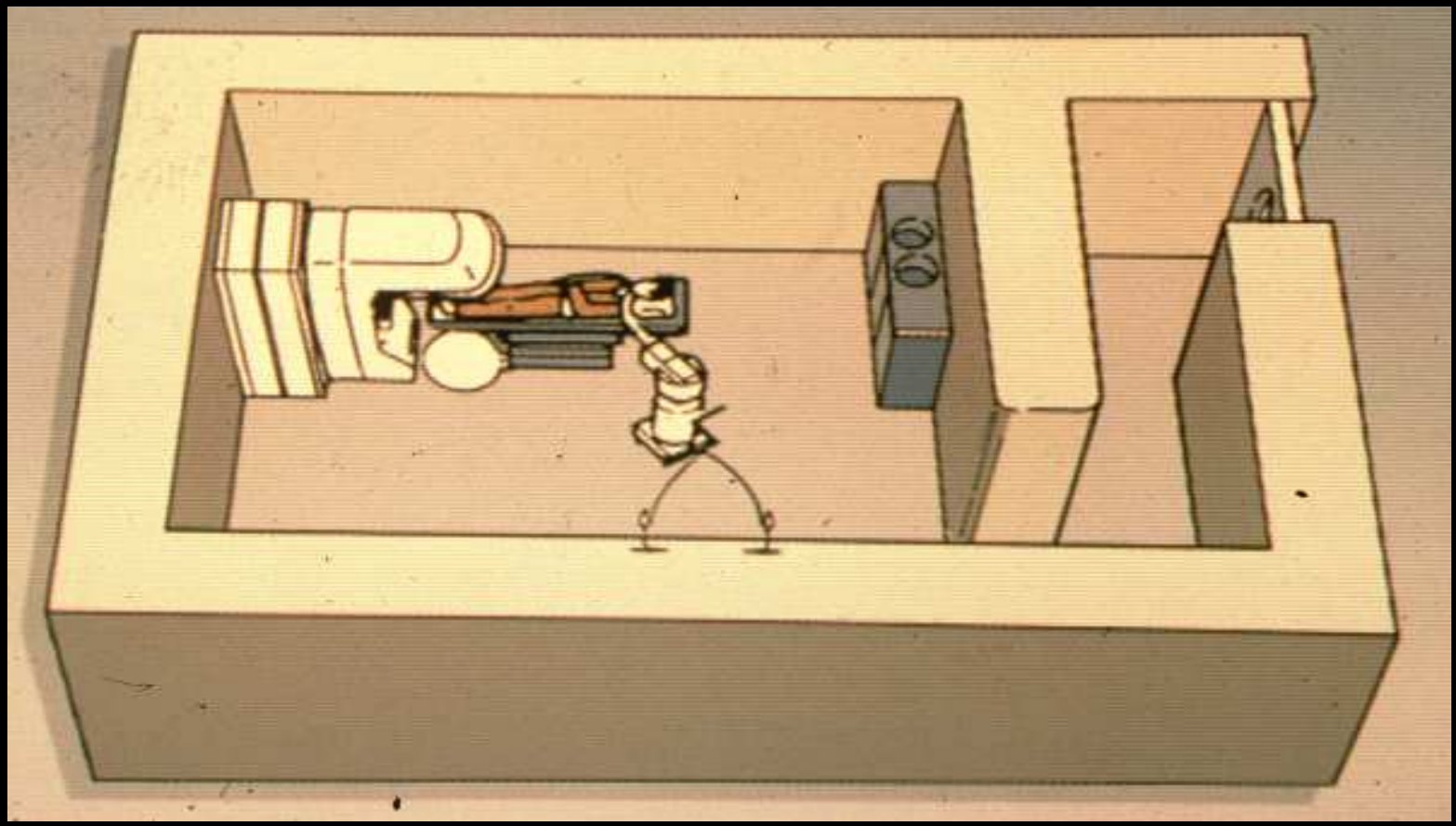
Moderate to high Shielding costs

Integrated controls and planning area

Potential for simulation and treatment with less patient movement

Dedicated storage of accessories

HDR in a Linac vault



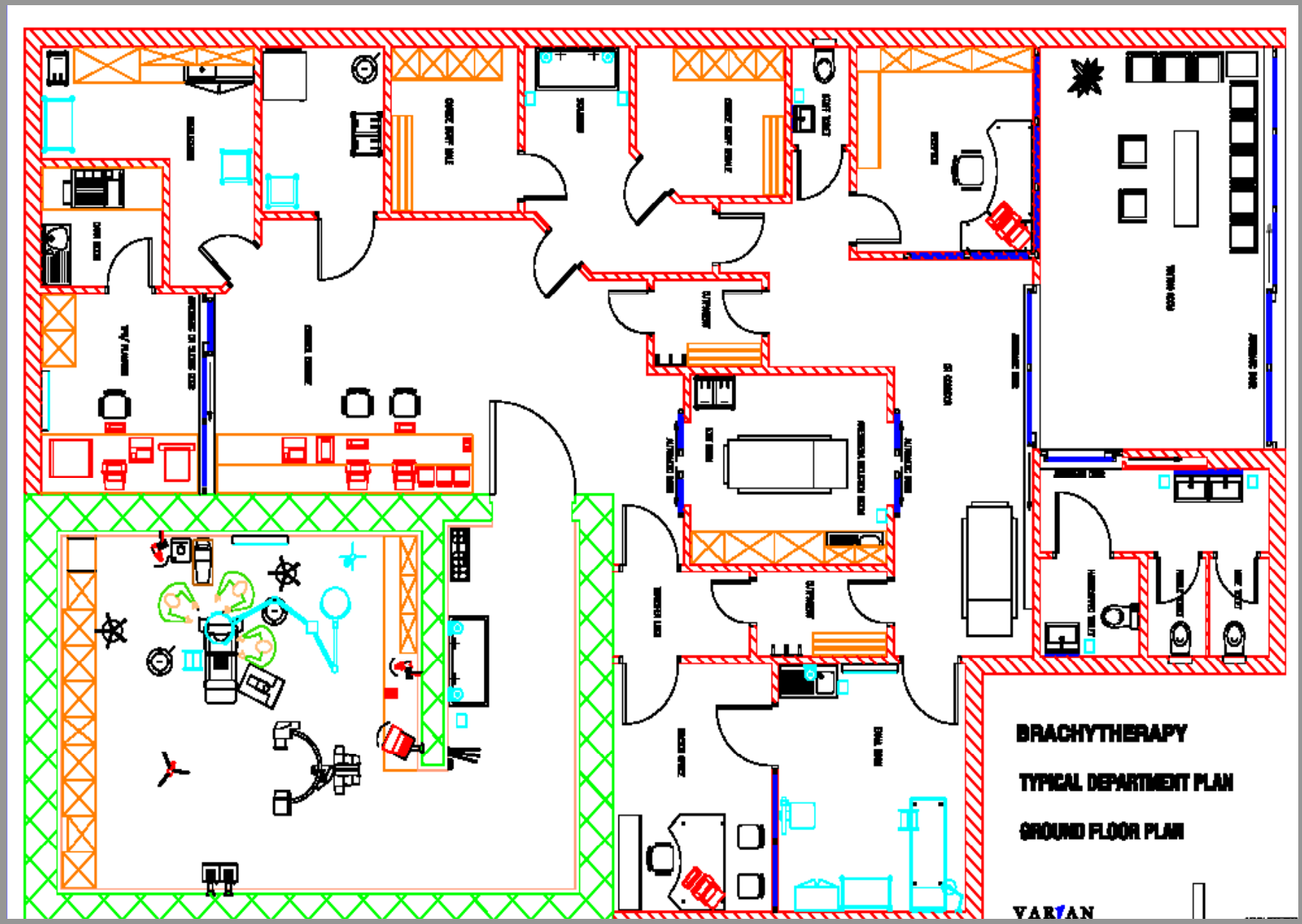
Reduced utilization of both units

Reduced Shielding costs

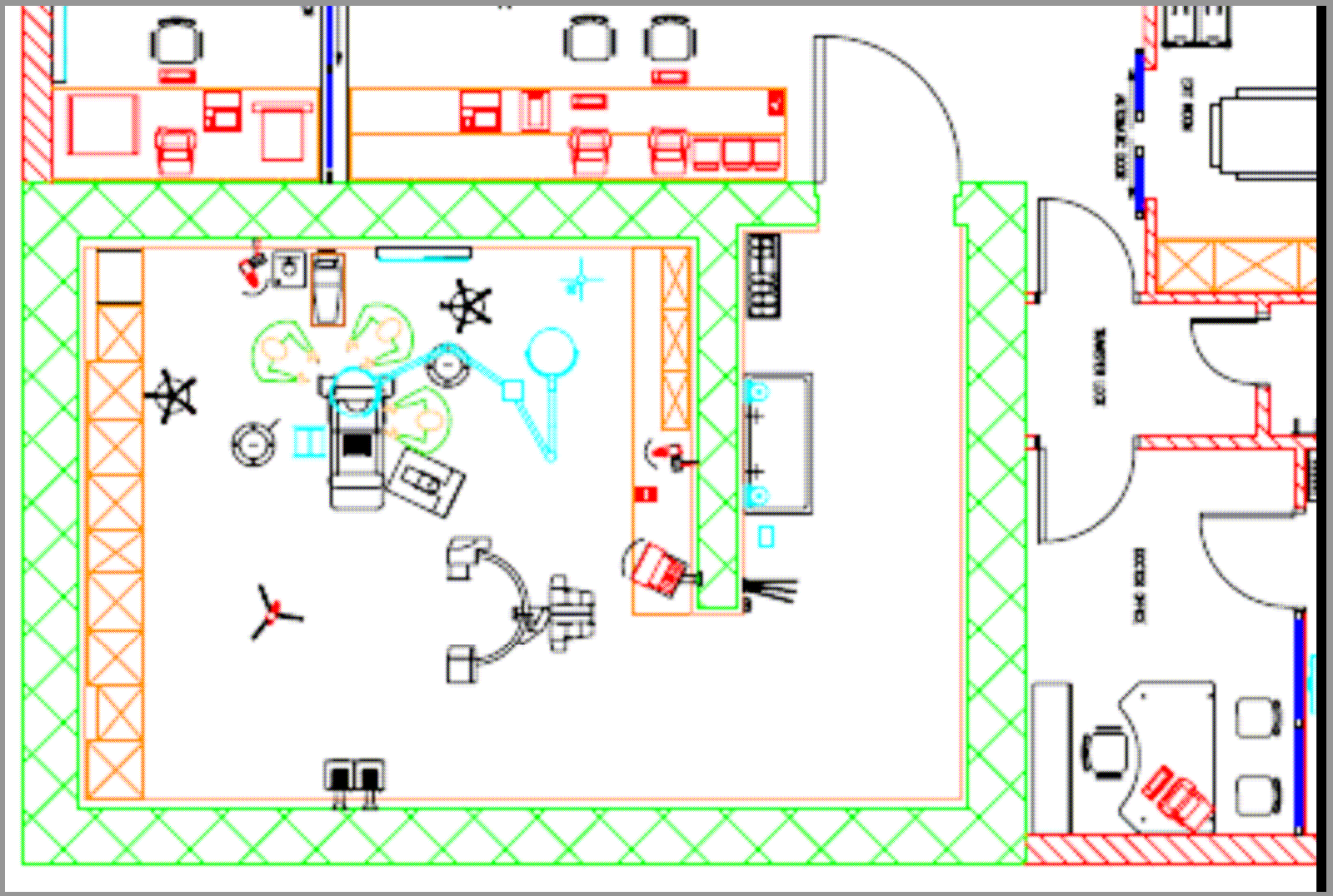
Separate controls and interlocks

Separate area for Planning and storage of accessories

Brachytherapy suite plan



Brachytherapy room detail



Shielding

Shielding for High Dose Rate
Remote Afterloader

Assumptions:

1 patient per hour
300 seconds (maximum) on time for a 10 Curie source per hour
250 treatments/year ⇒ 5 treatments/week. Assume maximum of 10 per week
Source: 10 Curies of Iridium 192
Distance from source to person outside room: 2 meters
Occupational exposure: 5000 mR/yr ⇒ 100 mR/week ⇒ 2.5 mR/hour. Use 2 mR/hour
Γ = 4.72 rads/mCi hr at 1 cm = 0.472 rads/Ci hr at 1 meter

Use: NCRP Report 49, figure 12

Rate for 10 Curie source at 2 meters:

10 x 0.472 / 4 = 1.18 rads / hour

For an instantaneous rate of < 2 mR/hour, need reduction of:

2 / 1180 = 0.0017
Corresponding to 42 cm concrete = 16.5 inches

For an average rate per hour (treatment) of < 2 mR/hour, need reduction of:

2 / 98.3 = 0.020
Corresponding to 26 cm concrete = 10.2 inches
This comes from 300 seconds (= 0.083 hours) effective "on" time per hour

Averaged over a day with a maximum of four patients per day:

2 / 49.2 = 0.041
Corresponding to 21 cm concrete = 8.3 inches

Shielding

- Room Design
- Unit Location
- Shielding Verification
  - **First Source**
  - **Each Source Change**

Shielding Verification

GammaMed Plus Unit Surveys

	Date	10/13/05			1/11/06								
	Meter	Eberline			Inovision								
	Model	E-120			451P								
	Serial #	813			137								
	Background	0.02			0.02								
Housing	Top	0.20			0.13								
	Bottom	0.30			0.18								
	Left	0.04			0.12								
	Right	0.04			0.12								
	Front	0.10			0.24								
	Rear	0.20			0.20								
		Reading	Hourly	Yearly	Reading	Hourly	Yearly	Reading	Hourly	Yearly	Reading	Hourly	Yearly
Area	A	0.02	0.003	1.7	0.02	0.003	1.7		0.000	0.0		0.000	0.0
	B	0.02	0.003	1.7	0.02	0.003	1.7		0.000	0.0		0.000	0.0
	C	0.03	0.005	2.5	0.04	0.007	3.3		0.000	0.0		0.000	0.0
	D	0.12	0.020	10.0	0.06	0.010	5.0		0.000	0.0		0.000	0.0
	E	0.02	0.003	1.7	0.02	0.003	1.7		0.000	0.0		0.000	0.0
	F	0.02	0.003	1.7	0.02	0.003	1.7		0.000	0.0		0.000	0.0
	G	0.03	0.005	2.5	0.03	0.005	2.5		0.000	0.0		0.000	0.0
	H	0.02	0.003	1.7	0.02	0.003	1.7		0.000	0.0		0.000	0.0
	Readings by:	RL			KD / INI								
	RSO Review:												
	Date:	10/13/05			1/11/06								

1 Readings in mR/hour
2 Housing Readings in the source "off" position. Readings at 10 cm from housing. Acceptable: < 1.0 mR/hr
3 Area Readings with source "on." Acceptable (A-G): < 2.0 mR/hr and 5000 mR/year (H): < 0.2 mR/hr and 100 mR/year

GammaMed Survey

3/13/2006

ENVIRONMENT

- Audio/Video Contact
- Indicator lights
- Interlocks
- Controlled access

Commissioning

The unit
The applicators
The planning system
Planning accessories
Image data : sources and transfer

SOURCES

- High activity Iridium-192 – 10 Ci
- Source integrity
- Battery backup for source retraction in case of power loss

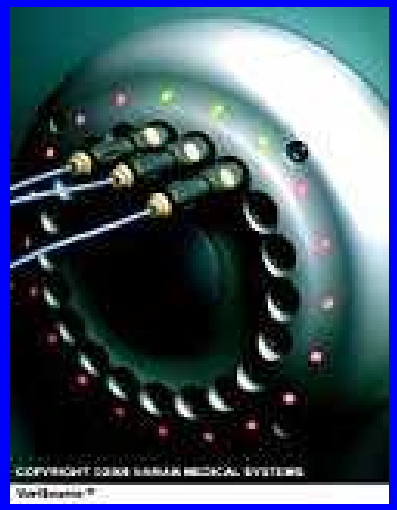
Source Size

- VariSource: 0.6 mm diam. x 5 mm long
- GammaMed: 0.9 mm diam. x 4.5 mm long
- Nucletron: 0.9 mm diam. x 3.5mm long

Source Travel Technique

- VariSource: Pull from most distal source dwell position
- GammaMed: Pull from end of travel
- Nucletron: Push to most distal treatment position

Source and Cable



Source Positioning

- VariSource: 20 channels with 20 positions
- GammaMed: 24 channels / 60 positions
- Nucletron: 18 channels / 48 positions

Source Security

- Locked Storage

Source Security

- Locked Storage
- Locked Room

Source Security

- Locked Storage
- Locked Room
- Multiple Sources of Radiation

Source Security

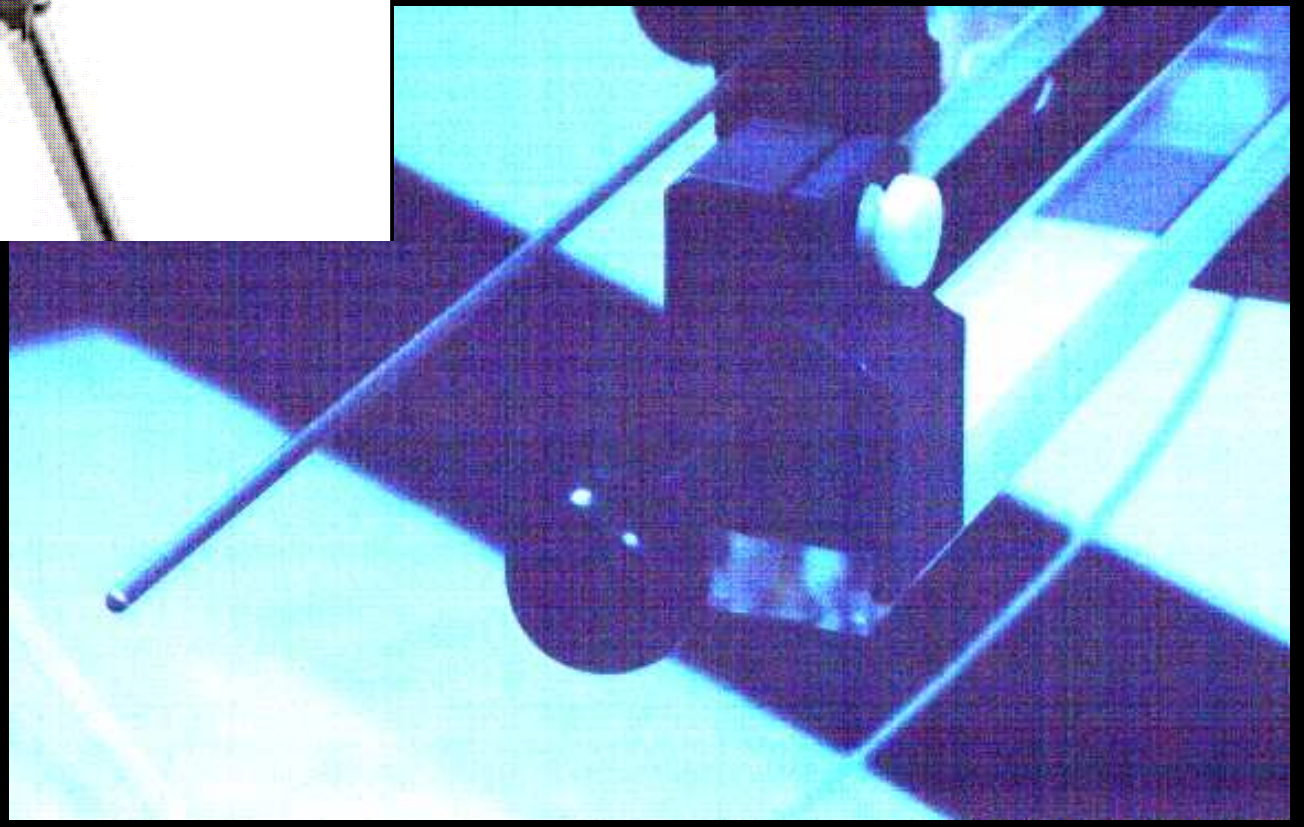
- Locked Storage
- Locked Room
- Multiple Sources of Radiation
- Key Storage

CALIBRATION -HDR

- Timer accuracy
- Transit Time Measurement
- Room scatter
- In-air calibration
- Specialized Well Chambers

Shonka air-equivalent spherical chamber

In-air calibration - chamber and source holder

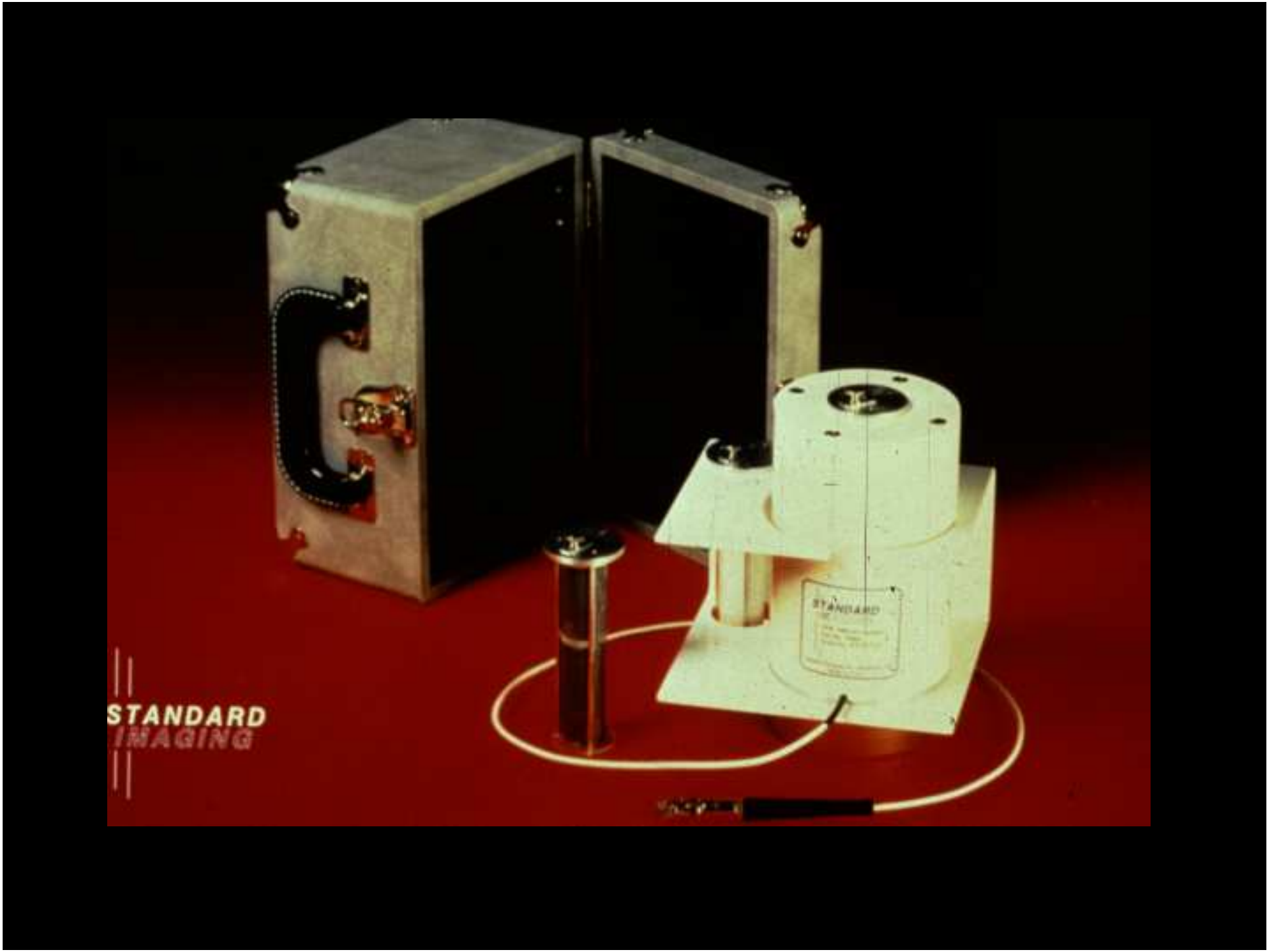


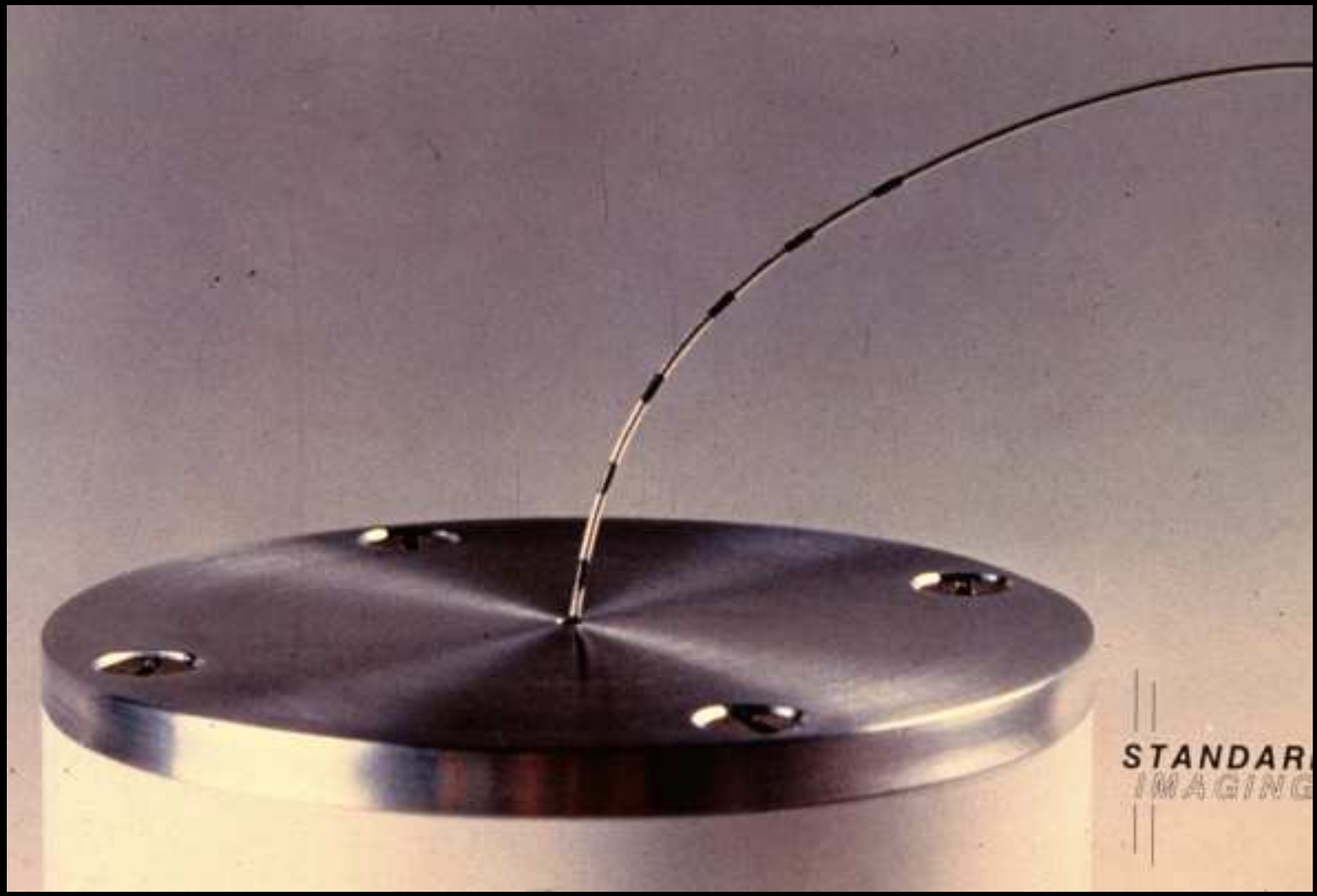
SOURCE CALIBRATION GUIDELINES -I

- Chamber to source distance:
  - accurate to 0.5%
  - small enough so Ion current > 100 x leakage
- Scatter correction small:
  - Corrected by measurements at various distances
  - Shadow shield measurements

SOURCE CALIBRATION GUIDELINES - II

- Chamber calibration by ADCL :
- Factor interpolated between orthovoltage and Cs-137.
- Wall thickness ≥ mg/cm^2 and wall attenuation accounted for.
- Static source technique measuring time between two voltages.


STANDARD
IMAGING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IMAGING


ELECTROMETER

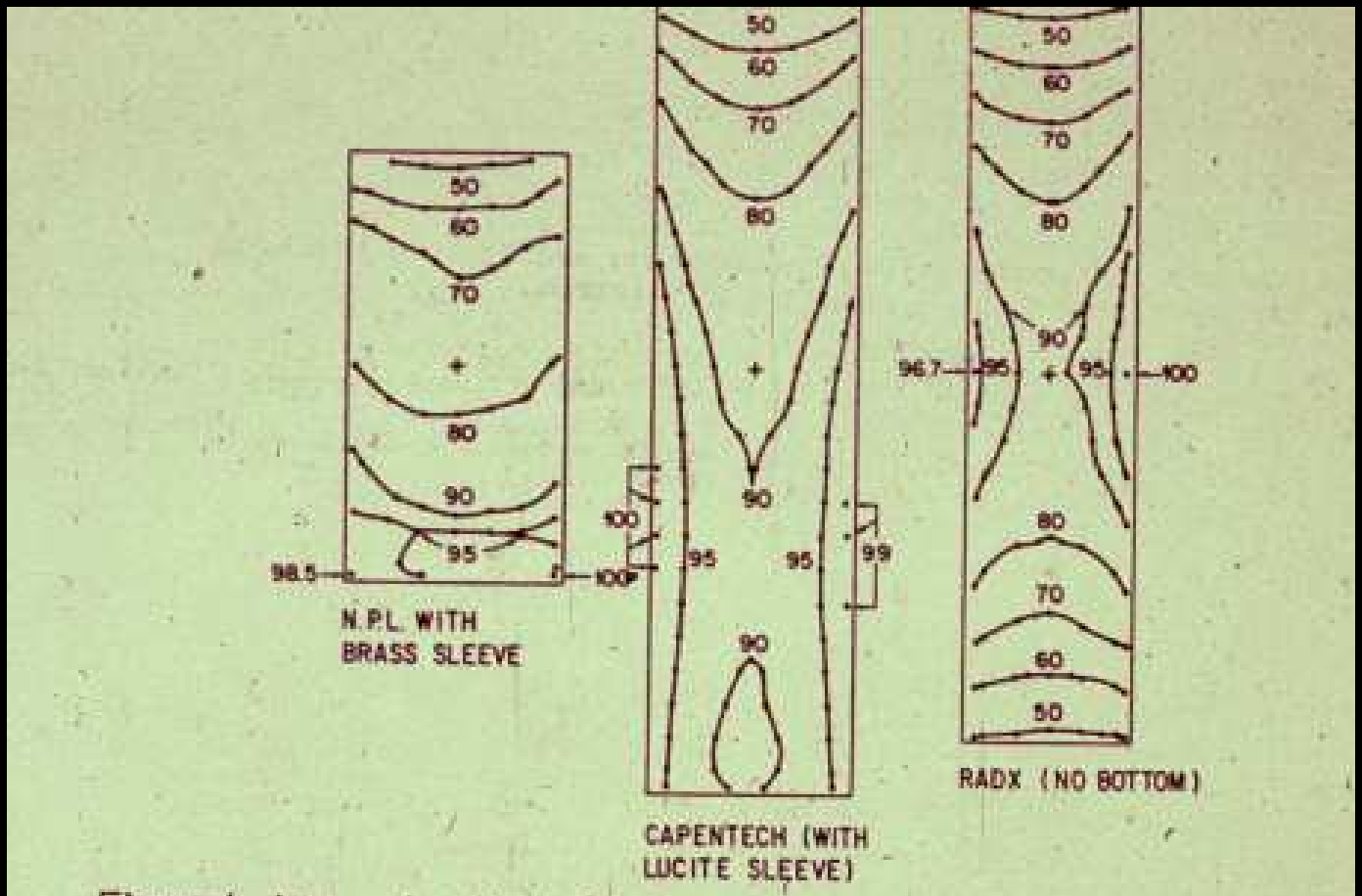


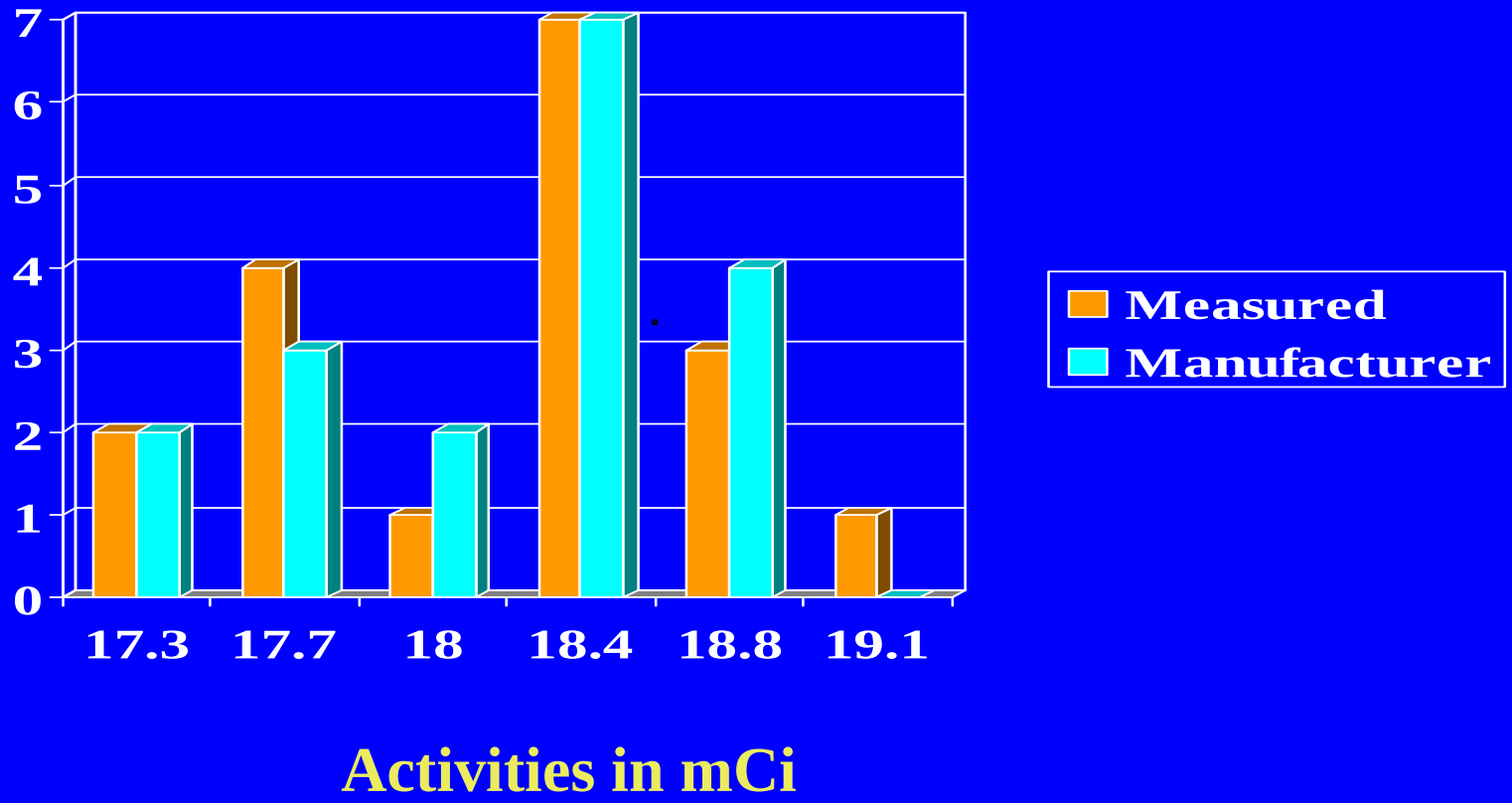
Figure 4. Internal well sensitivity. The lines represent isosensitivity curves within three commercially available well chambers to an ^{192}Ir source. A 0.125 inch thick brass sleeve was presented in the NPL chamber. An 0.125 inch thick lucite sleeve was present in the Capintec chamber. The Radx chamber had no additional well wall sleeve.

CALIBRATION -LDR

- In-air calibration
- Well chamber
- Activity distribution (LDR)


ELECTROMETER

Distribution of Cs pellet activities



EXAMPLES OF BRACHY CALCULATION ERRORS

(Williamson, in *QA in RT Phys*, Med Phys Pub '91)

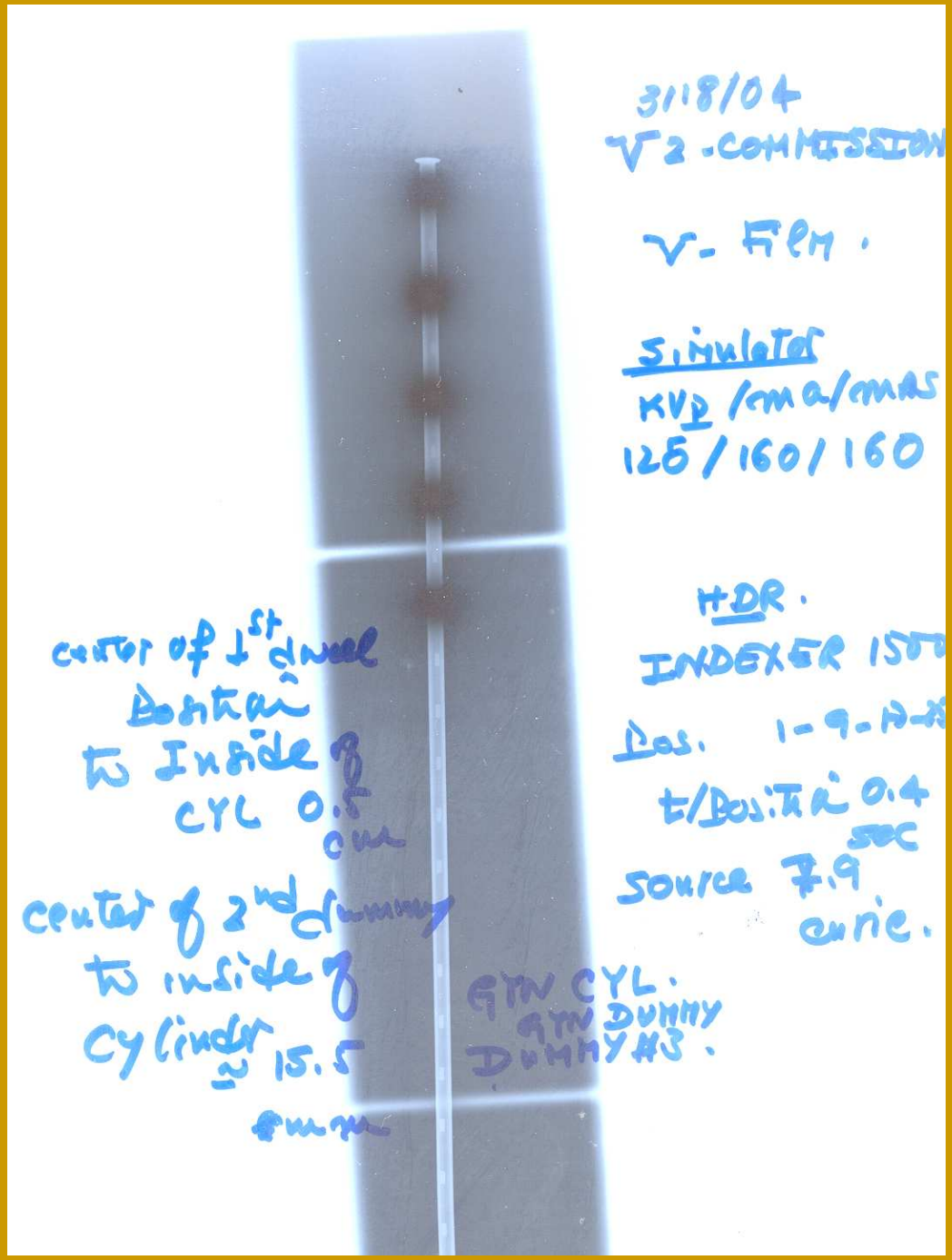
Quantity Involved	Error
• dose in water/ water kerma in free space	wrong units for polynom fitting coefficients: cm instead of mm
• exposure rate const	filtered vs unfiltered
• attenuation coeff	platinum instead of steel
• L, line source approx of seeds in ribbon	anything other than number times spacing

CATHETERS

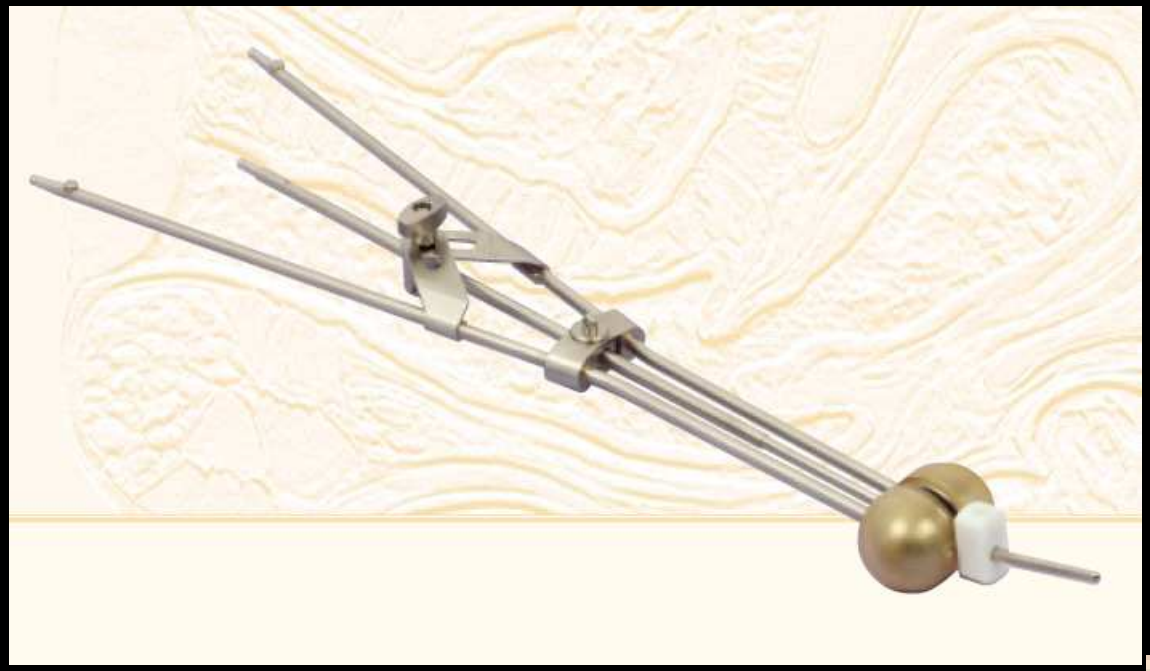
- Reference length with / without fittings
- Catheter coordinates
- Transfer tubes
- Coincidence between sources and markers
- Reproducibility, accuracy
- Curvature limitations

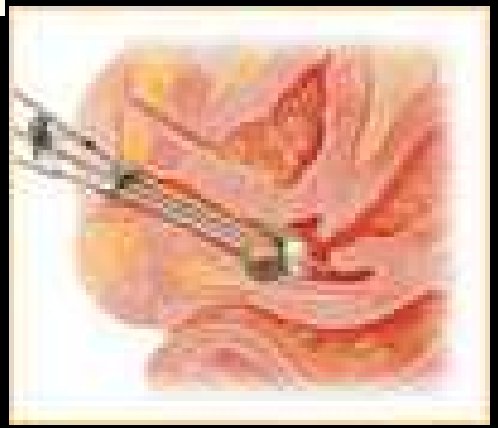
RIGID APPLICATORS

- Condition
- Shields vs. source locations
- Source positions in special applicators
- Comparison with prior systems
- Transfer tubes

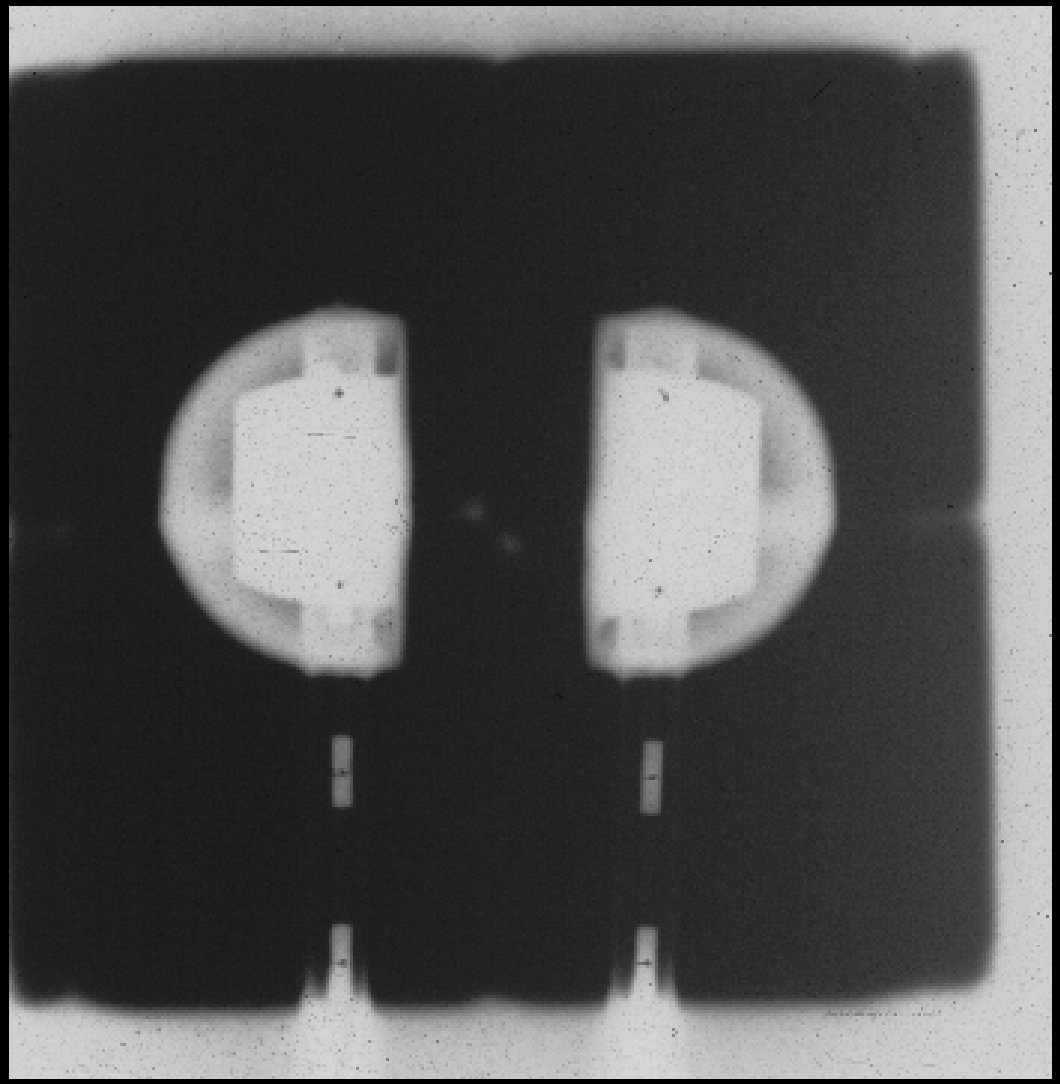

3/18/04
V2 - COMMISSION
V - Film.
Simulator
KVP / ma / mas
125 / 160 / 160
center of 1st dummy
to Inside of
CYL 0.5
cm
center of 2nd dummy
to inside of
Cylinder 15.5
cm
GTN CYL.
GTN DUMMY
DUMMY #3.
HDR.
INDEXER 150
Dos. 1-9-D-
t/Dosi. 0.4
sec
source 7.9
curie.

Henschke HDR Applicator



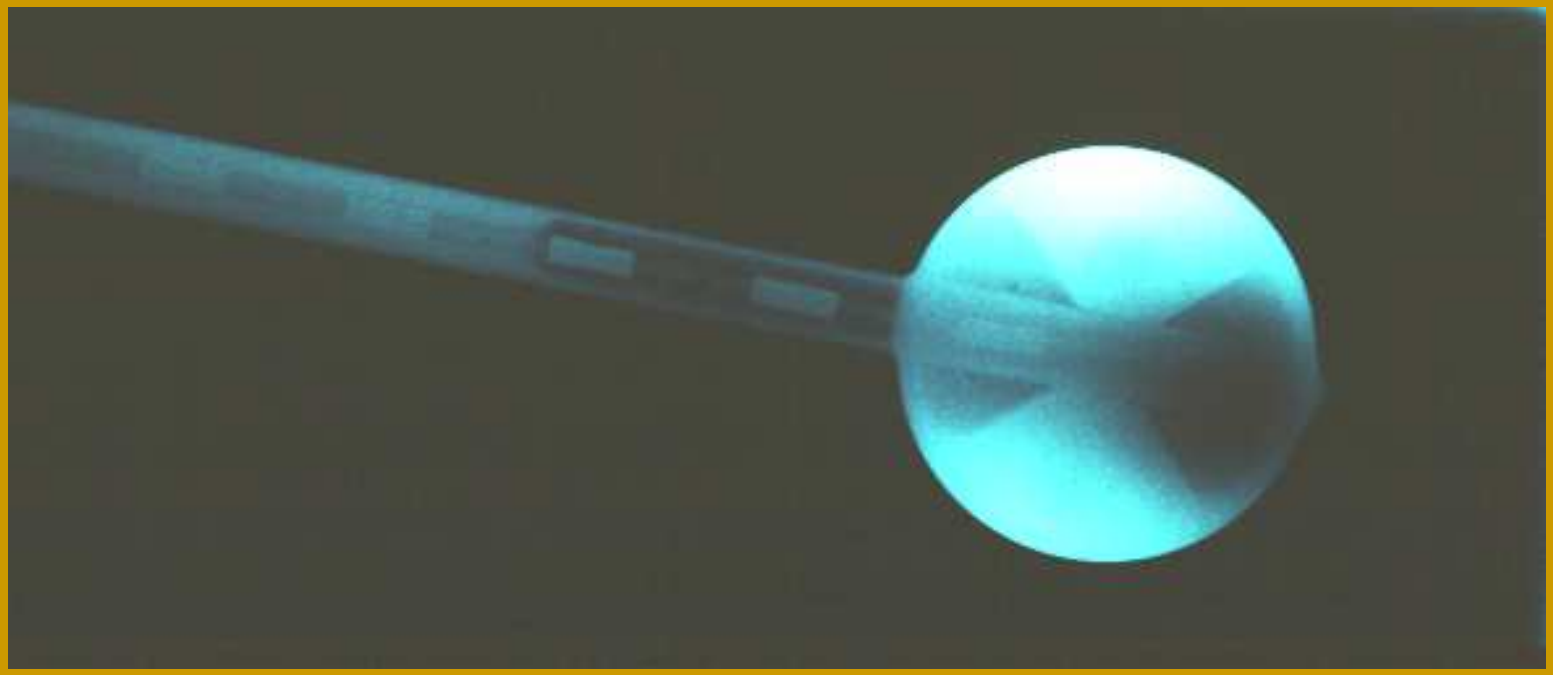


HDR Shields and source locations

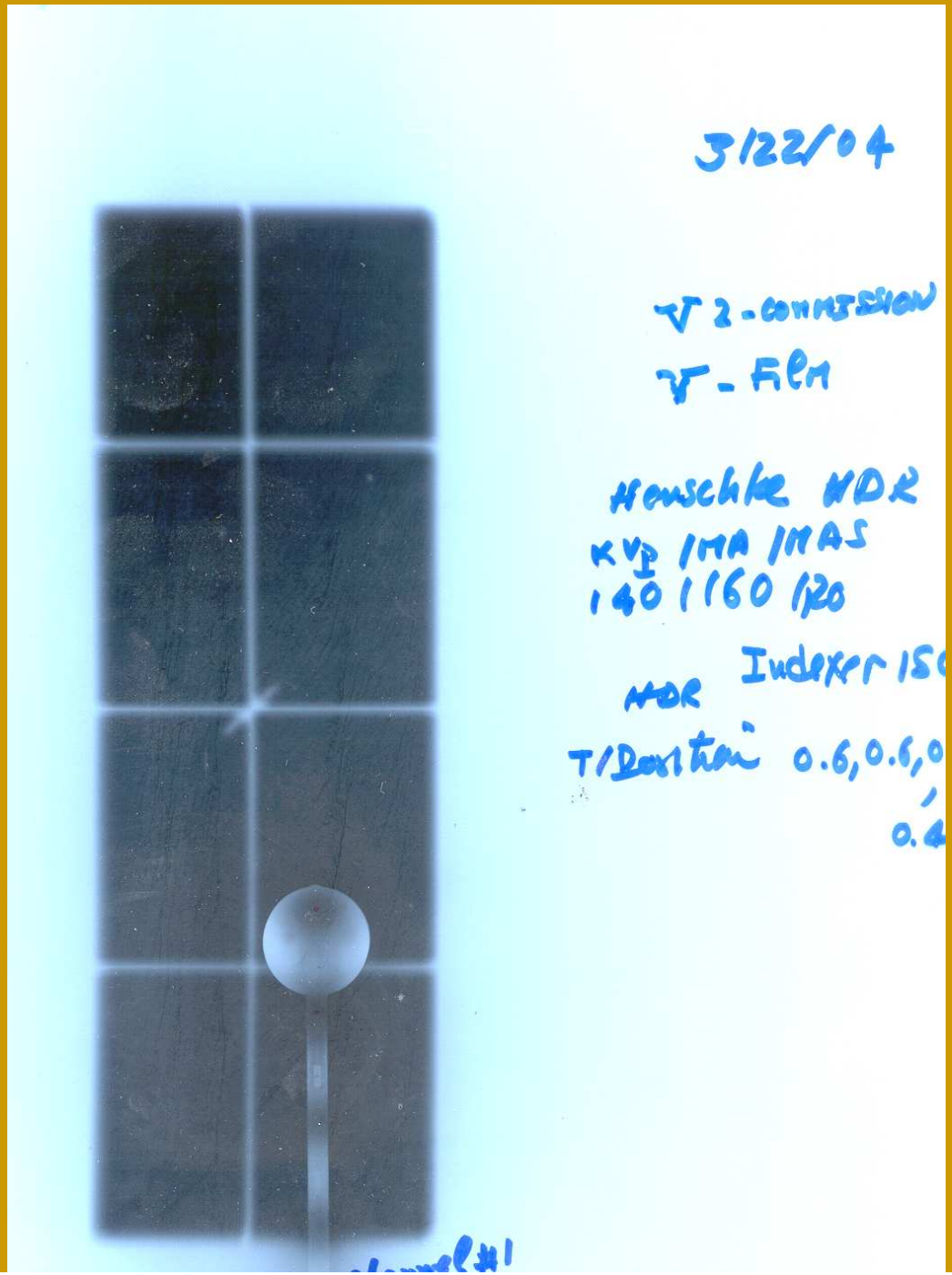


Source autoradiograph and marker registration

(90 kVp, 140 mAs, 80 cm TFD, 0.2 sec, position 1)

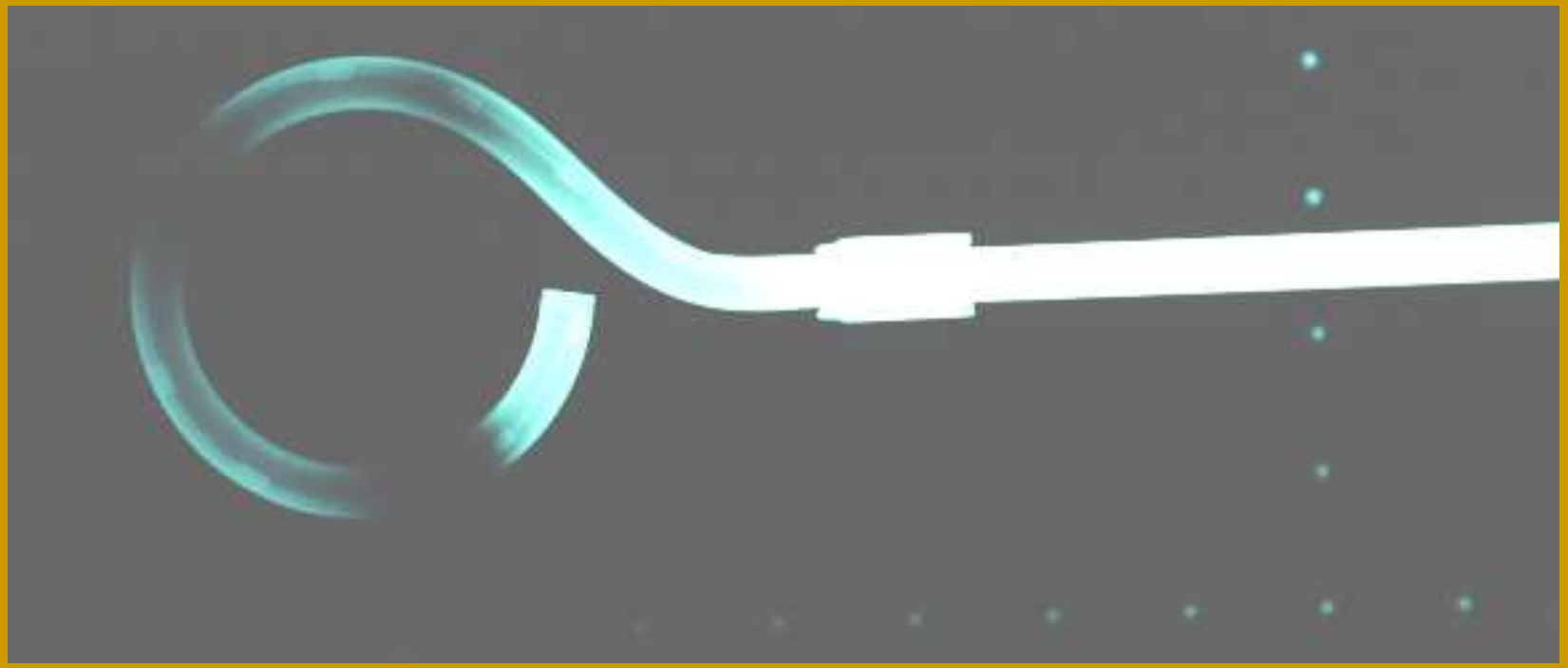


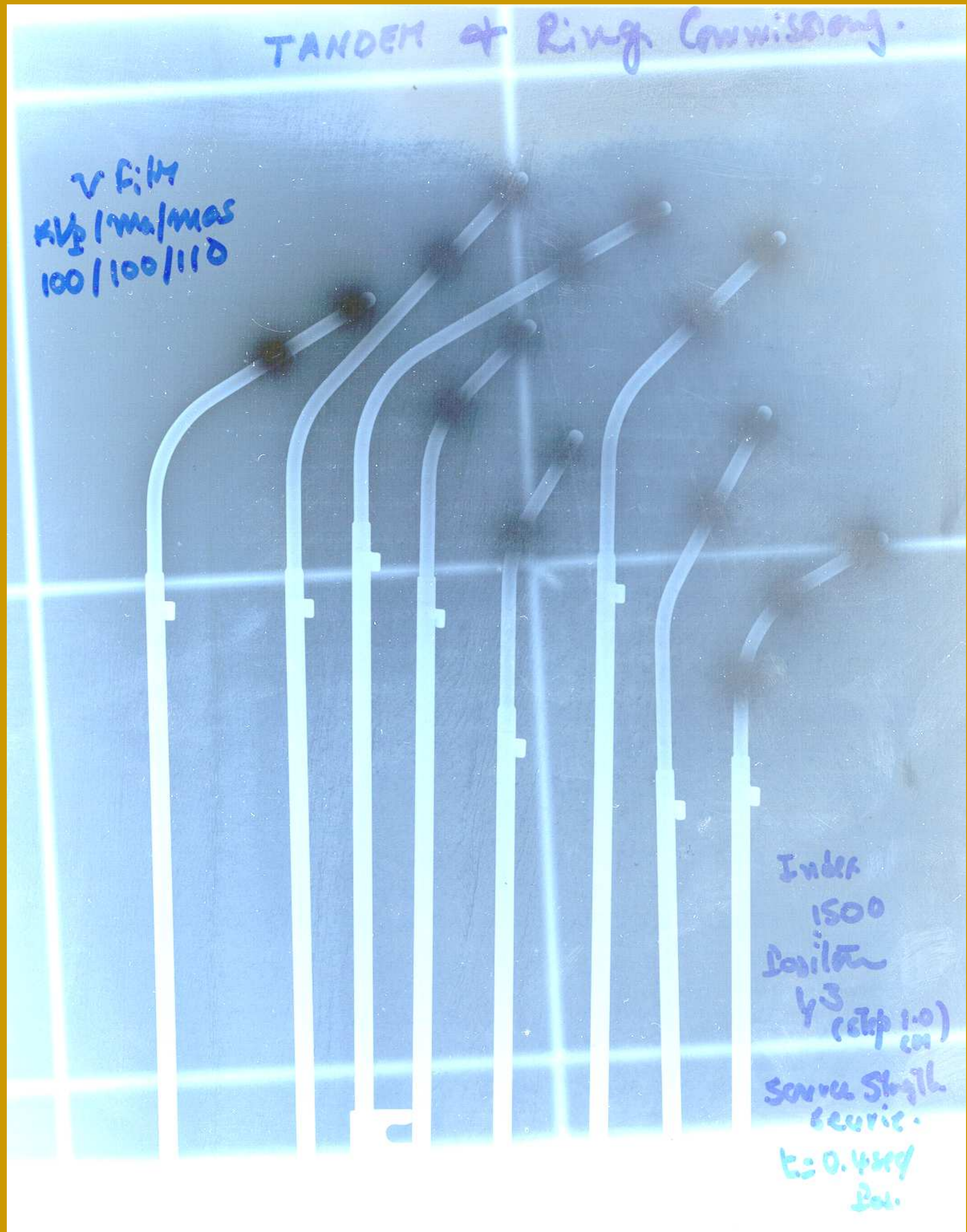
Repeat tests when there is any hardware change!

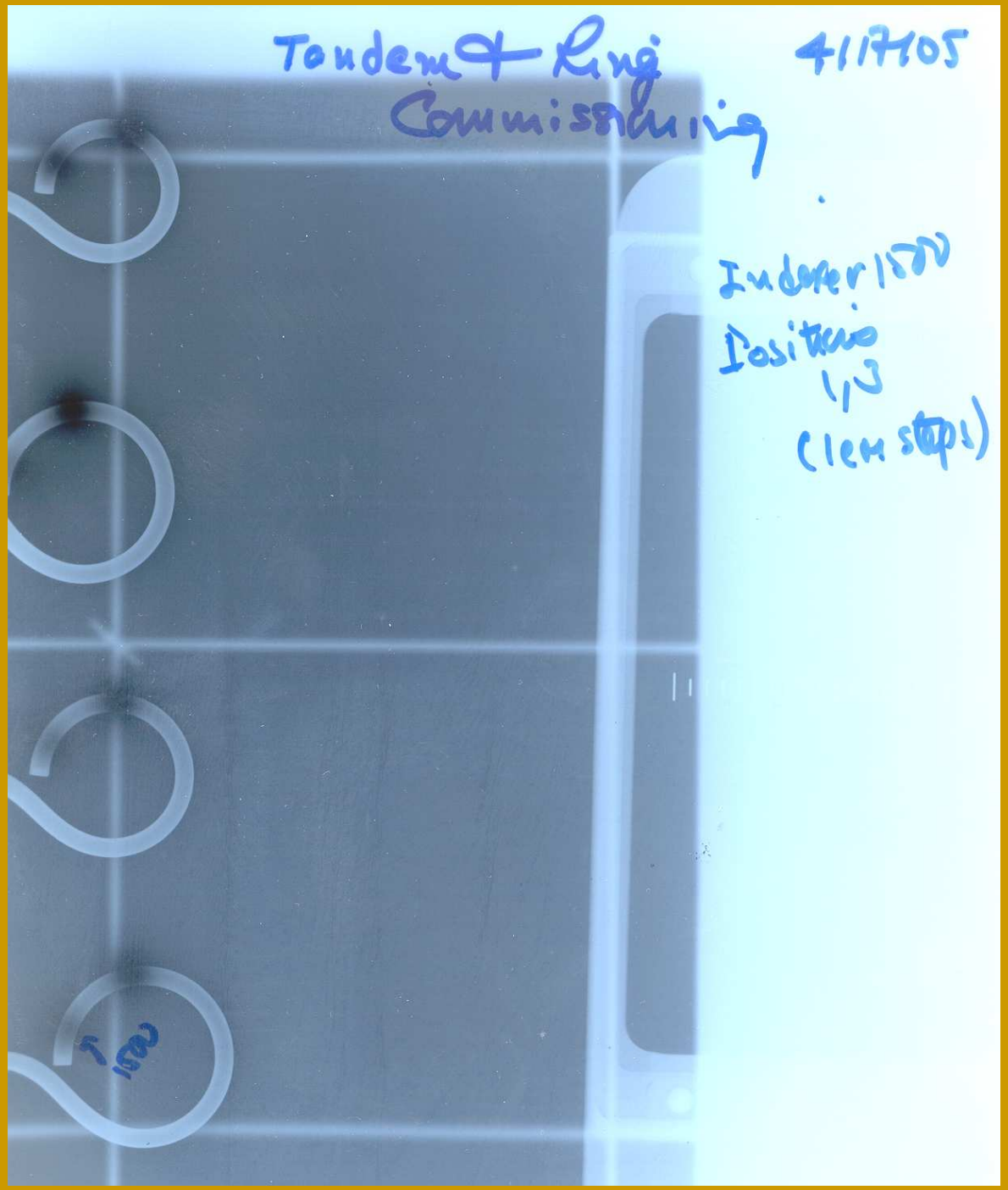


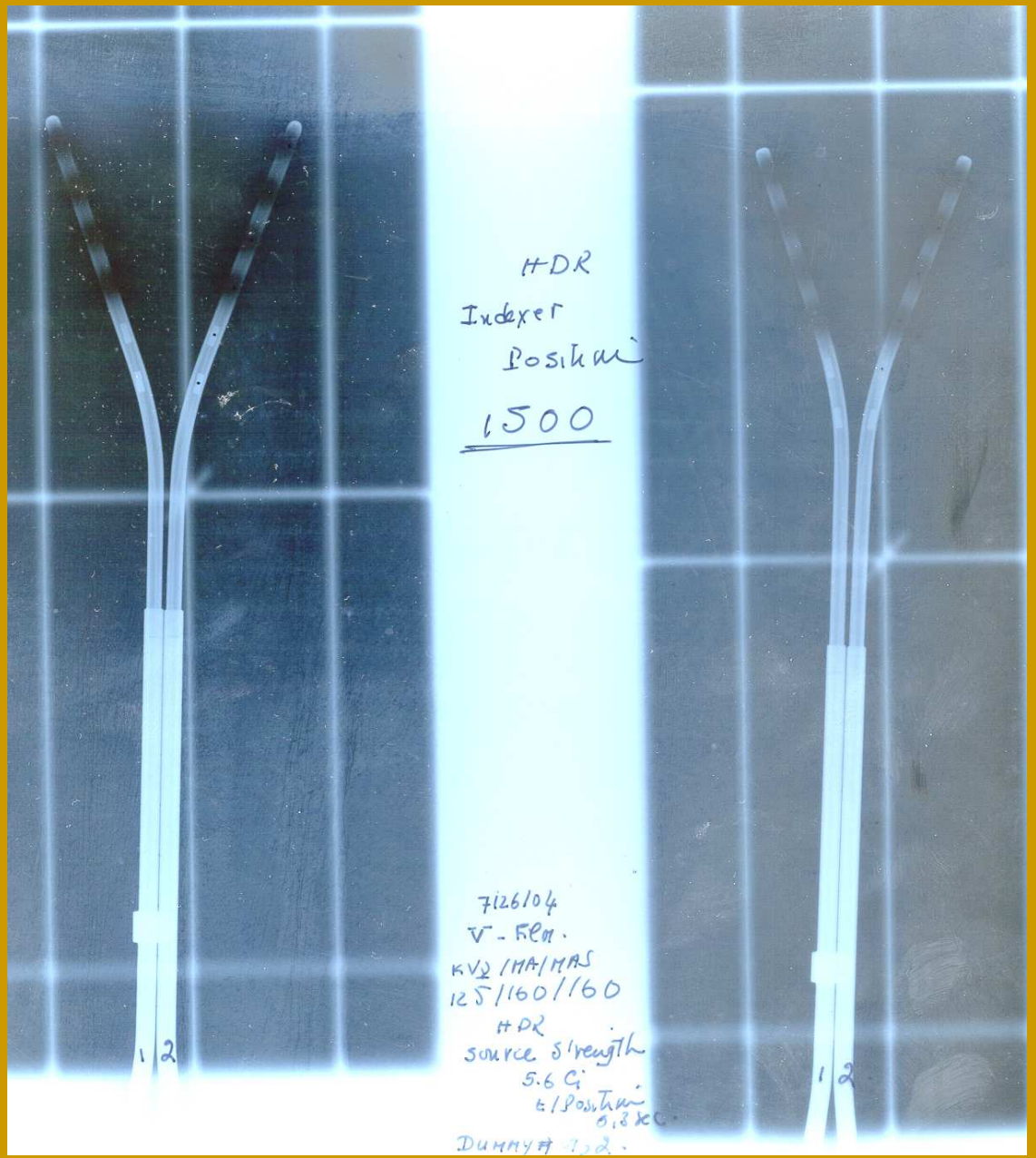
Source autoradiograph and bronchial marker registration

(70 kVp, 250 mAs, 80 cm TFD, 0.2 sec, positions 5 & 21)

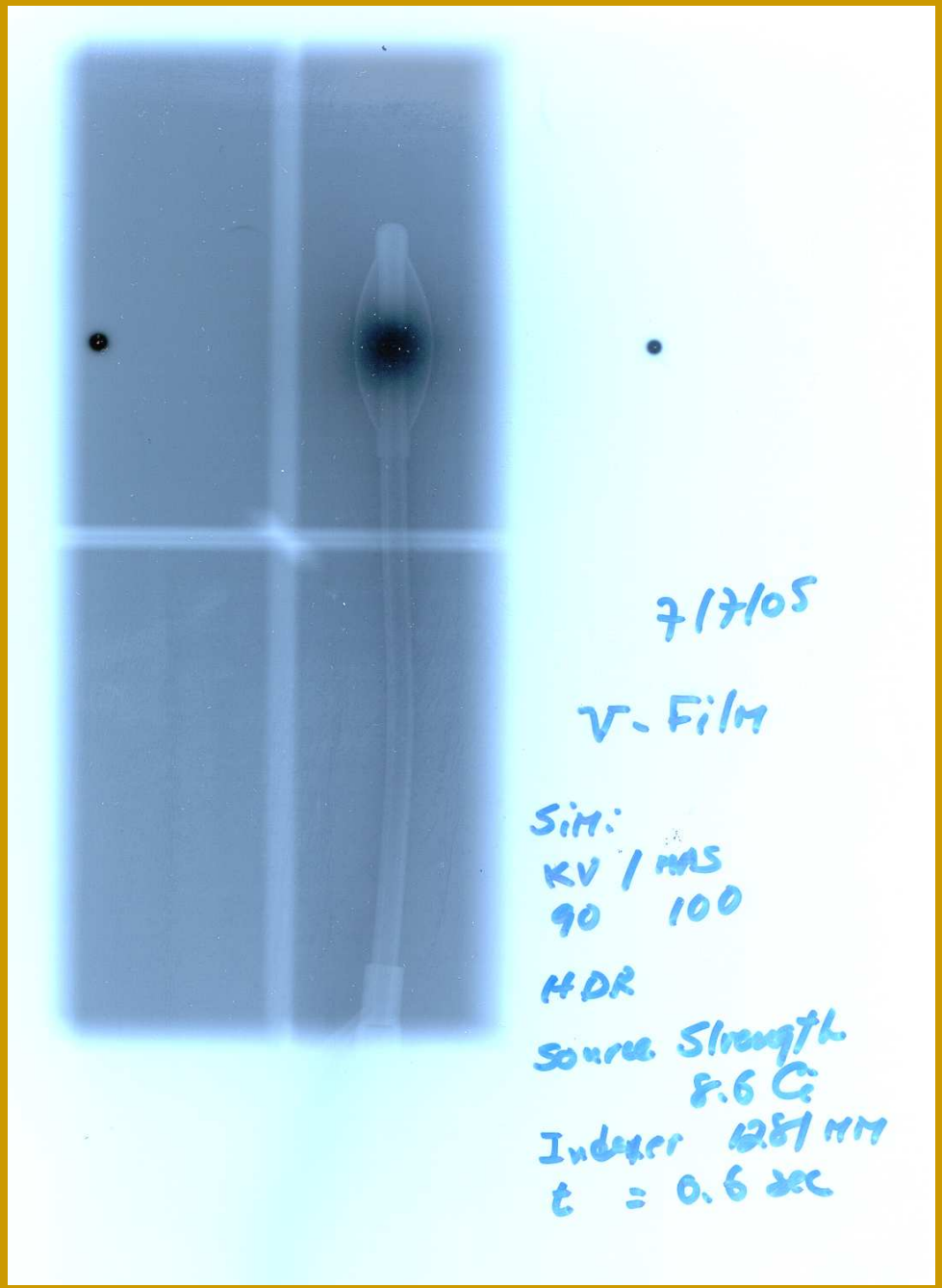



TANDEM & Ring Commissioning.
V Film
KVp/ma/mas
100/100/110
Index
1500
4/3
Source Strength
t= 0.4849

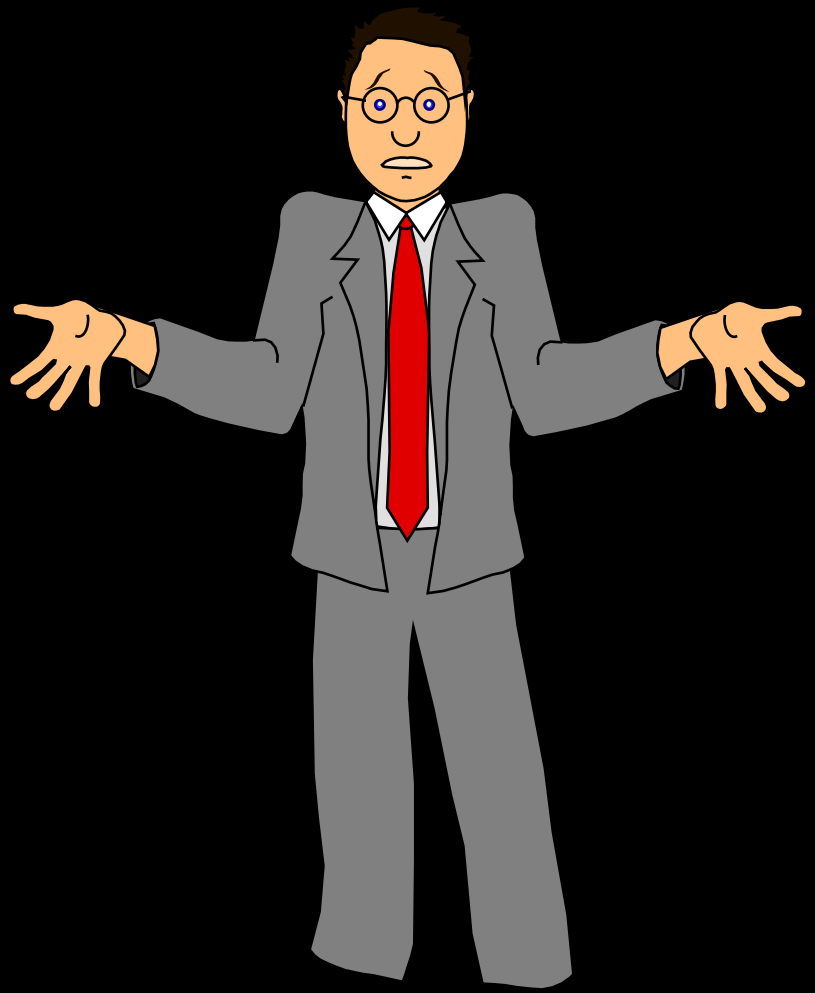

Tandem + Ring
Commissioning
4/17/05
Inductor 1500
Positive
1/3
(1cm steps)
1500


HDR
Indexer
Positron
1500
7126104
V-Film.
KVP/MA/MAS
125/160/160
HDR
source strength
5.6 Ci
E/Positron
0.38 MeV
Dummy # 1 2.
1 2
1 2

MammoSite balloon catheter for Partial Breast irradiation

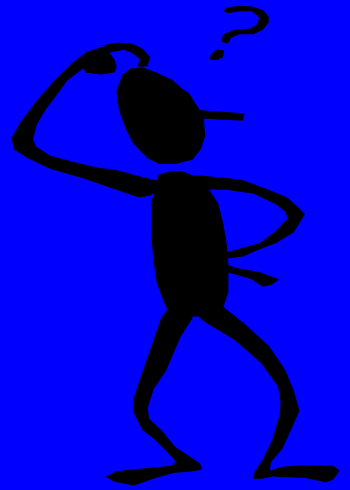


Do we know how things work?

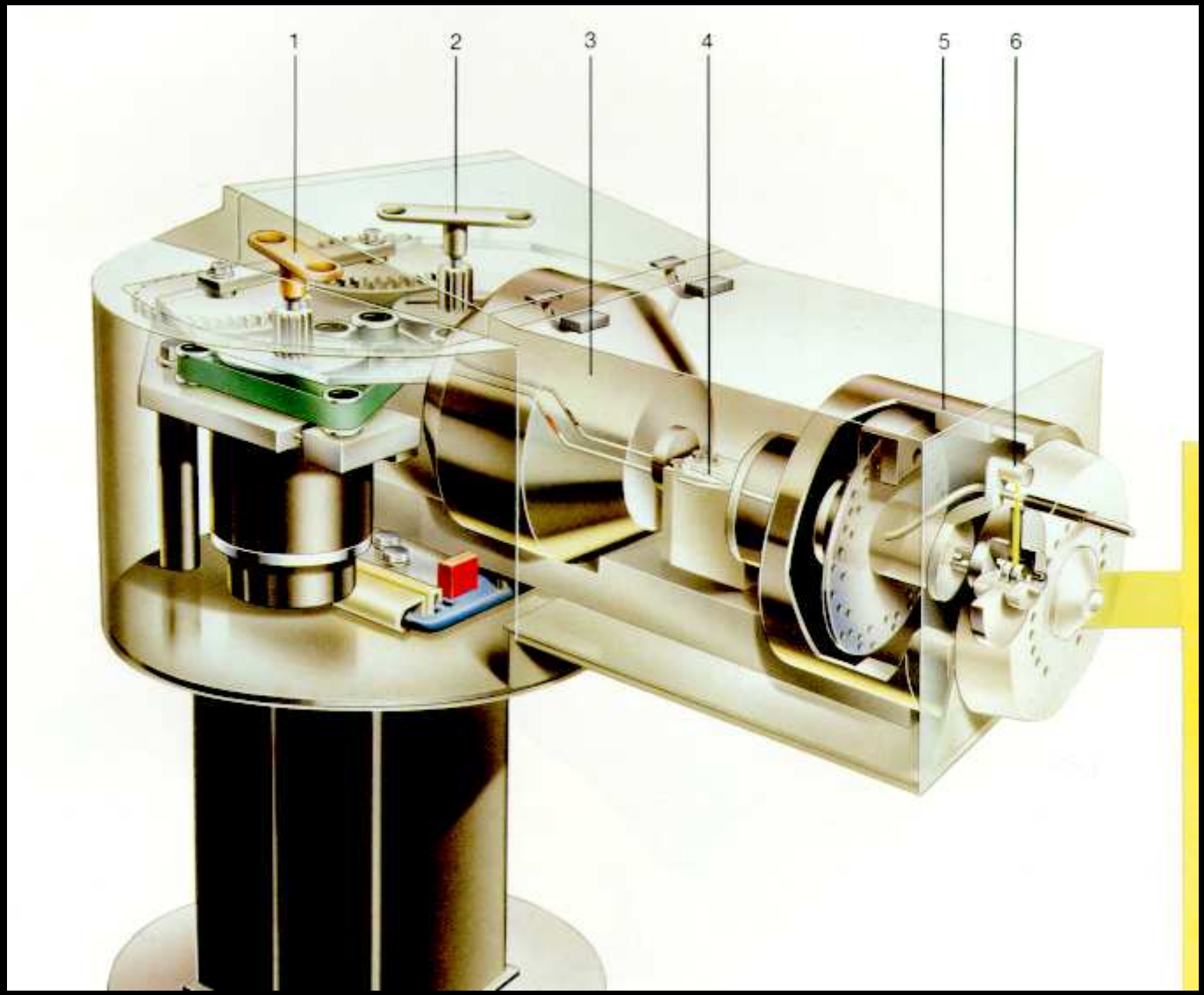


AFTERLOADER FUNCTION

- Design
- Interlocks
- Significance of Potential Malfunctions
- Warning Signs and Indicators
- Error Messages
- Recovery modes



HDR Source Driving system



HDR Daily QA tests

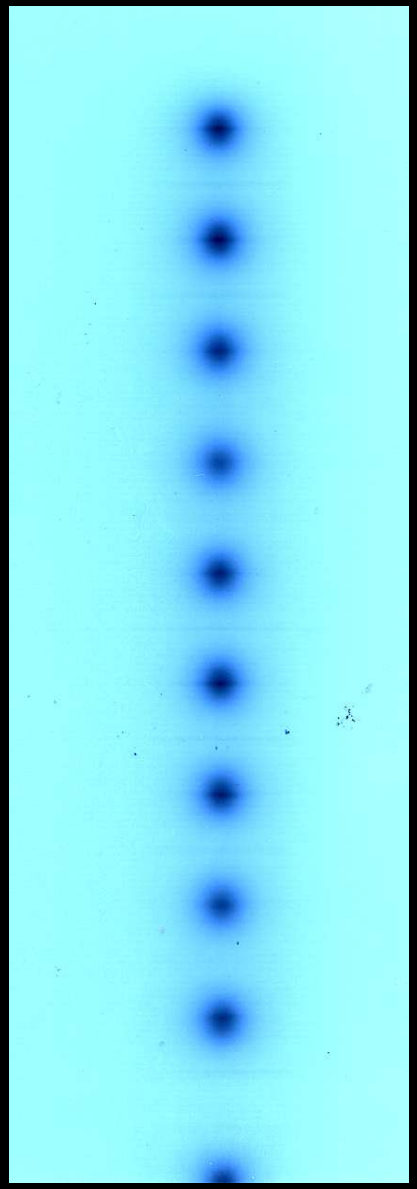
1. Remote After Loader Interlocks checks
   -Interrupt Button on the HDR computer console
   -Emergency Button on the HDR computer console.
2 . Remote After loader source positioning and source stepping accuracy test
3 Remote After Loader Primary Radiation Monitor test
4. Remote After loader Computer Ir-192 source decay factor
5. HDR Treatment Room Backup Radiation Monitor performance test
6 Patient's Video Monitoring Device test
7. Patient's Audio Communication Device test
8. Backup Survey Meter performance checks
9. Emergency Procedure availability
10. Emergency Container availability

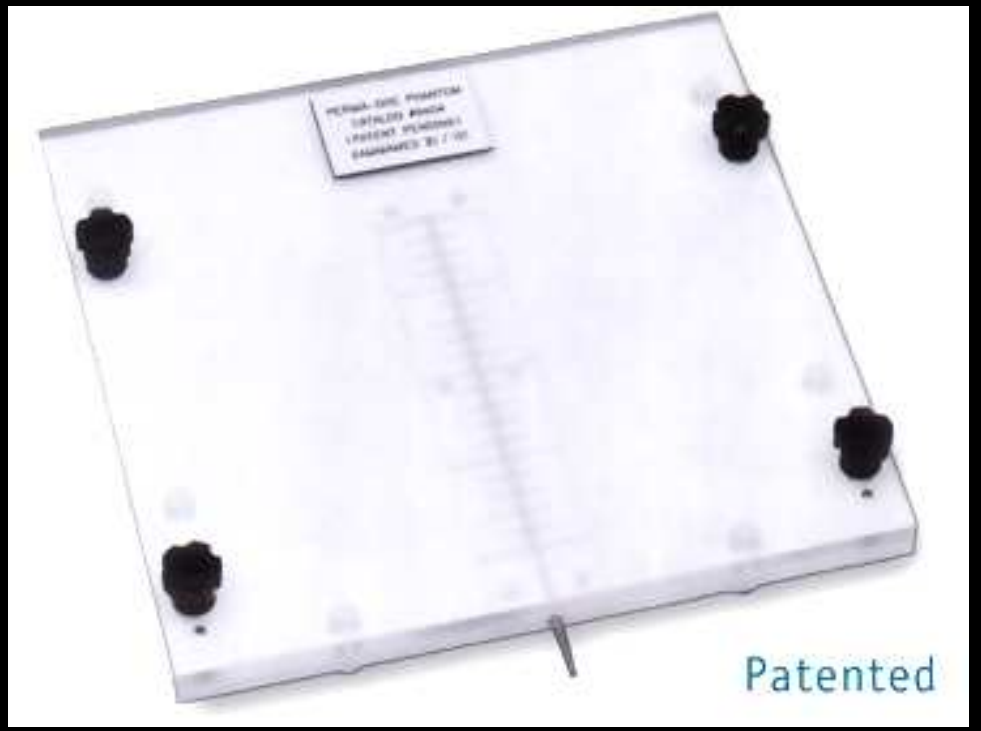
Source position QA tool

Name: QA4
Initials: HG
Plan Session: 37 of 49

Step size: 10.0 mm

	Channel 1	
Ref.	1.500 mm	
Pos	Plan(s)	Act(s)
1	1.3	1.3
2		
3	1.3	1.3
4		
5	1.3	1.3
6		
7	1.3	1.3
8		
9	1.3	1.3
10		
11	1.3	1.3
12		
13	1.3	1.3
14		
15	1.3	1.3
16		
17	1.3	1.3
18		
19		
20	1.3	1.3
21		
22		
23		
24		
25		
26		
27		
28		
29		
30	26.8	26.8
31		
32		
33		

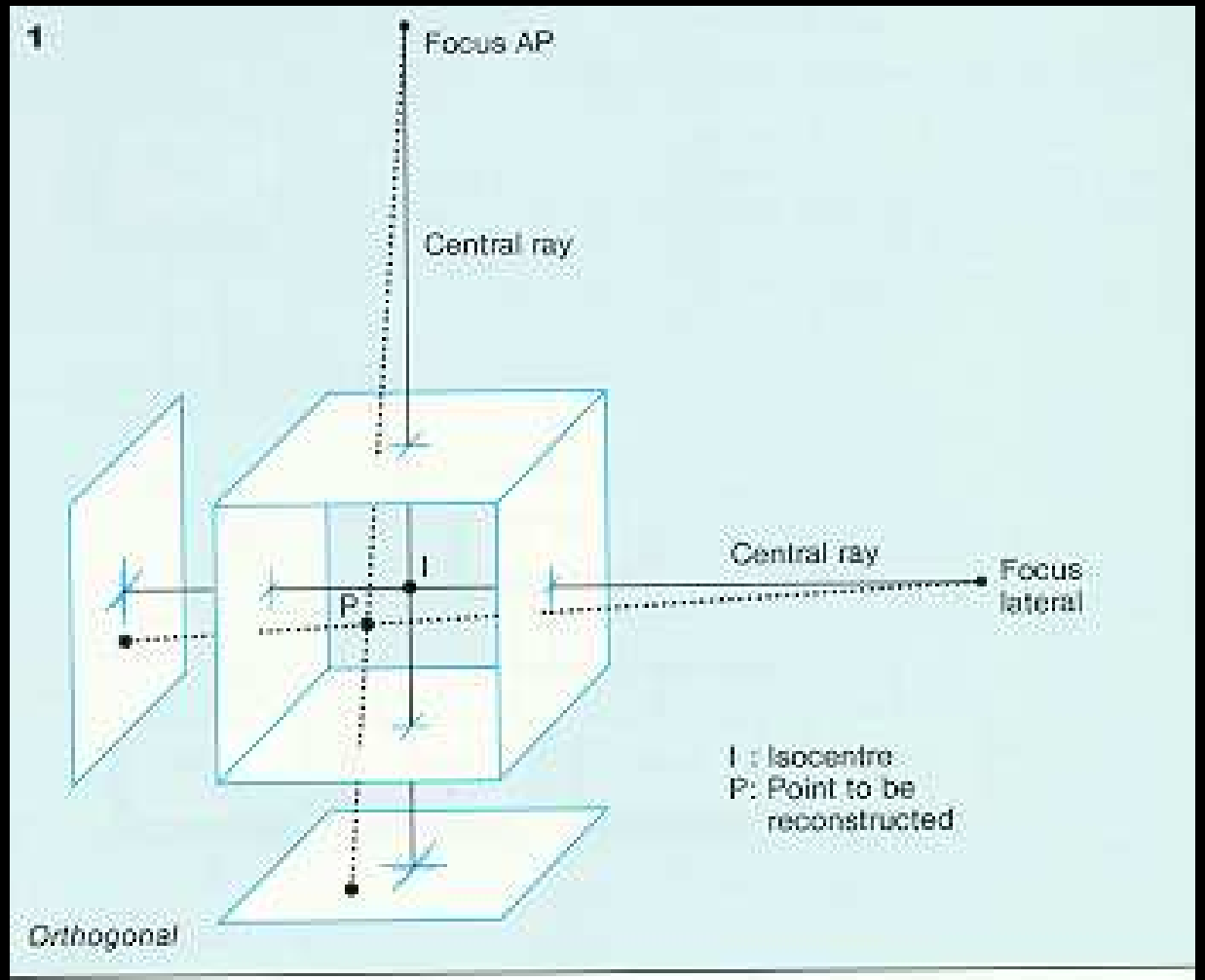




LONG ISLAND JEWISH MEDICAL CENTER
DEPARTMENT OF RADIATION ONCOLOGY
HDR DAILY QA CHECKLIST

Date	HDR				Primary Rad. Mtr	Tx Room Rad. Mtr	Survey Mtr.	Audio Device	Video Device	Emergency Container	Physicist Signature
	Accuracy of Timing Device	System Interlocks	Source Stepping Accuracy	Source Decay vs. Planning System							

Treatment Planning can be based on planar films or on 3D image sets

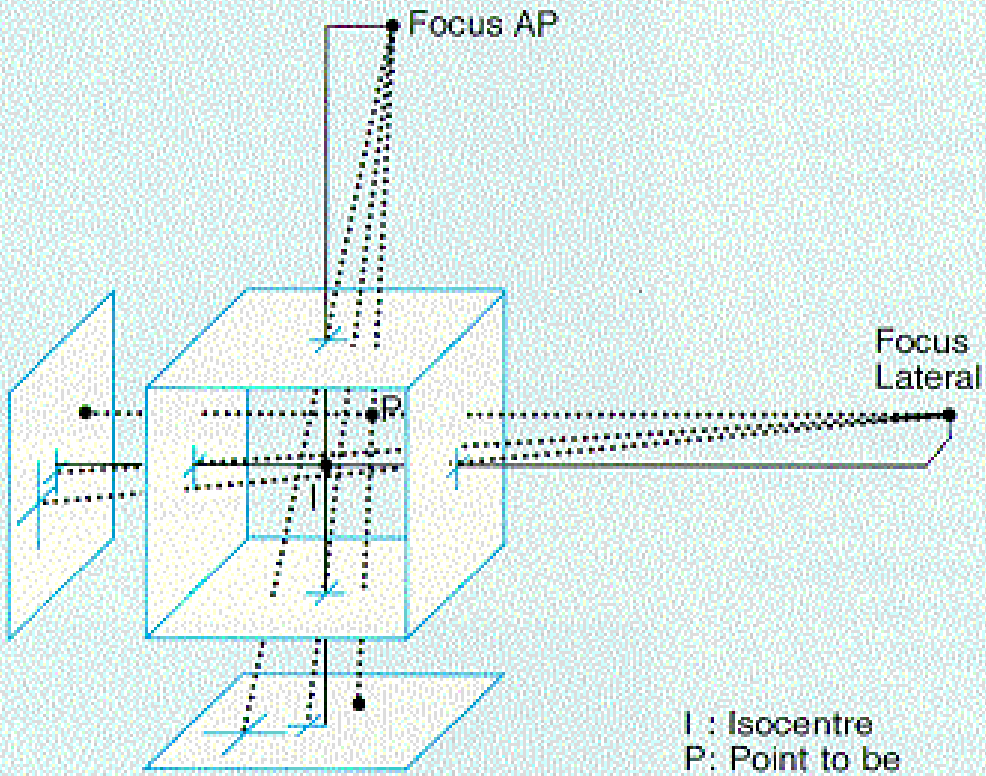


Parameters to be noted are:

- Focus to film distance of AP and lateral radiographs
- Focus to isocentre distance of AP and lateral radiographs

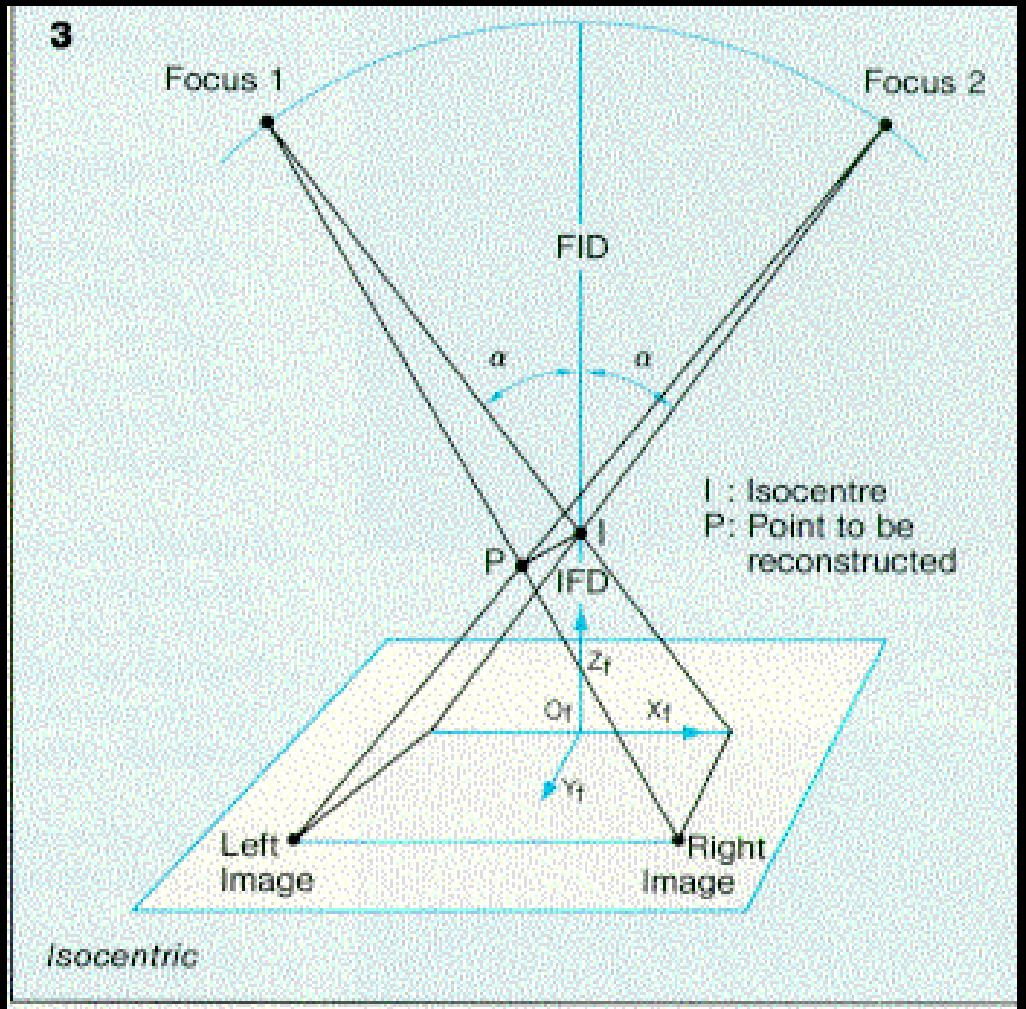
*Nucletron reconstruction device**

2



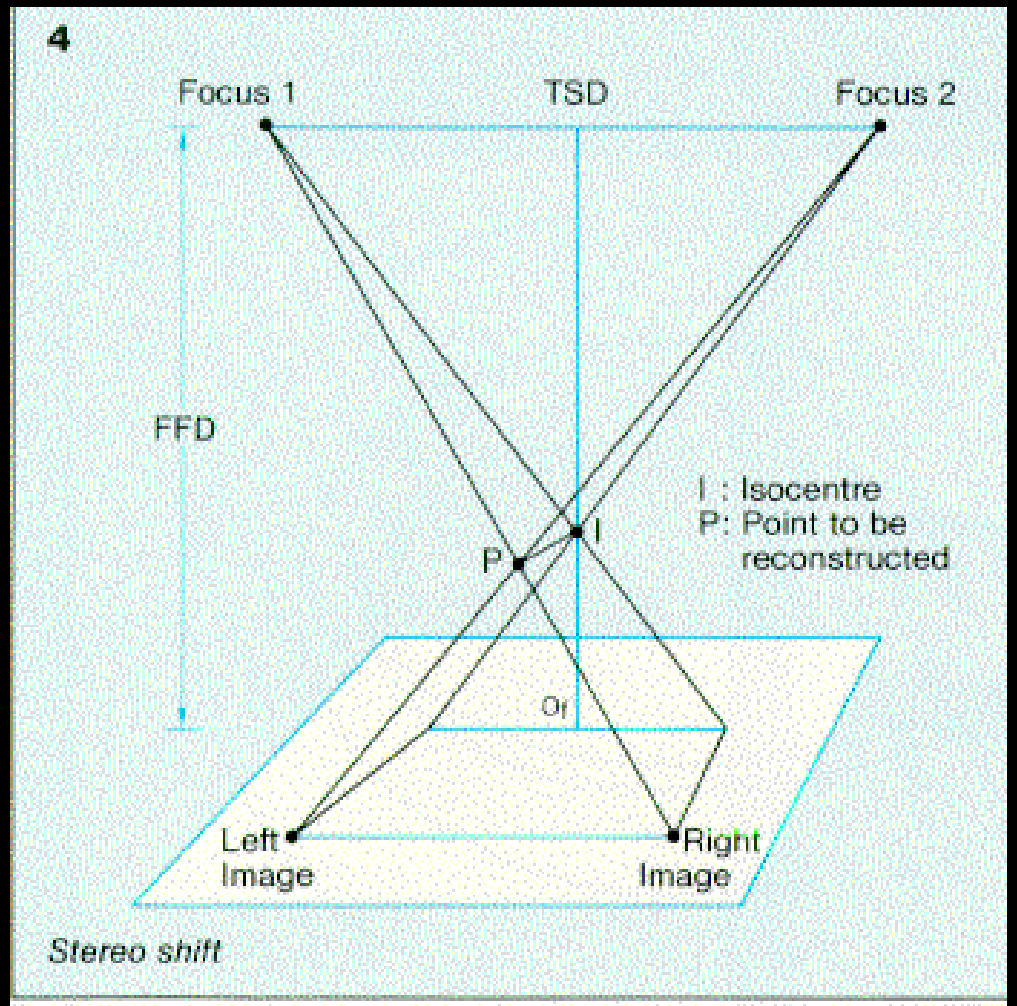
Parameters to be noted are:

- Dimensions of the Nucletron Reconstruction Device
- Cross wires on the faces of the reconstruction device



Parameters to be noted are:

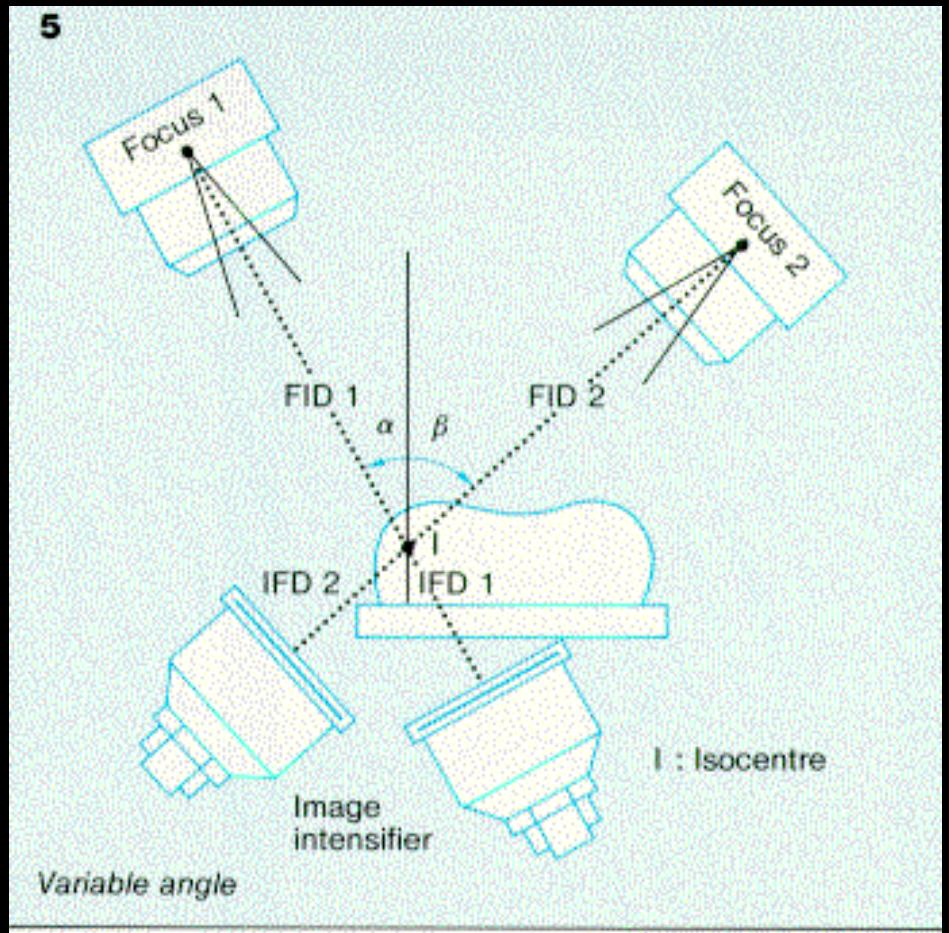
- α = reconstruction angle
- FID = focus to isocentre distance
- IFD = isocentre to film distance



Parameters to be noted are:

- TSD = tube shift distance
- FFD = focus-to-film distance
- Distance from radiograph to corresponding face of the reconstruction device
- Central ray direction for each radiograph relative to patient

5



Parameters to be noted are:

- α = gantry angle beam 1
- β = gantry angle beam 2
- FID 1 = focus to isocentre distance beam 1
- FID 2 = focus to isocentre distance beam 2
- IFD 1 = isocentre to film distance beam 1
- IFD 2 = isocentre to film distance beam 2

PLANNING SYSTEM - I/O

- Digitization vs. keyboard entry
- Treatment Templates
- CT Image transfer
- Film digitizer
- Data transfer to Tx control unit

PLANNING SYSTEM
DOSE CALCULATION

- Point source: calculation vs. measurement.
- Multiple point sources - multiple points.
- Isodose plot vs. points.
- Accounting of Applicator shields.
- Optimization options
- Handling of Anisotropy

Clinical Procedures

- Quality Assurance Program
- Site specific clinical “How-to” scripts
- Develop forms and documentation
- Record billing charges

Nucletron

Treatment Record

Patient ID: X00003

Name: QA4

Initials: HG

System Overview

	Ci	Ci	Date	ΔTime
Initial Source Strength	9.491	9.491	2005/08/25 13:26:00	
Current Source Strength	4.398	4.398	2005/11/15 10:48:33	81d;21h
Associated Source Strength	5.902	5.902		(73.83 / 0.4658)

Treatment Overview

Plan Version: 8
Plan Session: 37 of 49

Applicator: (none)
Standard: (none)
Diagnosis:
Notes:

Plan Origin: MANUAL
Planned By: hgaballa, hg
Δ Dose:

	Planned	Received
Total Reference Air Kerma Strength (cGy·m²)	0.01985	0.01985
Total Radiation Time	0 h 0 m 39.8 s	0 h 0 m 39.8 s

Position Description	Planned Session Dose	Unit
		cGy

DEPARTMENT OF RADIATION ONCOLOGY
LONG ISLAND JEWISH MEDICAL CENTER

Ir-192 HIGH DOSE RATE
Nucletron micro-Selectron Remote Afterloading

HDR Syed Implant

Patient Name:	Chart #
Physician:	Diagnosis:

PRESCRIPTION

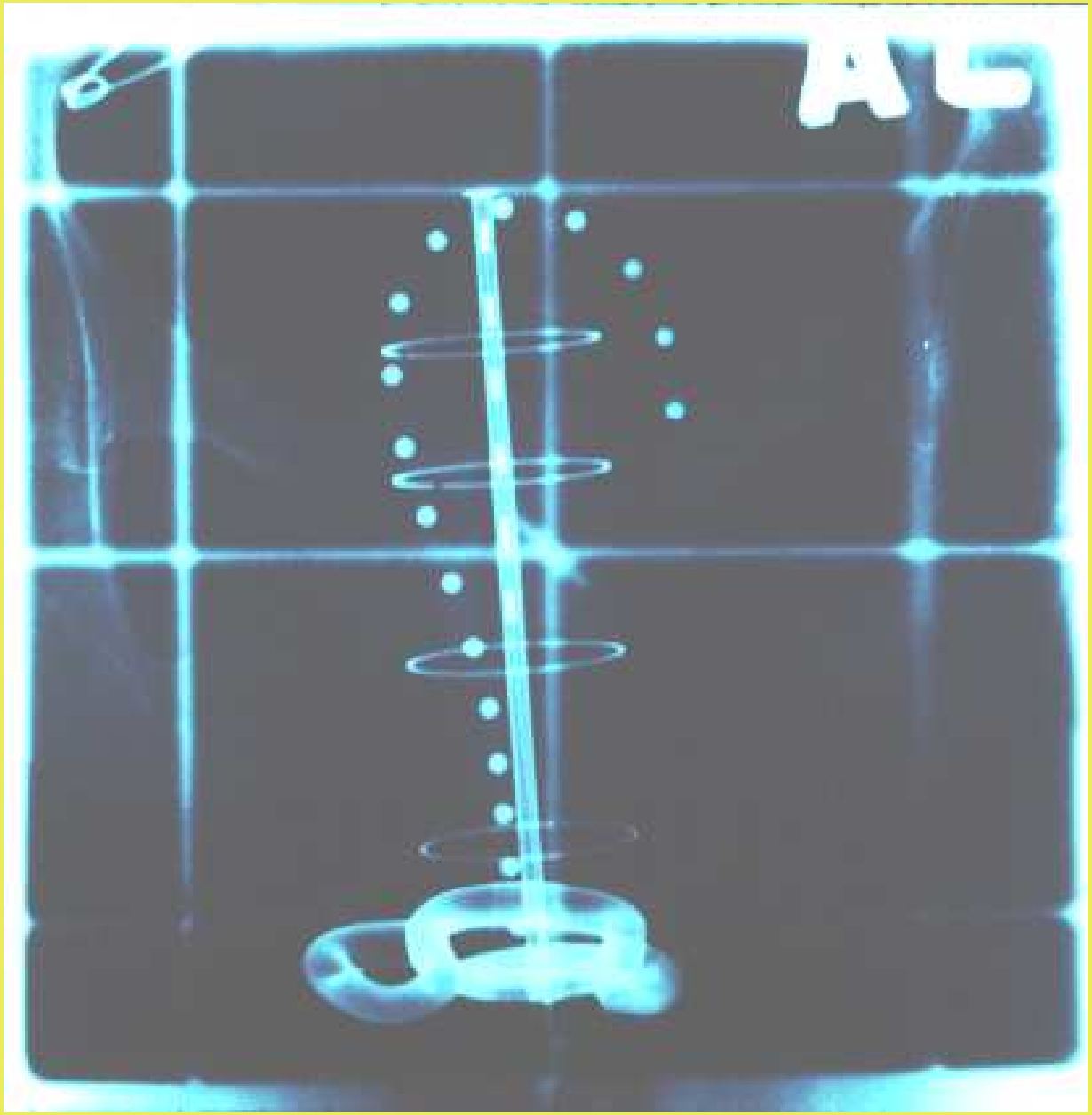
Total Dose (cGy)	Dose/ Fraction	# of Fractions	Elapsed Time/Fraction Scheme

Signature:	Date:
Special Physics consult requested by:	
Remarks:	

GYN Cervix Treatment

TREATMENT RECORD

Fx #	Tumor Dose (cGy)		Rectal Dose (cGy)		MD		Physicist		Survey	Remarks
	Daily	Cumulative	Daily	Cumulative	Date	Signature	Date	Signature		
1										
2										
3										
4										
5										
Notes:										



HDR Vaginal Cylinder Template QA Check
Total Time (sec) to Deliver 500 cGy to 0.5 cm from Cylinder Well
Source Strength 10.0 Ci

Cyl. Length cm.	Cyl. Diameter 2.0 cm.	Cyl. Diameter 2.5 cm.	Cyl. Diameter 3.0 cm.	Cyl. Diameter 3.5 cm.
6.0	197.8	236.8	281.4	329.2
6.5	208.2	251.1	294.5	347.8
7.0	218.8	262.3	309.6	370.0
7.5	230.3	276.1	324.7	386.8
8.0	241.6	287.9	339.6	404.0
8.5	252.2	302.0	354.3	420.3
9.0	263.3	313.9	370.3	437.9
9.5	274.0	326.9	383.8	453.9
10.0	285.2	340.6	400.1	471.4

Planned by: _____ Date: _____

Checked by: _____ Date: _____

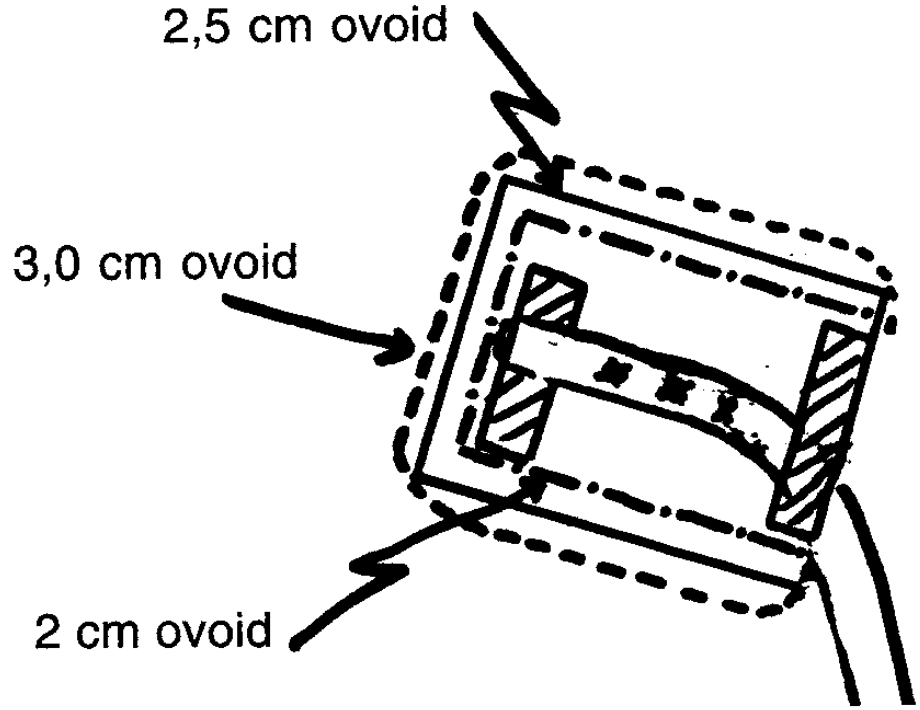
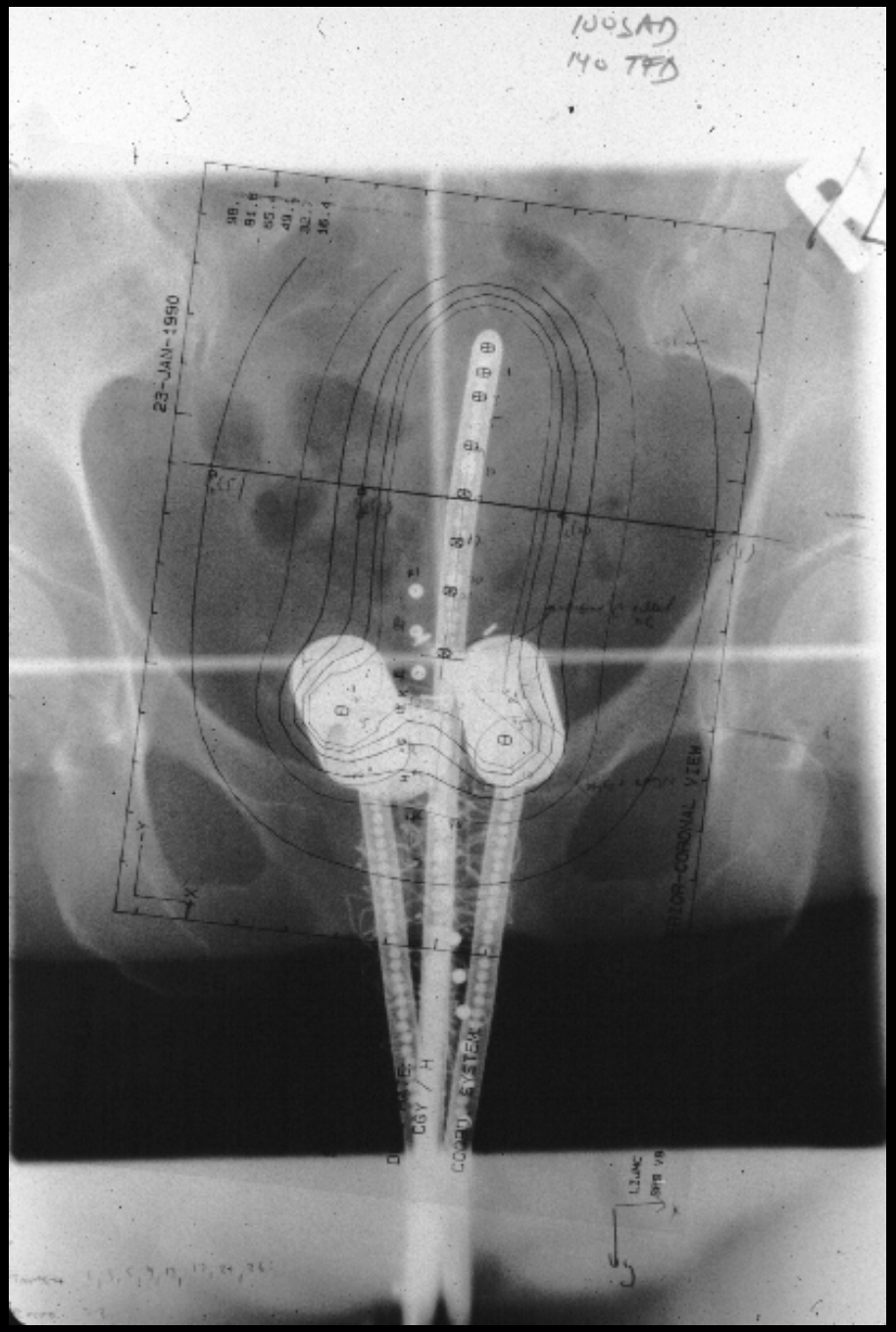


Figure 6. A template derived a lateral radiograph of a Fletcher-Suit colpostat showing the applicator boundaries and active dwell positions as defined by a radiographic marker. This template, when appropriately magnified, can be superimposed on the image of each colpostat as seen on the lateral radiograph of the patient, localising the active dwell positions for treatment planning.

Projecting isodose curves on a radiograph may be somewhat useful, <u>but</u> they are only correct and appropriate to only one plane!



Nucletron

Treatment Record

Patient ID: X00003

Name: QA4

Initials: HG

Session Log

Event	Date / Time	Code	Description	Notes/Info
1	2005/11/15 10:48:33	2011	The treatment is started.	
2	2005/11/15 10:49:04	2041	Treatment is interrupted, interrupt button has been pressed.	
3	2005/11/15 10:49:11	2011	The treatment is started.	
4	2005/11/15 10:49:37	2040	Emergency stop has been pressed.	
5	2005/11/15 10:49:46	2011	The treatment is started.	
6	2005/11/15 10:50:09	2015	Door has been opened.	
7	2005/11/15 10:50:14	2038	Treatment is interrupted, door has been opened.	
8	2005/11/15 10:50:52	2023	Door is closed.	
9	2005/11/15 10:50:59	2011	The treatment is started.	
10	2005/11/15 10:51:52	2014	Treatment is completed.	

PROCEDURES

- 2nd Physics check before 50% administered
  - ***Same Physicist - different method***
  - ***Other trained person - by specified method***
- Approximation by discrete point sources on straight line *or* by a straight and continuous linear source

Chart documentation records

LIJ – DEPARTMENT OF RADIATION ONCOLOGY

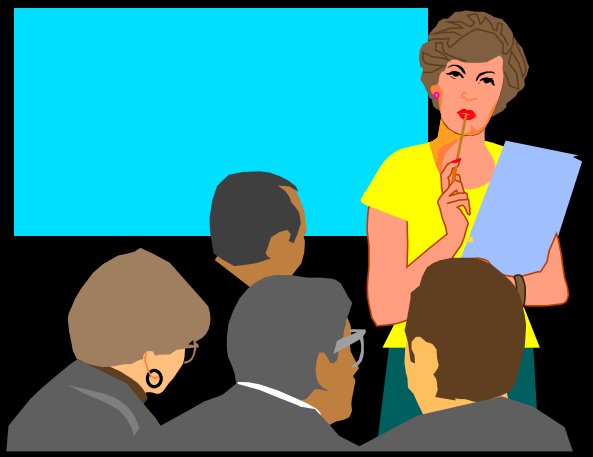
HDR PHYSICS CHART REVIEW

Patient Name: _____ ID#: _____ **Treatment Start Date: _____**

	Appl. 1	Appl. 2	Appl.3	Appl.4	Appl 5	Appl.6	Appl.7	Appl.8	Appl.9	Appl.10
Prescription										
# of fractions										
Elapsed Time (Days)										
Computer Plan 2nd Chk										
Computer Plan Transfer to HDR Tx Console										
HDR Tx Console Source Decay Verification										
HDR Plan Parameters Verification (Step Size, Indexer Positions, Dwell Time) at the Tx Console										
HDR Operational QA										
HDR Connectors Integrity Chk Prior to Tx										
HDR Tx Complete										
Patient Survey Post Tx										
HDR Computer Console Dose Sum Chk (Post Tx)										
HDR Treatment Records (Physician &Physicist signature)										
Critical Organs Dose Summary										
R&V Pt. QA Check List Complete (Pt. next Tx verified)										
Physics Initials										
Date										

TRAINING AND INSTRUCTION

- Initiation of program
- Periodic refresher sessions
- New personnel - qualification of specific skills
- Hardware and software upgrades



REGULATIONS

- NRC
- State Laws / Regulatory Guides
- JCAHO

STANDARDS

- AAPM - TG43 : Dosimetry of Interstitial Brachytherapy Sources [MP 22(2) 1995]
- AAPM - TG56 : Code of Practice for Brachytherapy Physics [MP 24(10) 1997]
- AAPM - TG 59 Report: “High Dose-rate Brachytherapy Treatment Delivery”
- ACR - Radiation Oncology [1995]
- ACR - Performance of HDR Brachytherapy [1996]

REFERENCES

- Interstitial Brachytherapy -ICWG- Raven Press 1990. ISBN 0-88167-581-4
- Brachytherapy Physics AAPM Summer School 1994. Med.Phys Publishing. ISBN: 0-944838-50-2
- Brachytherapy Physics – 2005 AAPM Summer School-2nd Edition. AAPM Monograph31.
- Comprehensive QA for Radiation Oncology (1994) AAPM-TG40
- Remote Afterloading Technology (1993) AAPM-TG41
- NRC NUREG/CR-6125 Human Factors Evaluation of Remote Afterloading Technology (1995)

SUMMARY

- You learned about the components of remote afterloading commissioning
- Factors that impact on the effectiveness of this equipment
- Received information helpful in implementing this technology
- Learned about the material and manpower resources you may need