Brachytherapy Facility Design

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REMOTE AFTERLOADING TECHNOLOGY

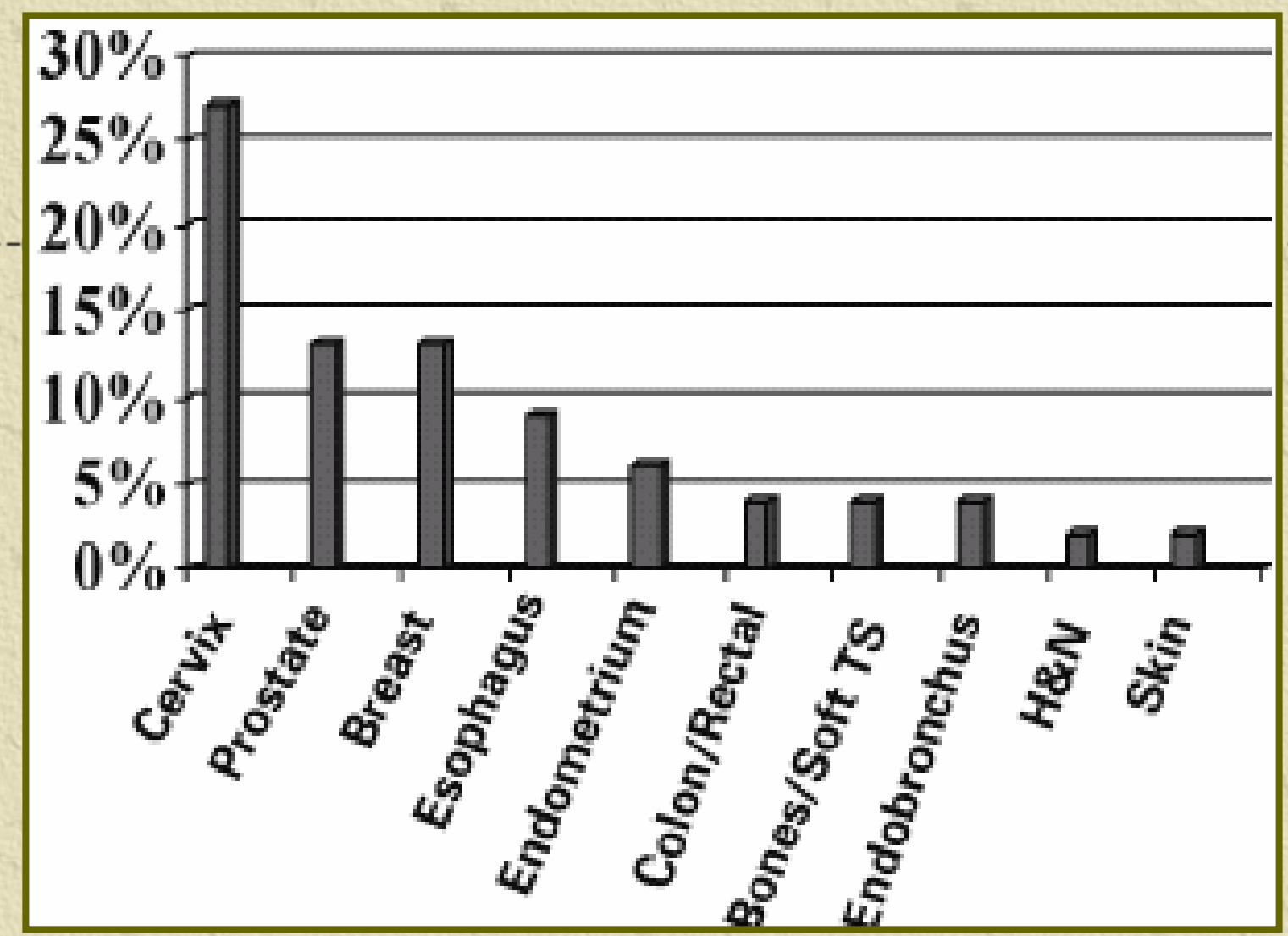


Figure 1. Of 45 articles reporting results for 10 anatomic sites, the percentage of articles by site.

Factors in Facility Design

(a) treatment programs are highly dependent on specific physicians and their interests and skills;

(b) The major goal of HDR brachytherapy remains to achieve, with acceptable complication rates, cure rates equivalent to those achieved with LDR brachytherapy;

(c) business plan projections (conjectures) about potential patient numbers are optimistically high by a factor of two to three

(d) brachytherapy is, more labor intensive per case than external beam procedures; and

(e) a facility will likely last longer than either the physicist designing it or the radiation oncologist using it.

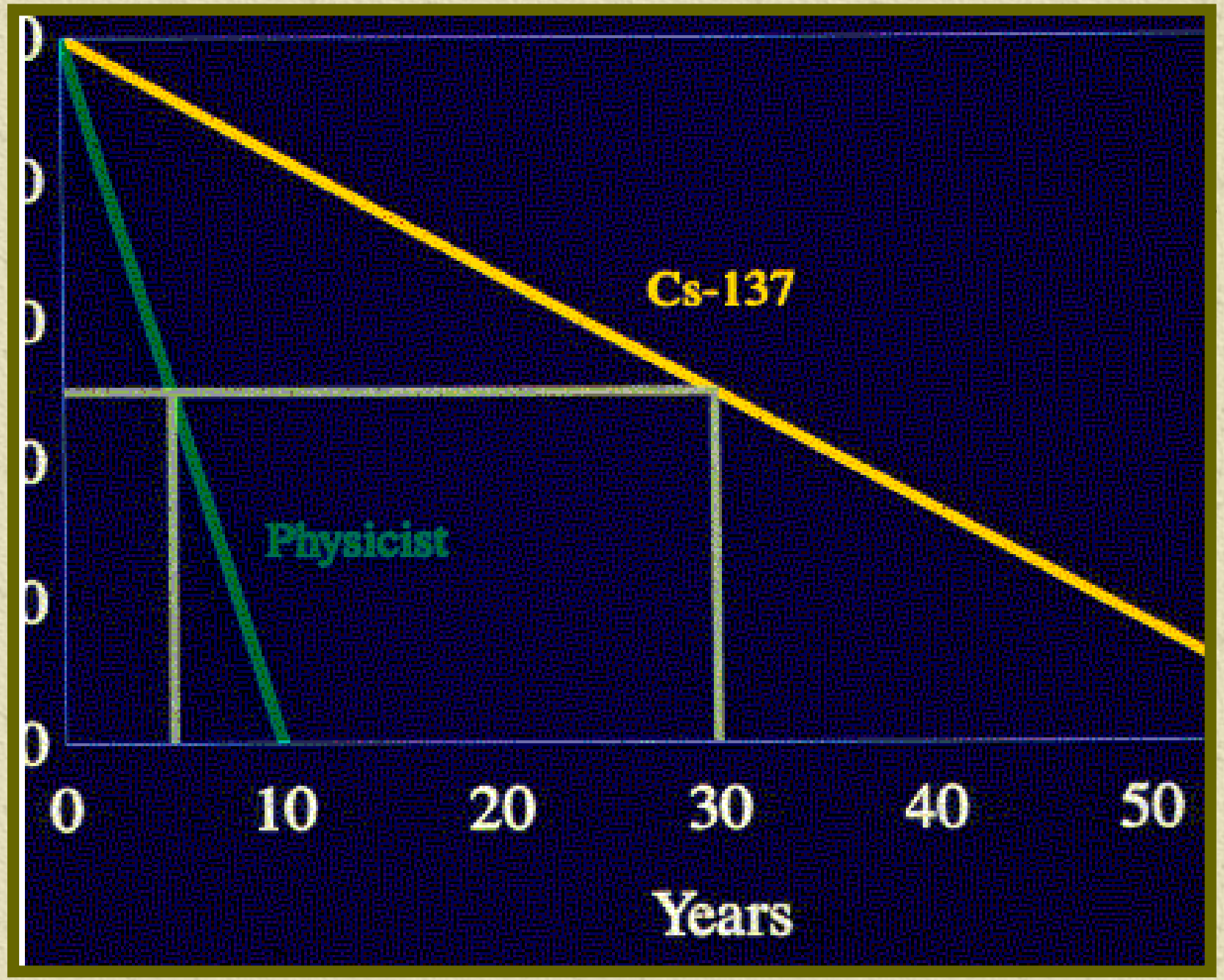
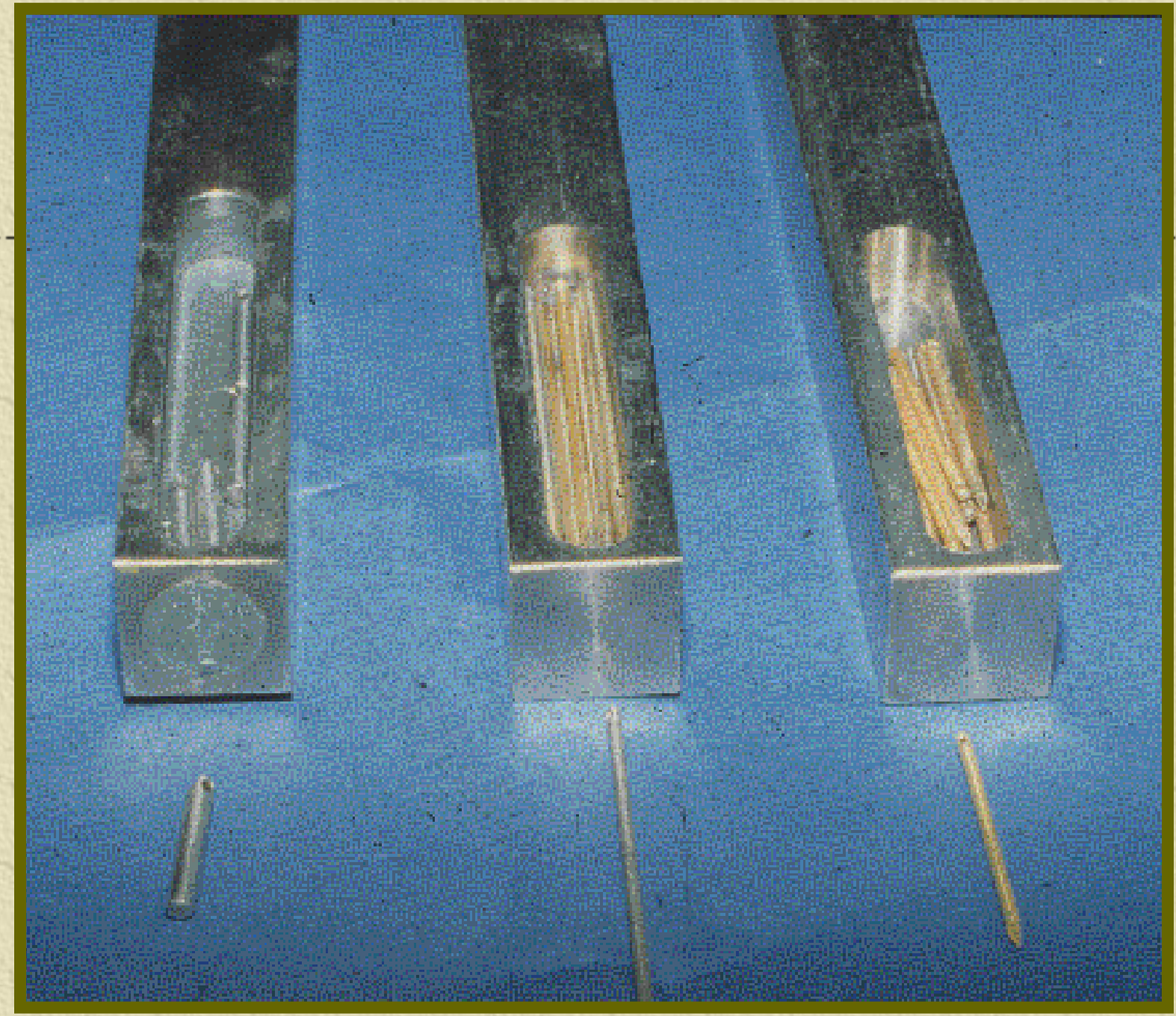

Cs-137
Physicist
0
10
20
30
40
50
Years

Table 1. Dose Equivalents (DE) and Area Designations for Protection against Radiation[a]

Member Designation	Dose Equivalent	Comment[b]
General Public	1 mSv Annually	5 mSv allowed via prior regulatory authorization with demonstrated need; visitors per authorized user approval
General Public	0.02 mSv in *any* one hour	In unrestricted area; *not* 0.02 mSv *per* hour
Embryo/Fetus	5 mSv over gestation period	Avoid substantial variations above uniform monthly exposure rate
Occupational Adults (External Whole Body)	50 mSv Annually	Deep DE (DDE) at 1 cm; excludes planned specials
Occupational Adult (Eye Lens)	150 mSv Annually	Deep DE (DDE) at 1 cm
Occupational Adult (Skin & Extremities)	500 mSv Annually	Shallow DE at 7 μm over 1 cm^2; knees & below; elbows & below
Occupational Minors	0.1 DE allowed adults	
////////////////////////////////////	////////////////////////////////////	////////////////////////////////////
Area Designation	**Limit**	**Comment[b]**
Unrestricted area		No restriction to access
Radiation Area	0.05 mSv in one hour at 30 cm from radiation source or surface radiation penetrates	Accessible to individuals; "Caution" signs may be used
High Radiation Area	1 mSv in one hour at 30 cm from radiation source or surface radiation penetrates	Controlled locked access; alarmed area; "Caution" or "Danger" signs may be used
Very High Radiation Area	5 Gy (5 Sv) in one hour at 100 cm from radiation source or surface radiation penetrates	Controlled locked access; alarmed area; deliberate entry; "Grave Danger" sign used

[a]See 10 *CFR* 20 "Standards for Protection Against Radiation" for complete definitions.
[b]Limited comments only; for a full description see 10 *CFR* 20.



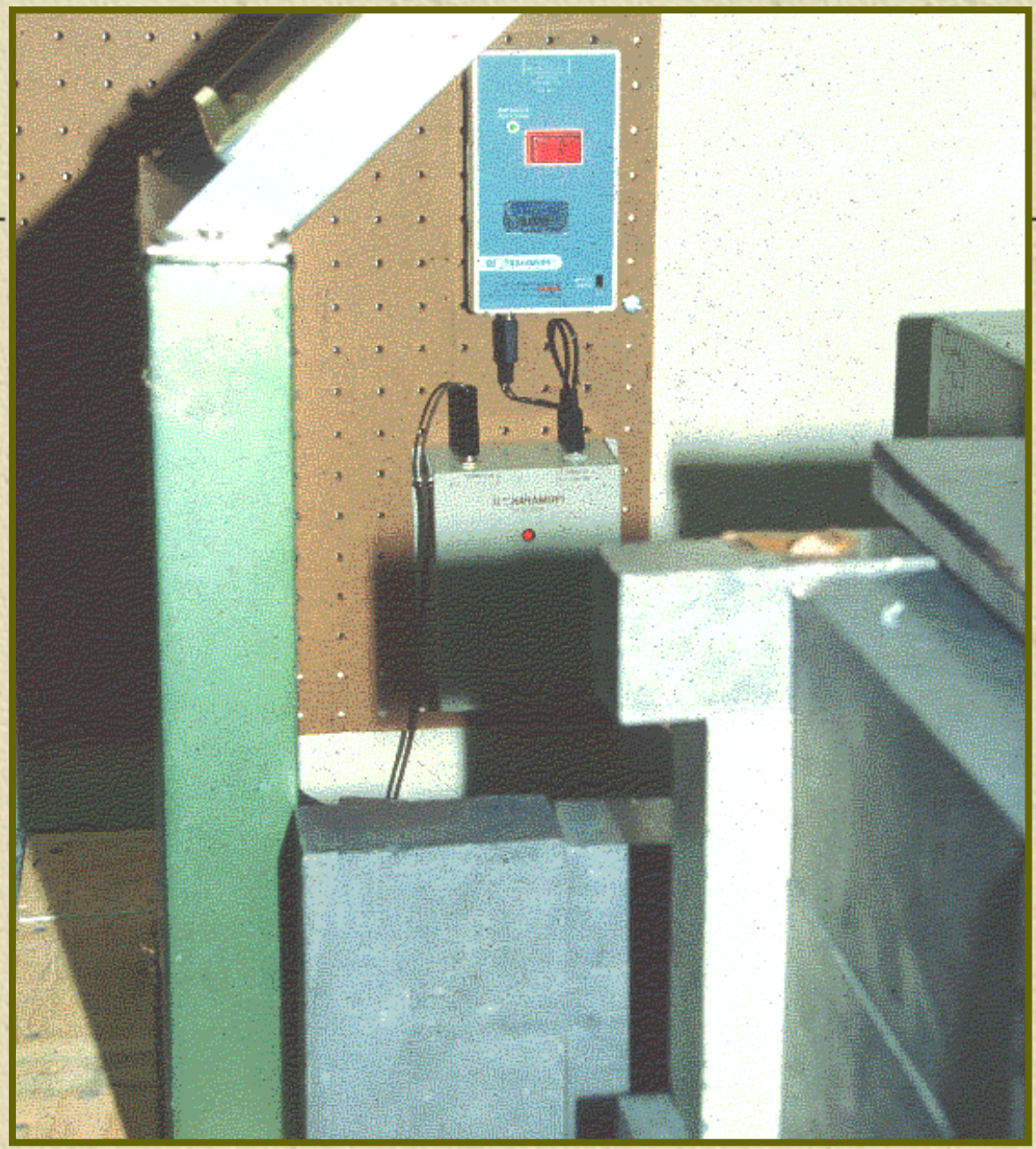
EXIT

DO NOT
BLOCK
THIS DOOR

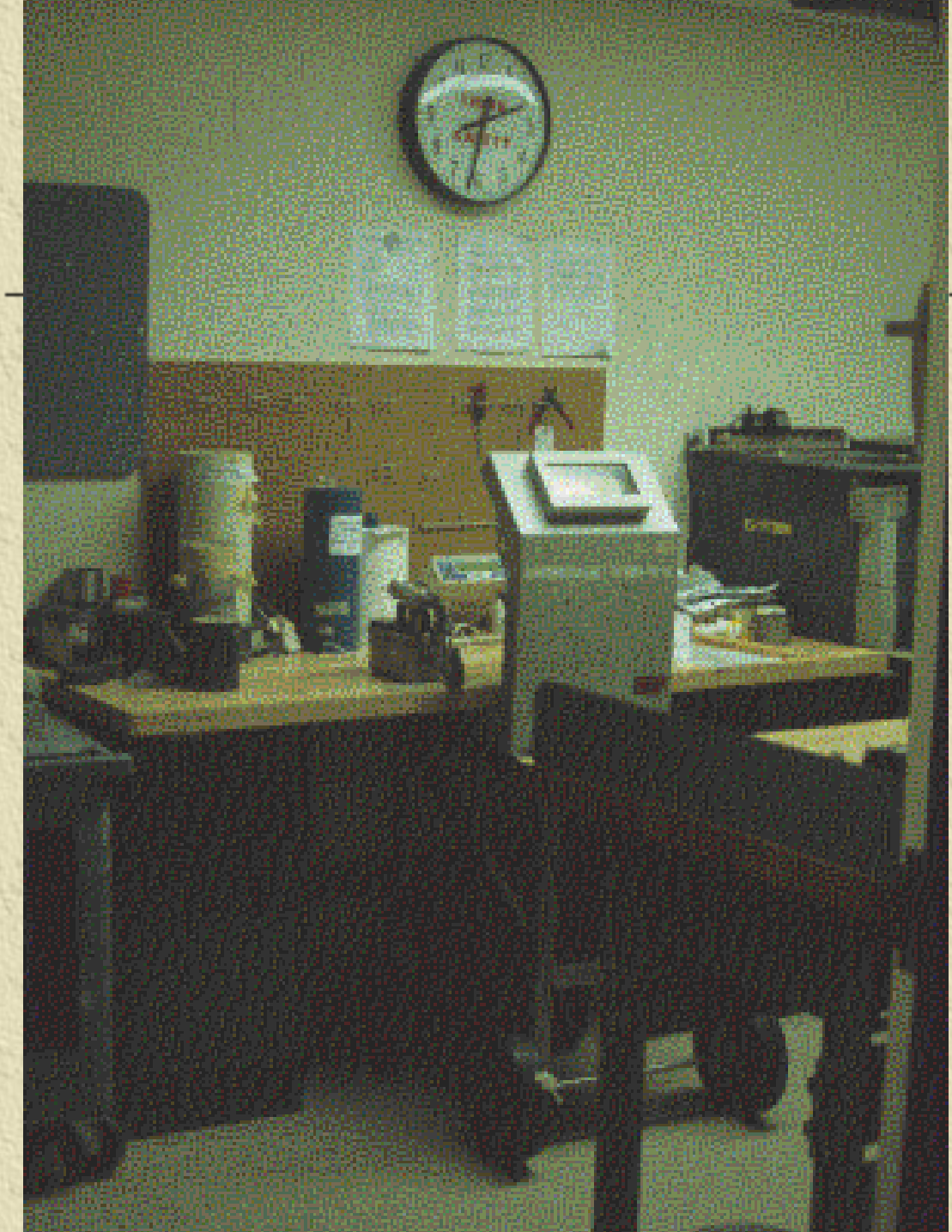
Table 2. Features of a Well-Designed Source Room

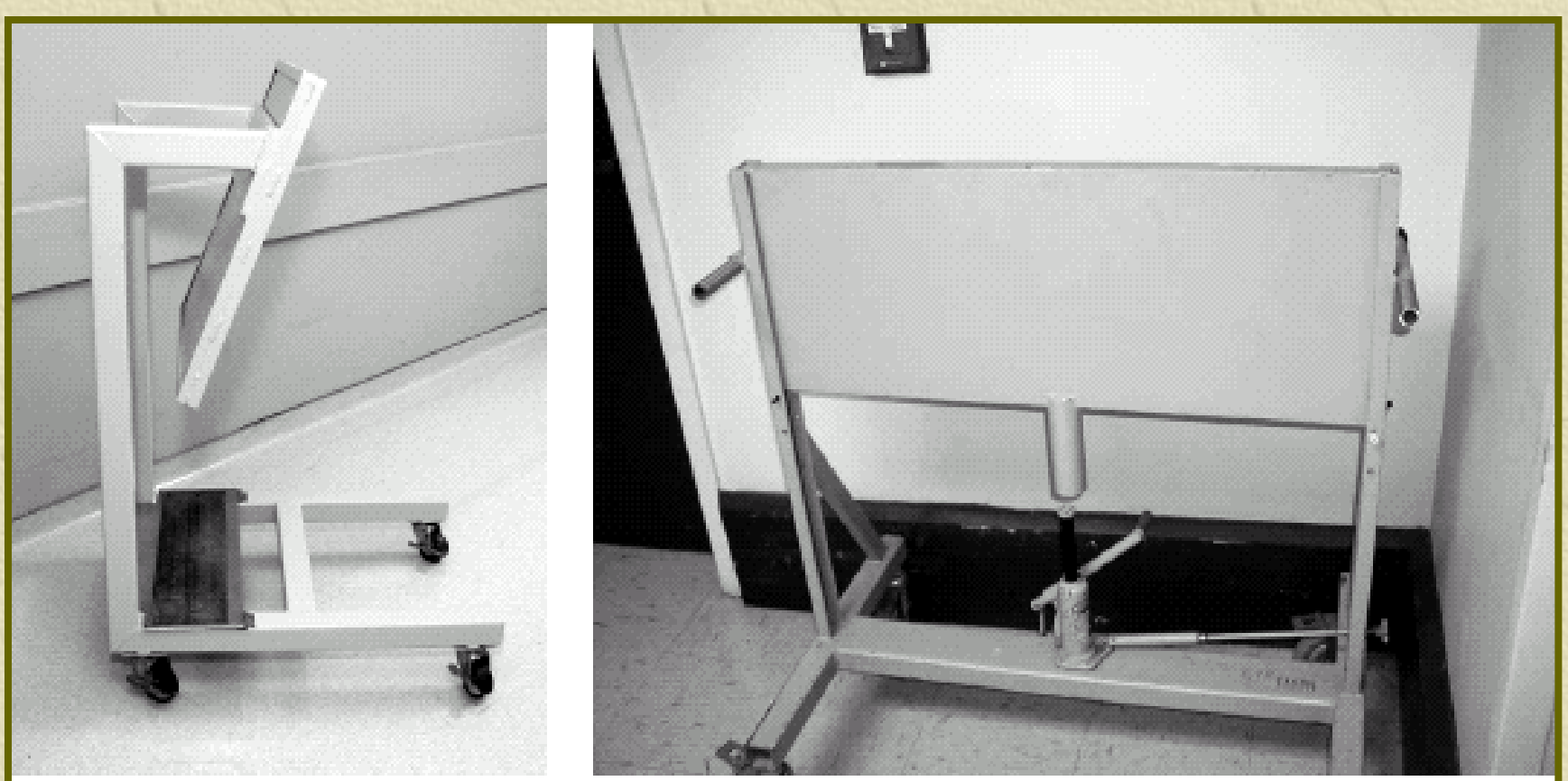
Physical Features	Accessible but reasonably isolated (away from public and employee work areas) large room with solid concrete walls; strong, locked, wide door (to accommodate transportable HDR RAU) (with warnings and emergency contact number postings) with automatic closer
Communications	Telephone (outside line for immediate vendor contact); computer (and printer); computer jacks; bulletin boards for regulatory postings
Interior Features	Well lit; water and cleaning supplies, sink with protected drain (mesh screening); workbenches with cabinet drawer storage; adequate electrical outlets above the workbenches; wall pegboards with hooks, bulletin boards; adjustable shelves; seamless tile floor; "Radioactive materials" waste can; film storage in lead bins
Tools	Conventional shop tools; flashlights, source handling tools, tweezers, forceps, etc.
Source Storage	Locked lead safe(s) or lead well; lead "L" blocks, lighted magnification lamp; temporary lead "pigs" for source sorting during preparation
QA Equipment	Area radiation monitor; radiation detection (NaI (Tl), GM) counters, survey meters; wipe test equipment (if needed); well-ionization chamber and electrometer; autoradiography equipment; barometer, thermometer
Transport Equipment	Shielded source transport containers; carts
Empty Container Storage	Cabinet, shelves to storage reusable or disposal containers, empty lead "pigs"
Work Area	Computer area; binders, blank forms, office equipment and supplies, calculators
Applicator Preparation and Storage	Applicators and accessories (by type) stored in large labeled clear plastic boxes in cabinets or on shelves
Everything Else	All those favorite "gadgets" that you use in your source room!

VAMP
VICTOREEN
1
3
10
30
100
mR/hr



CAUTION
RADIOACTIVE
MATERIALES





(a) (b)

Figure 2. (a) A homemade portable bedside shield featuring a slant design and an adjustable step. (b) A commercial radiation shield with adjustable height.

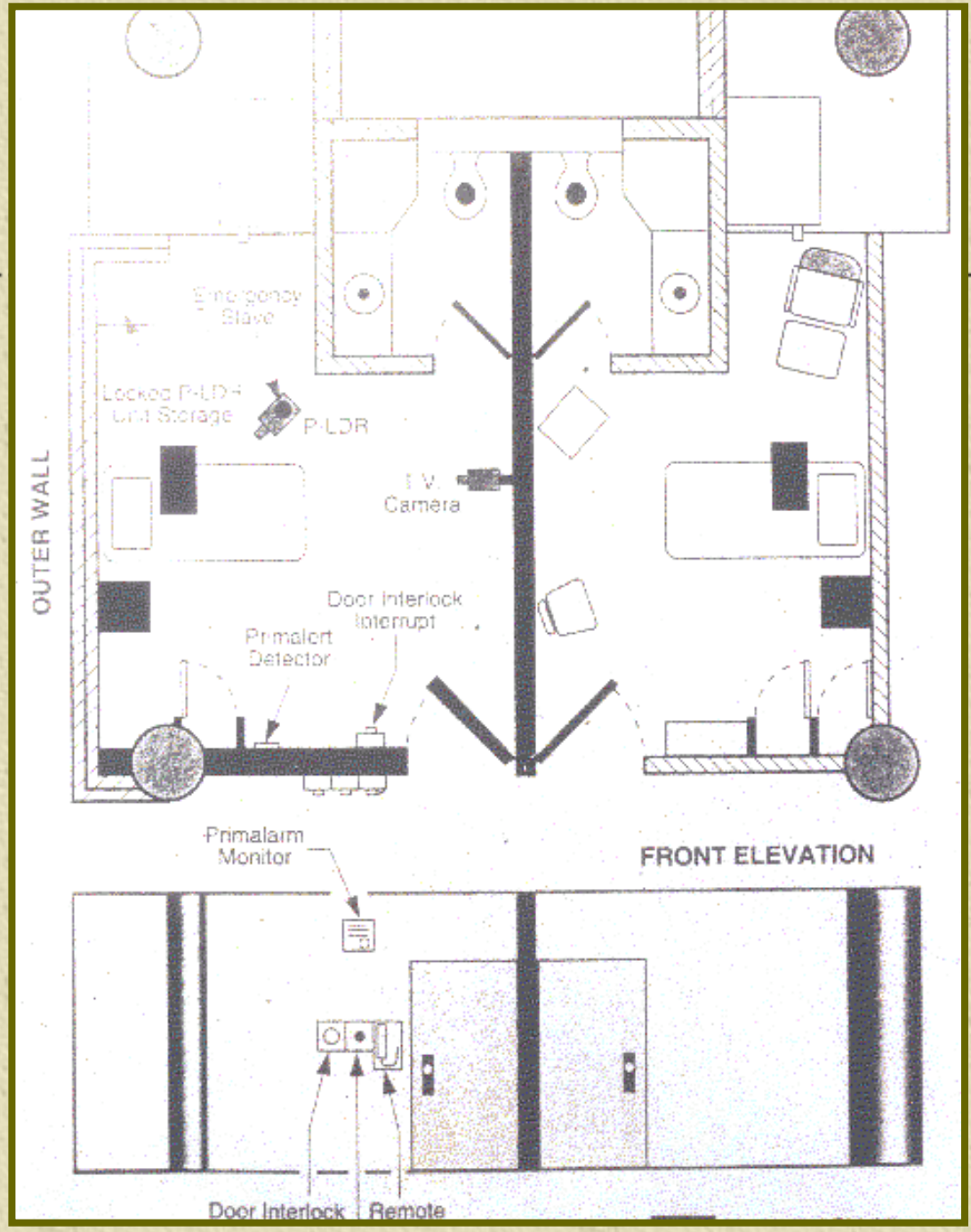
Table 3. Comparative Selected Broad-Beam TVL (cm) Shielding Data

Radioisotope	Concrete	Steel	Lead
Cobalt-60			
NCRP 40 & 49[a]	20.6	6.9	4.0
IPEM 75[b]	20.6	No data given	4.0
IPSM 46[c]	No data given	No data given	4.6
Boutroux-Jaffré	22	6.7	4.2
Cesium-137			
NCRP 40 & 49[a]	15.7	5.3	2.1
IPEM 75[b]	15.7	No data given	2.1
IPSM 46[c]	No data given	No data given	2.2
Boutroux-Jaffré	17.5	5	2.2
Ir-192			
NCRP 40 & 49[a]	14.7	4.3	2.0
IPEM 75[b]	11.3	No data given	1.5
IPSM 46[c]	No data given	No data given	1.2
Boutroux-Jaffré	14.7	4.3	1.6
Au-198			
NCRP 40 & 49[a]	13.5	No data given	1.1
IPEM 75[b]	13.5	No data given	1.1
IPSM 46[c]	No data given	No data given	1.0
Boutroux-Jaffré	No data given	No data given	No data given

[a] Approximate values obtained with large attenuation.
[b] No explicit statement that data is broad beam data.
[c] McKenzie et al. (1986).

Table 4. Effective Transmission Factors for ^{192}Ir and ^{137}Cs versus Patient Lateral Half-Pelvic Widths

Patient lateral half-pelvic (r) (cm)	Effective transmission factor K(r) for ^{192}Ir (Glasgow 2002b)	Effective transmission factor K(r) for ^{137}Cs (Glasgow 1985)
10	0.72	0.71
12	0.66	0.66
14	0.64	0.62
16	0.55	0.59
18	0.50	0.55
20	0.44	0.50
22	0.40	0.45
24	0.36	0.41
25	0.34	0.38


OUTER WALL
Emergency Stave
Locked P-LDR Unit Storage
P-LDR
T.V. Camera
Door Interlock Interrupt
Primalert Detector
Primalarm Monitor
FRONT ELEVATION
Door Interlock
Remote

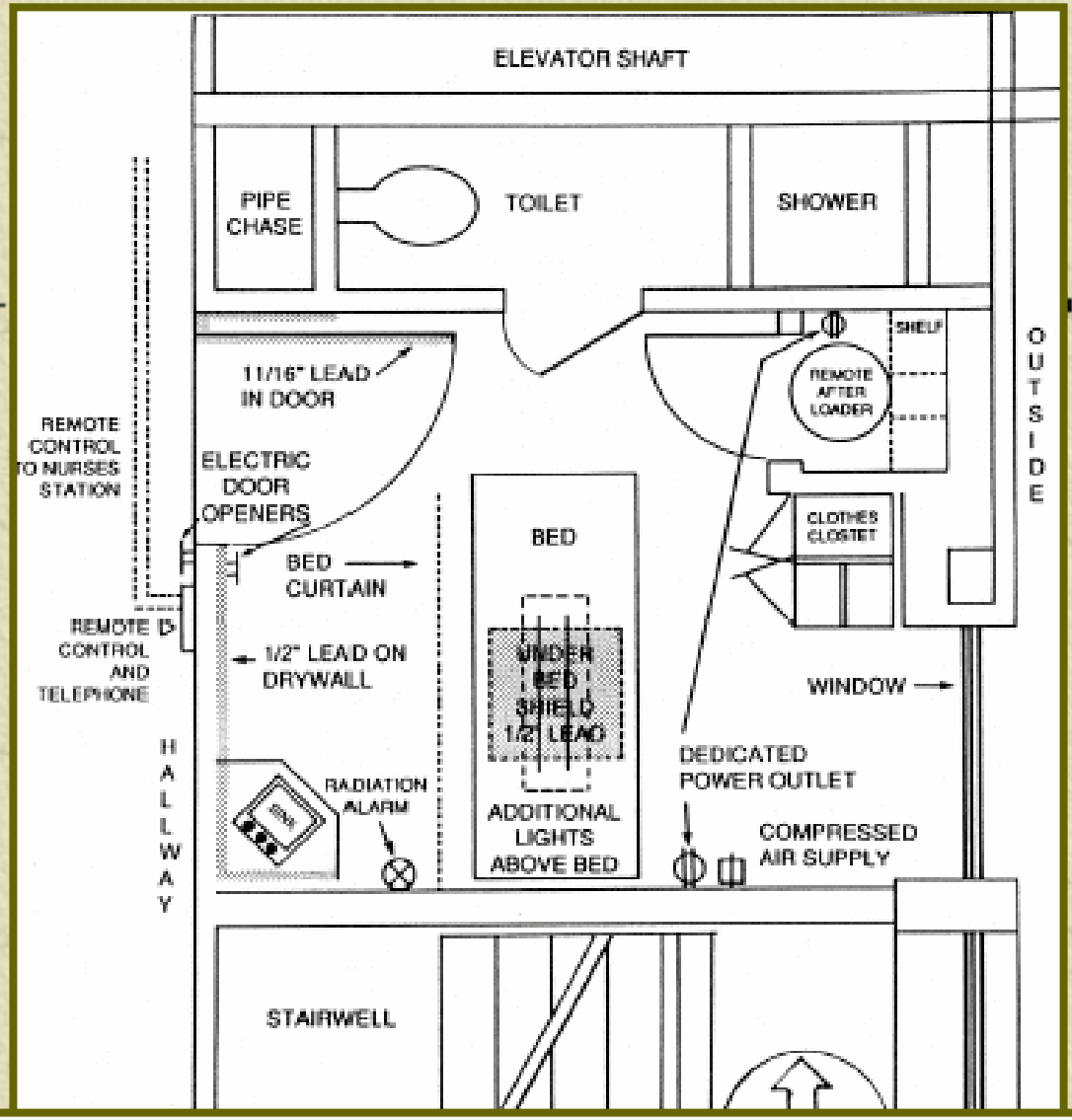


Figure 5a. A small second floor hospital room renovated to house an LDR remote afterloading device for gynecologic treatments. This room features an internal storage closet in which the LDR unit is stored when not in use. A 1.3 cm (1/2 in.) thick lead projection shield beneath the bed shields the area below; a 0.6 cm (1/4 in.) thick lead shield (not shown) is suspended from the ceiling above. Note the compressed air supply, dedicated electric outlet, radiation monitor, remote control and telephone, power-assisted door opener, 1.3 cm (1/2 in.) lead walls shields, and supplemental lights overhead.

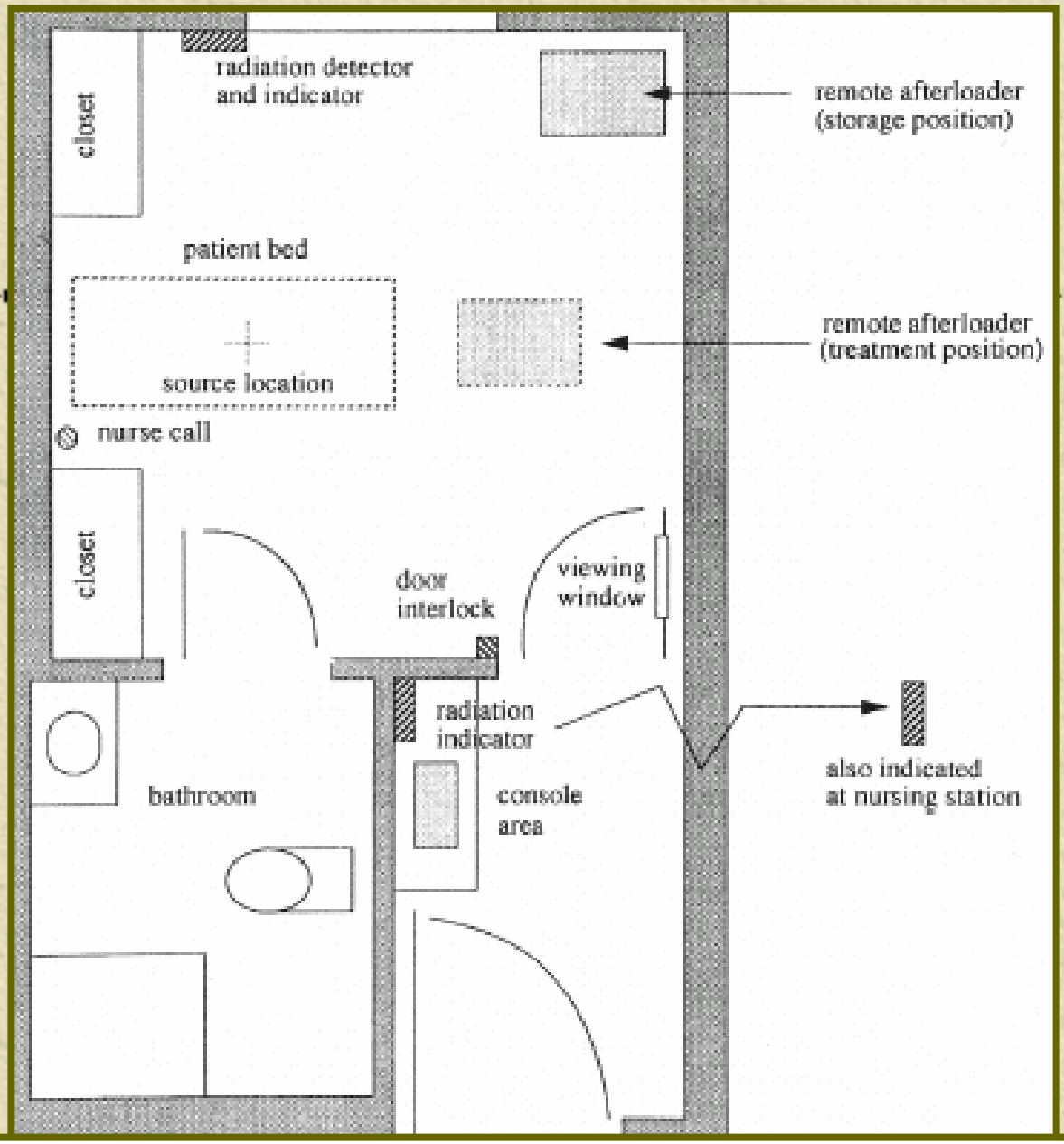


Figure 4. A dedicated LDR remote afterloading room with a small maze and viewing window. (Modified from B.M. Wilson et al., *Med Phys* 13: 608. © 1986, with permission from AAPM. Courtesy J. D. Bourland.]

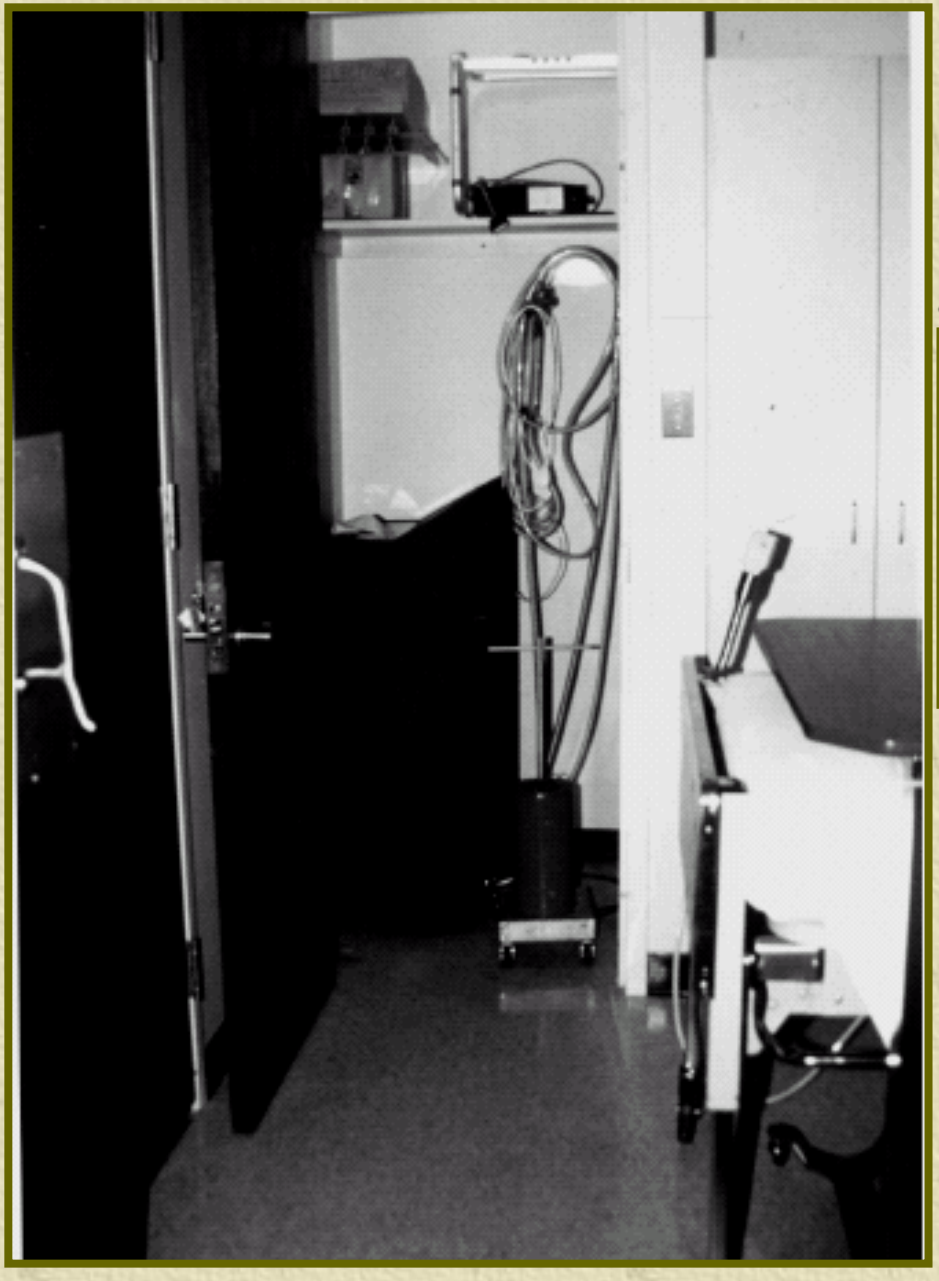


Figure 5b. Adjacent closet houses the Selectron-LDR, a low dose rate remote afterloading device for gynecologic treatments. Note the emergency source retrieval container.

Table 7. Facility Construction Costs[a]

Program	Square Foot Costs	Facility Costs for 600 sq ft[b]
New construction costs for medical building without shielded areas, i.e., offices, etc.	$100	
For an HDR suite for minor procedures, i.e., Class B operating room, add $400 per sq ft	$500	$300,000
For an HDR suite for major procedures, i.e., Class C operating room, add $100 per sq. ft.	$600	$360,000

[a]Calendar Year 2004.

[b]Assume 400 sq ft for treatment area and 200 sq ft console and support areas.

Table 8. Program Cost Estimates[a]

Parameter	Mobile	Low End	High End
HDR Device	$150K–$300K	$250K–$350K	$250K–$350K
Applicators	$100K–Dupl	$50K–Basic	$100K–Many
Table	$35K	$35K	$75K
Van	$25K		
Physics QA	$25K	$25K	$50K
Image System	Use Existing	$120K C-Arm	$600K IBU
Vault	Use Existing	$175K–Sm	$235K–Lg
Totals	$310K–$460K	$655K–$815K	$1325K–$1525K

Table 6. Equipment List: Dedicated HDR Remote Afterloading/Minor Procedures Suite

Remote afterloader storage and treatment location; source guide tubes; in-room radiation detector; check source	Anesthesia area: Medical gases and vacuum; designated location and electrical power for patient monitoring equipment; remote displays
Remote afterloader control console	Operating room/procedures light
Visual communications: 2 systems	Applicator storage and medical and nursing supplies
Audio communications	Sink/scrub/gown/glove area
Secure locked door; door interlock	Treatment applicators
Multiple position patient procedure table; x-ray compatible	Applicator positioning clamp: Integral with procedures table
Overhead track-mounted radiography with X-ray generator and X-ray control console; or,	Emergency off buttons at console, in maze, and in room
Mobile C-arm x-ray unit with fluoroscopy; fiducial marker device	Emergency lighting; wall or ceiling mounted
Emergency recovery equipment and container; "Open source" sign, etc.	Emergency power for selected equipment: Audio, video, anesthesia patient monitoring, lighting, radiation detectors and indicators; remote afterloader
Survey meters	Patient monitors
Optional ultrasound imaging system	Optional treatment planning workstation

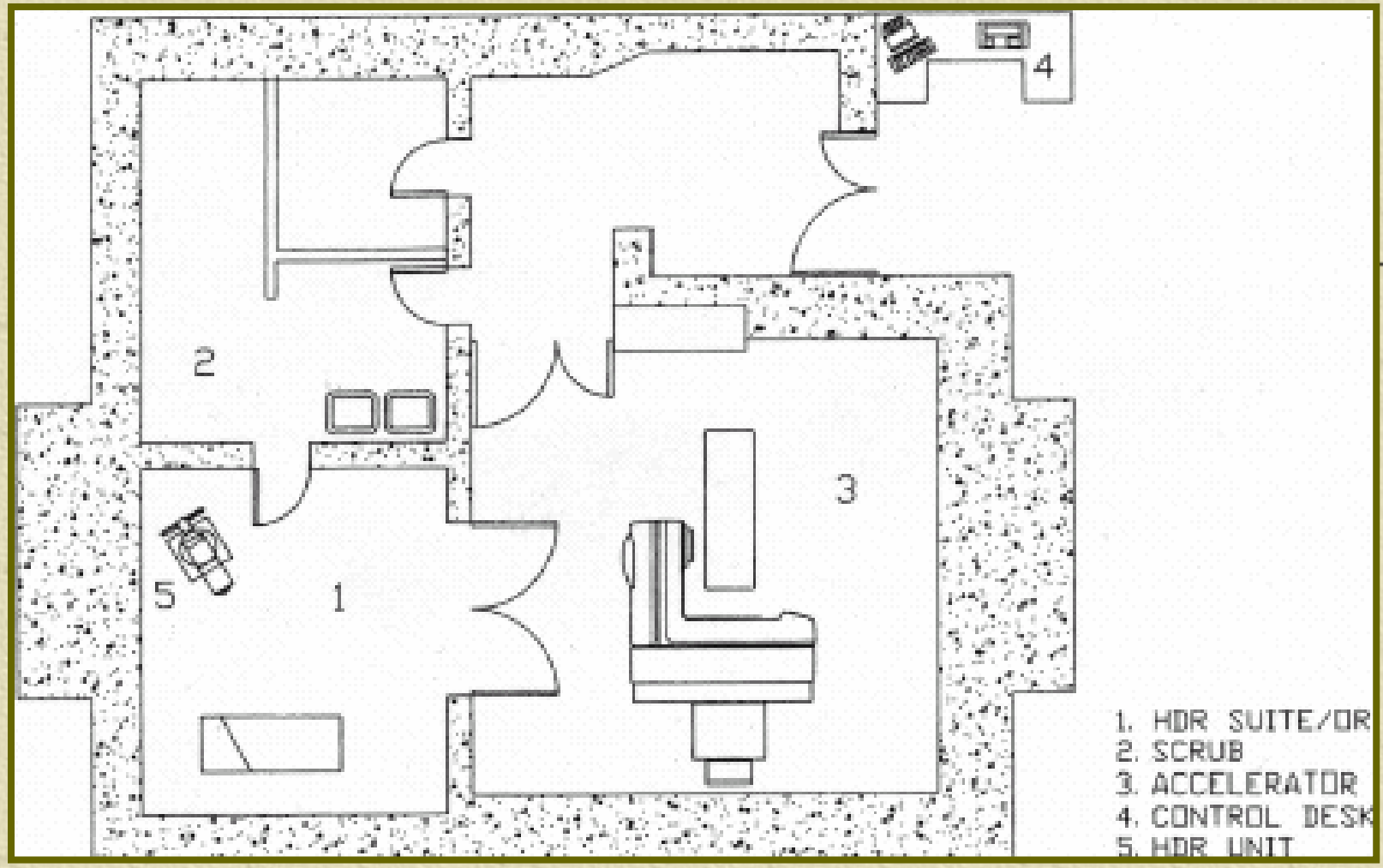


Figure 6. Dedicated intraoperative radiotherapy facility at the Regional Cancer Center at Baptist Hospital of Miami. The facility is also used as an HDR suite. [Reprinted from "Design and Implementation of a Program for High Dose Rate Brachytherapy" by P. V. Houdek, G. P. Glasgow, J. G. Schwade, and A. A. Abitbol in *High Dose Rate Brachytherapy: A Textbook*. S. Nag (ed.). Armonk, NY: Futura Publishing Co., © 1994, with permission from Blackwell Publishing.]

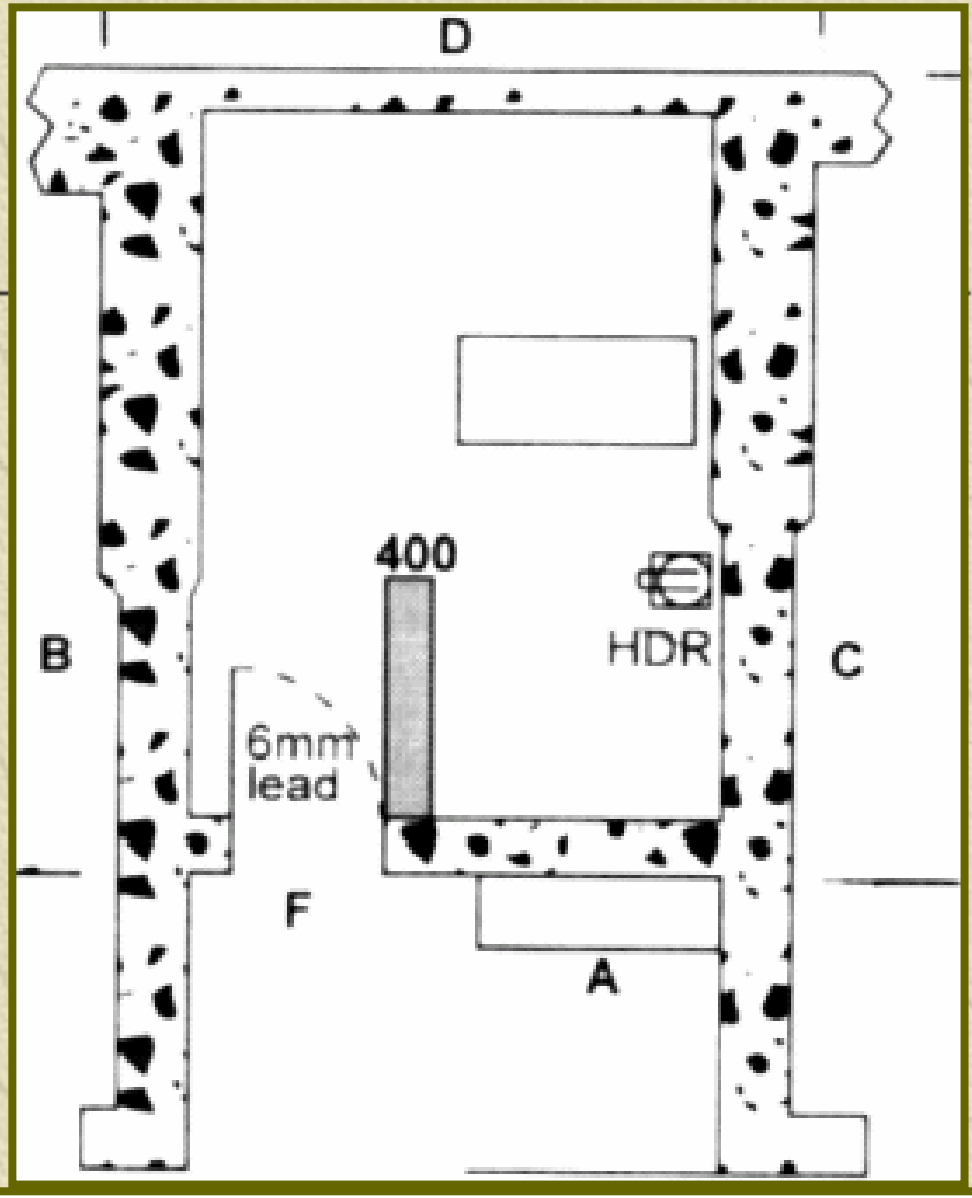


Figure 8. HDR treatment room in a modified orthovoltage room. [Reprinted from Stedeford, B., H. M. Morgan, and W. P. Mayles, "Brachytherapy Room Design" in *The Design of Radiotherapy Treatment Room Facilities*, Institute of Physics and Engineering in Medicine. © 1997. Reproduced with permission.]

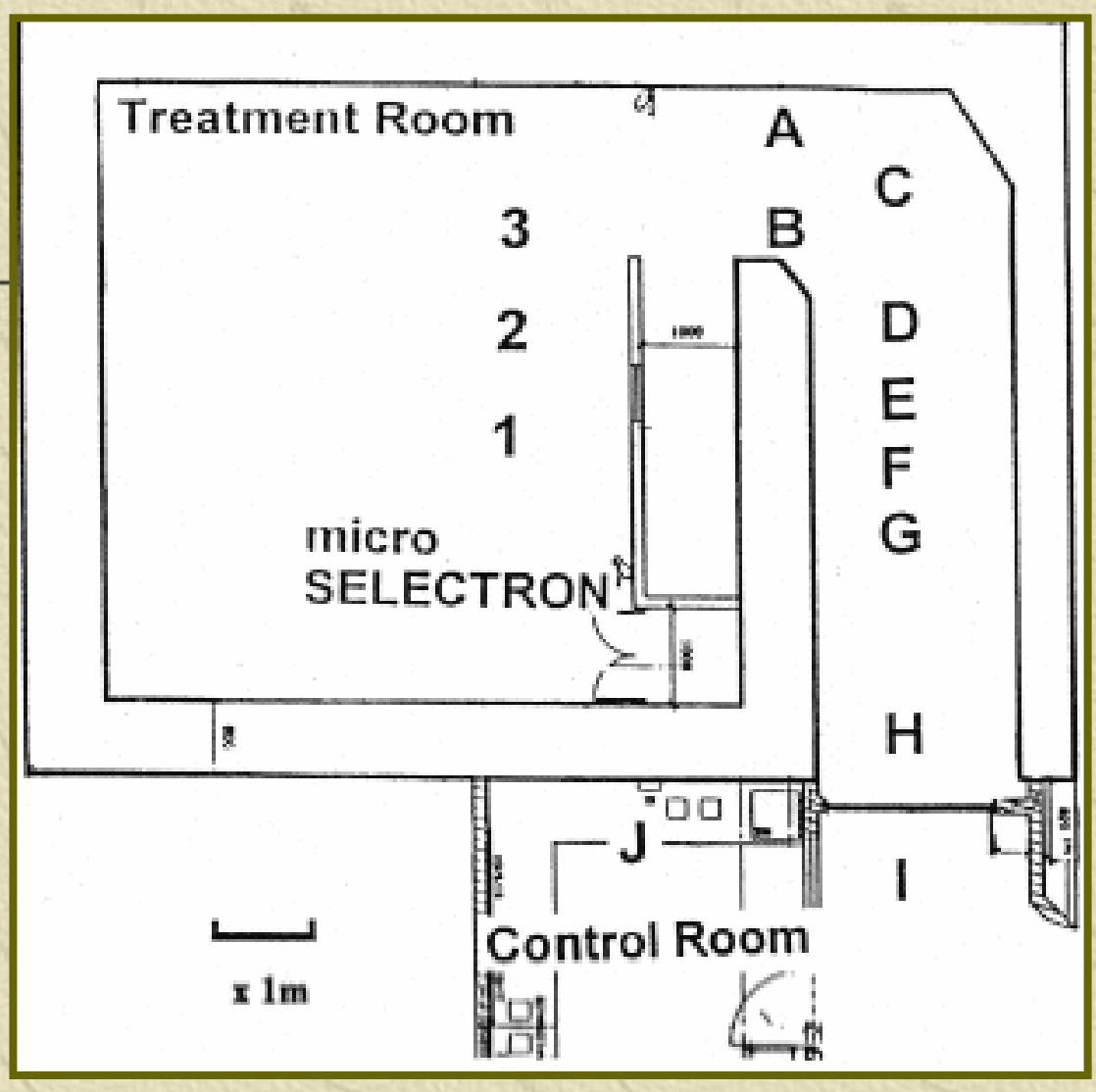


Figure 9. HDR treatment room (shielded operating theatre). [Reprinted from Stedeford, B., H. M. Morgan, and W. P. Mayles, "Brachytherapy Room Design" in *The Design of Radiotherapy Treatment Room Facilities*, Institute of Physics and Engineering in Medicine. © 1997. Reproduced with permission.]

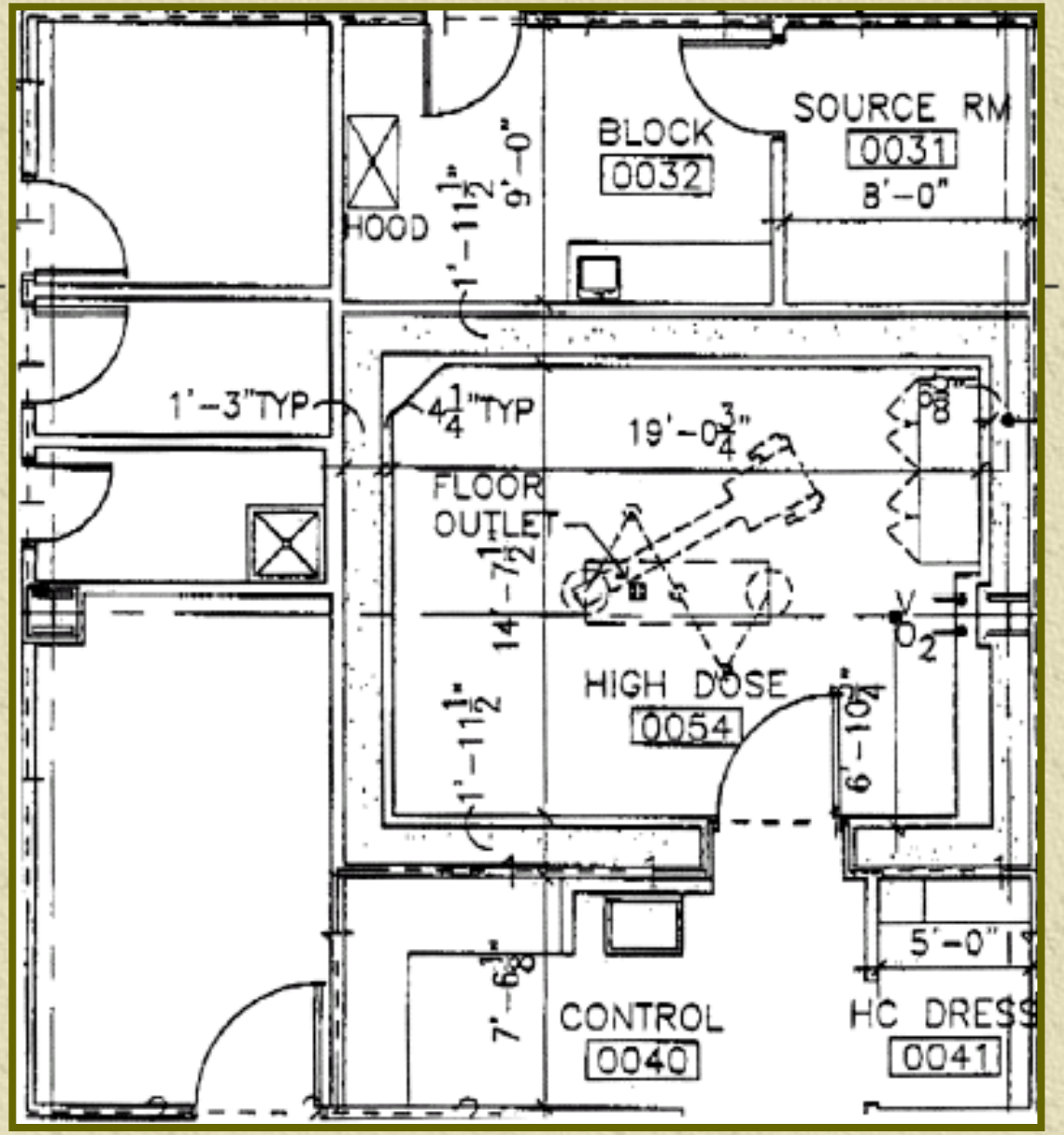
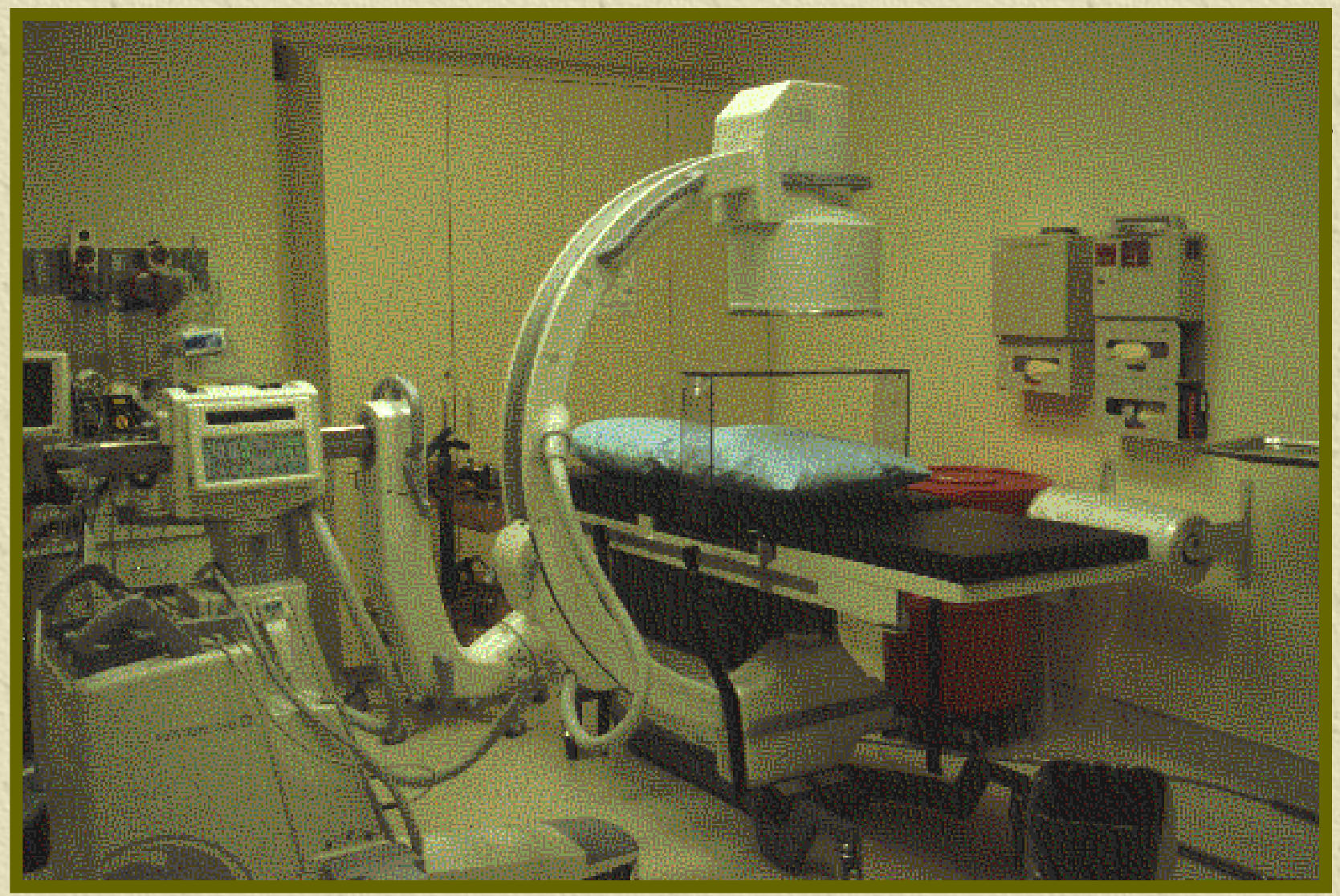


Figure 10. A dedicated "Class B" (minor procedures) HDR suite. (Loyola University Medical Center Outpatient Clinic, 2003)



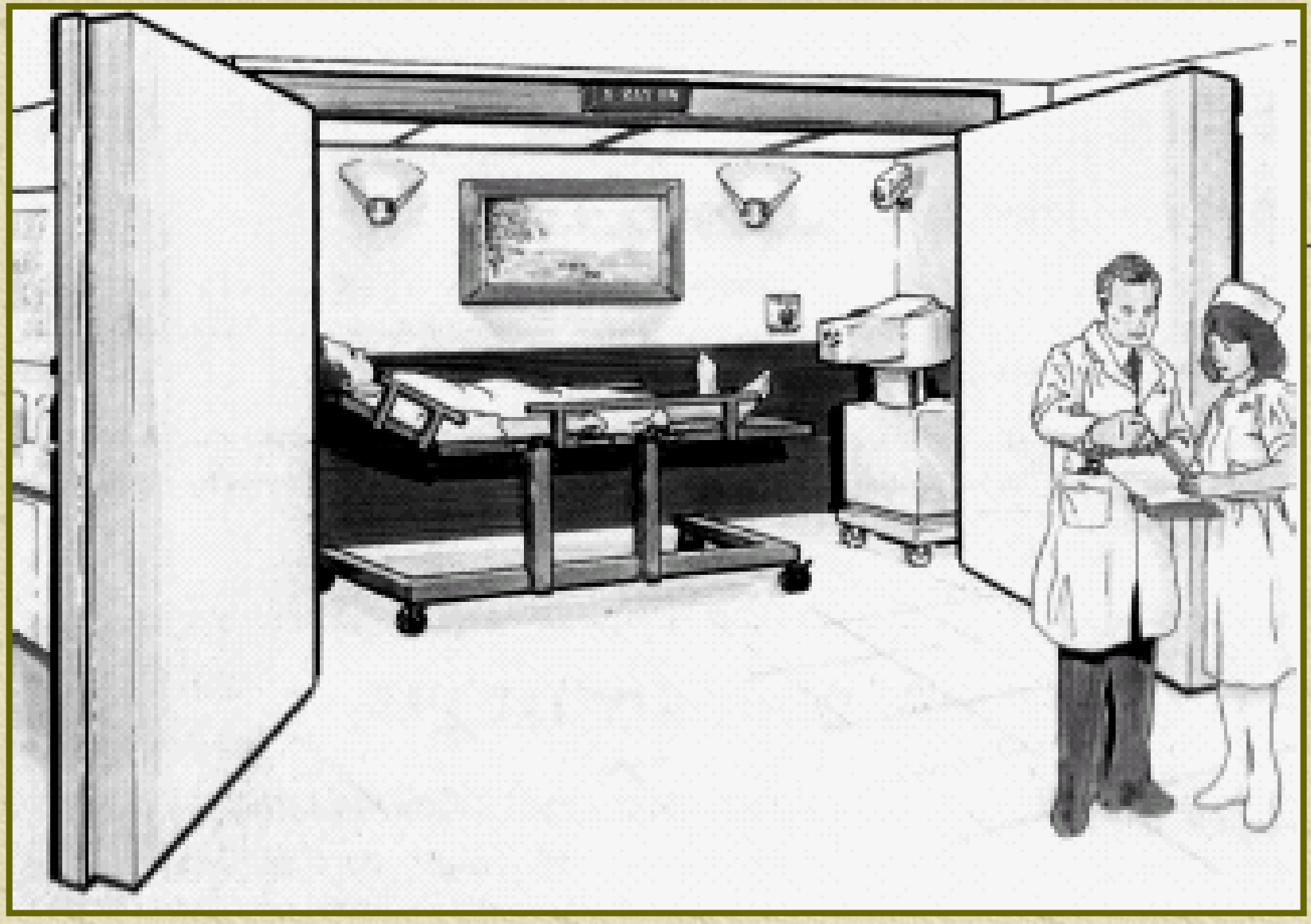


Figure 11. A pre-fab HDR suite. (Courtesy Rick LeBlanc, NELCO, Woburn, MA.

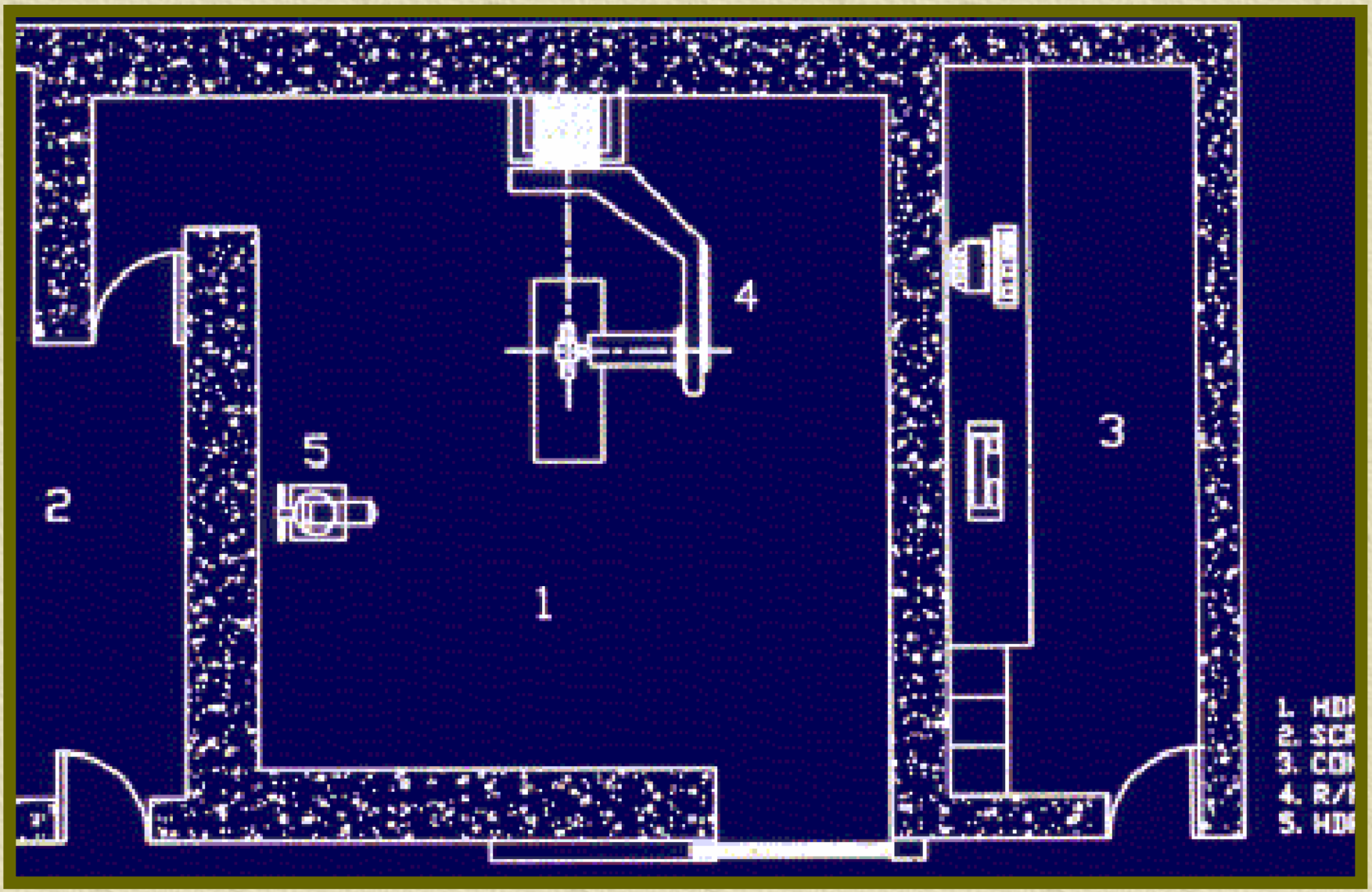

4
5
2
3
1

Figure 13. “On the road, again!” A movile HDR van. (Courtesy Plato Lee.)

Brachytherapy Facility Design

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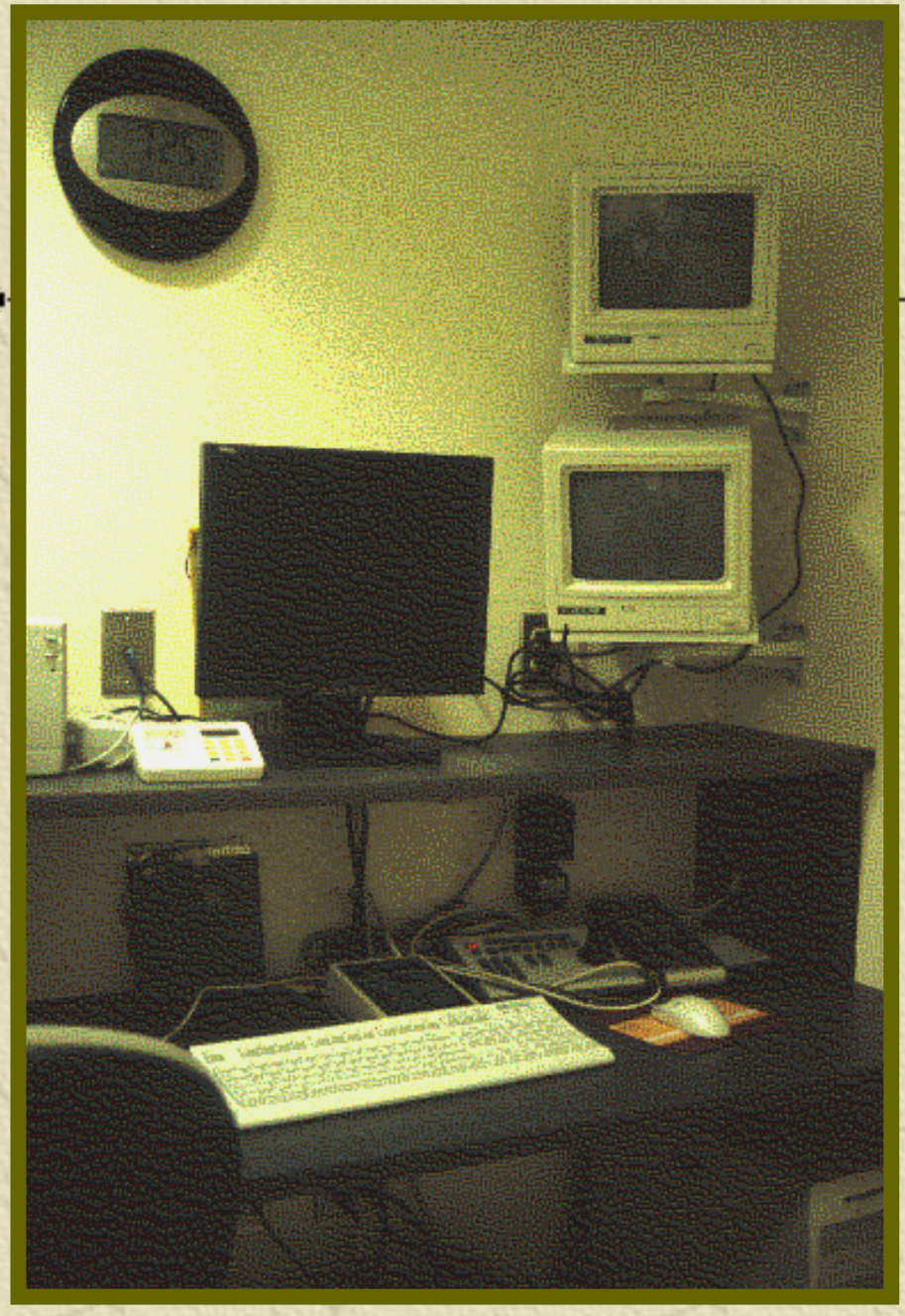
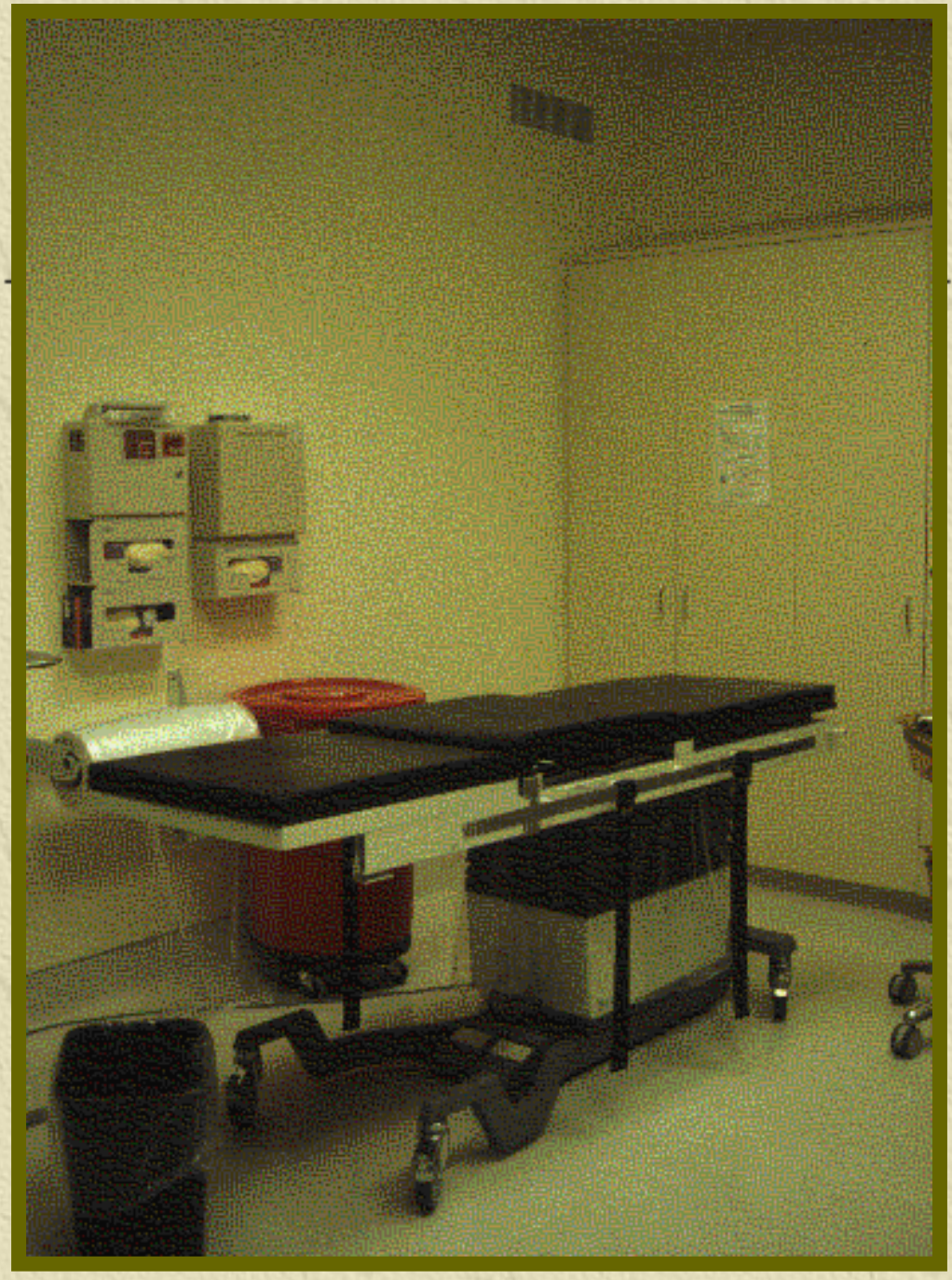
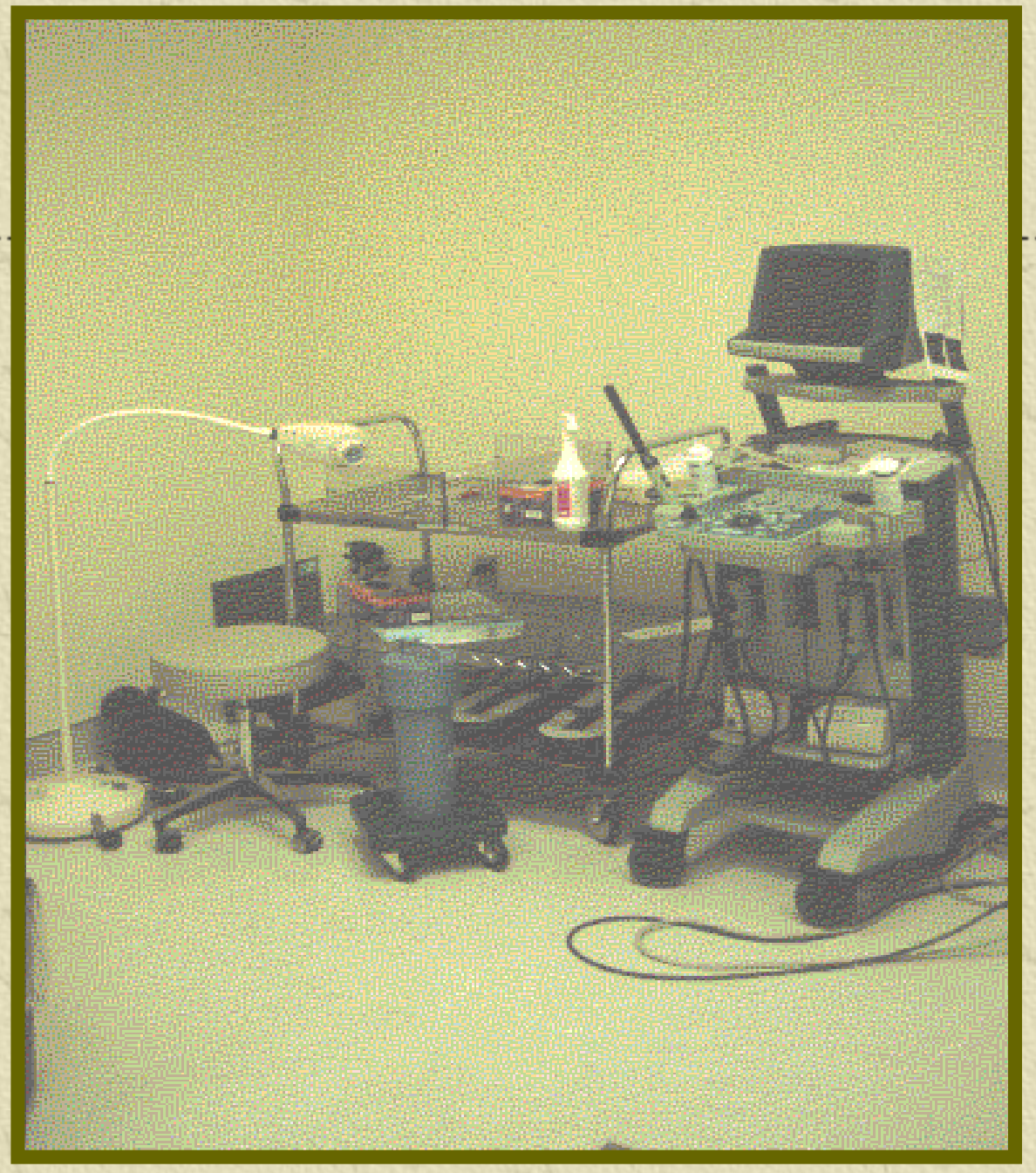
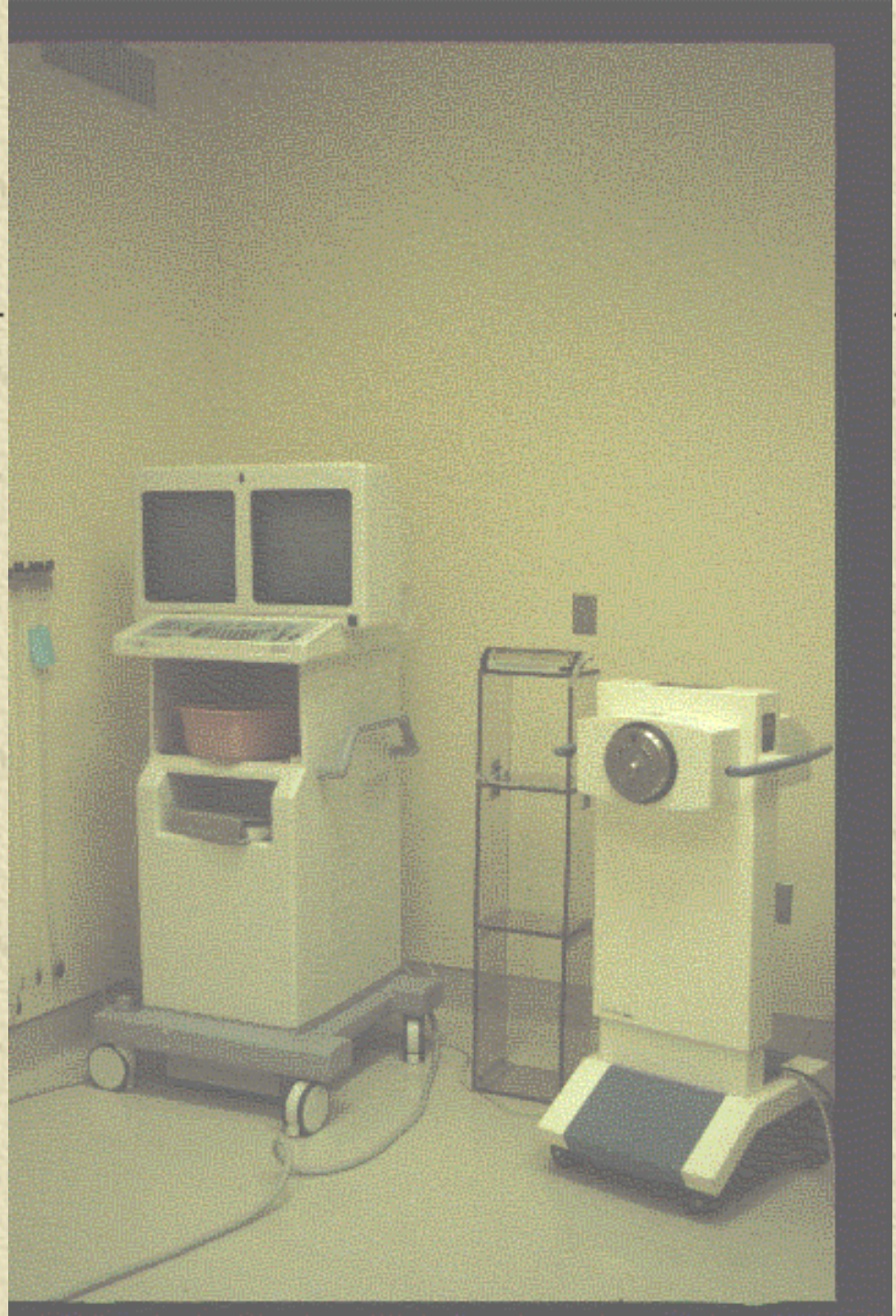
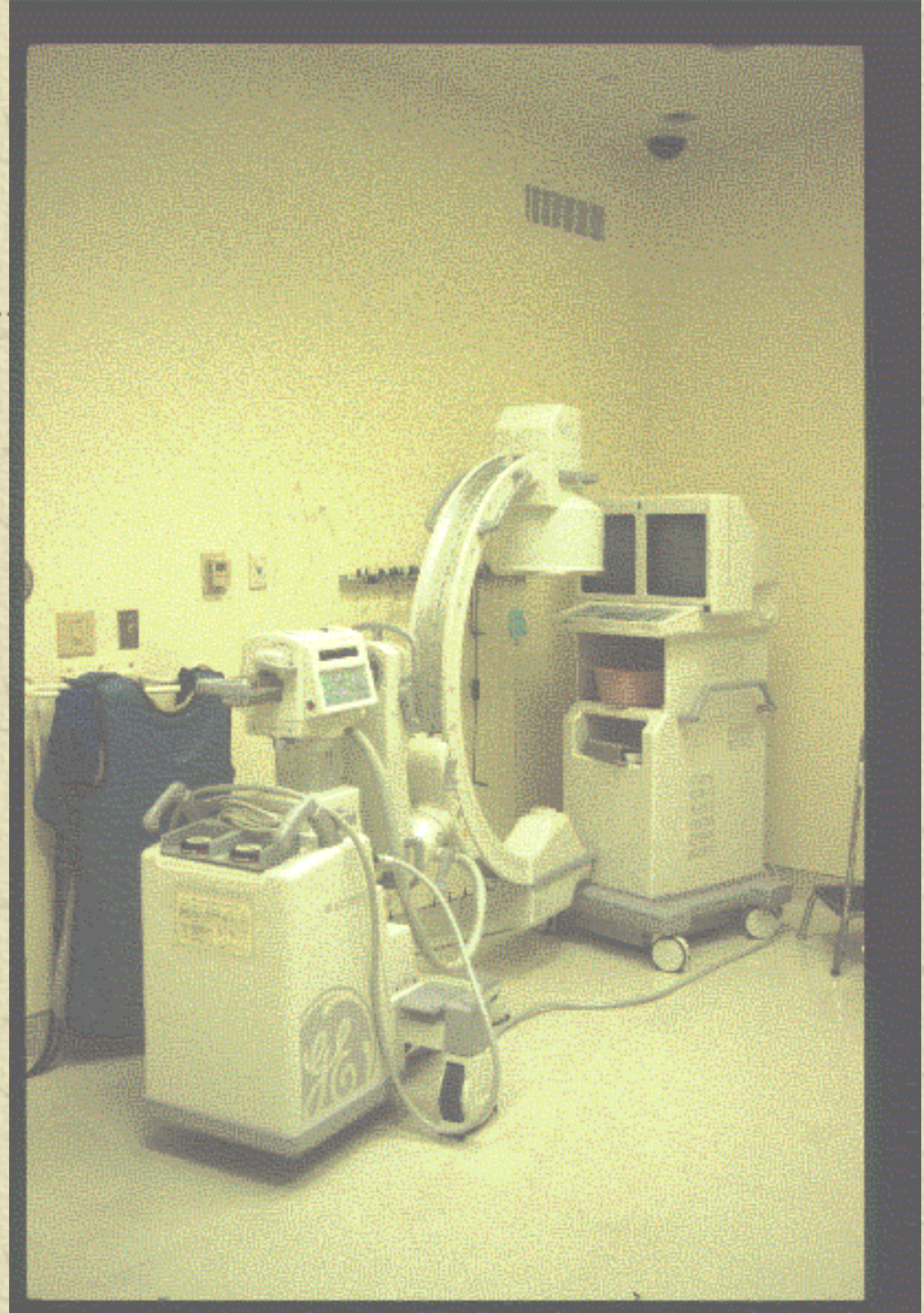
BEAM
ON











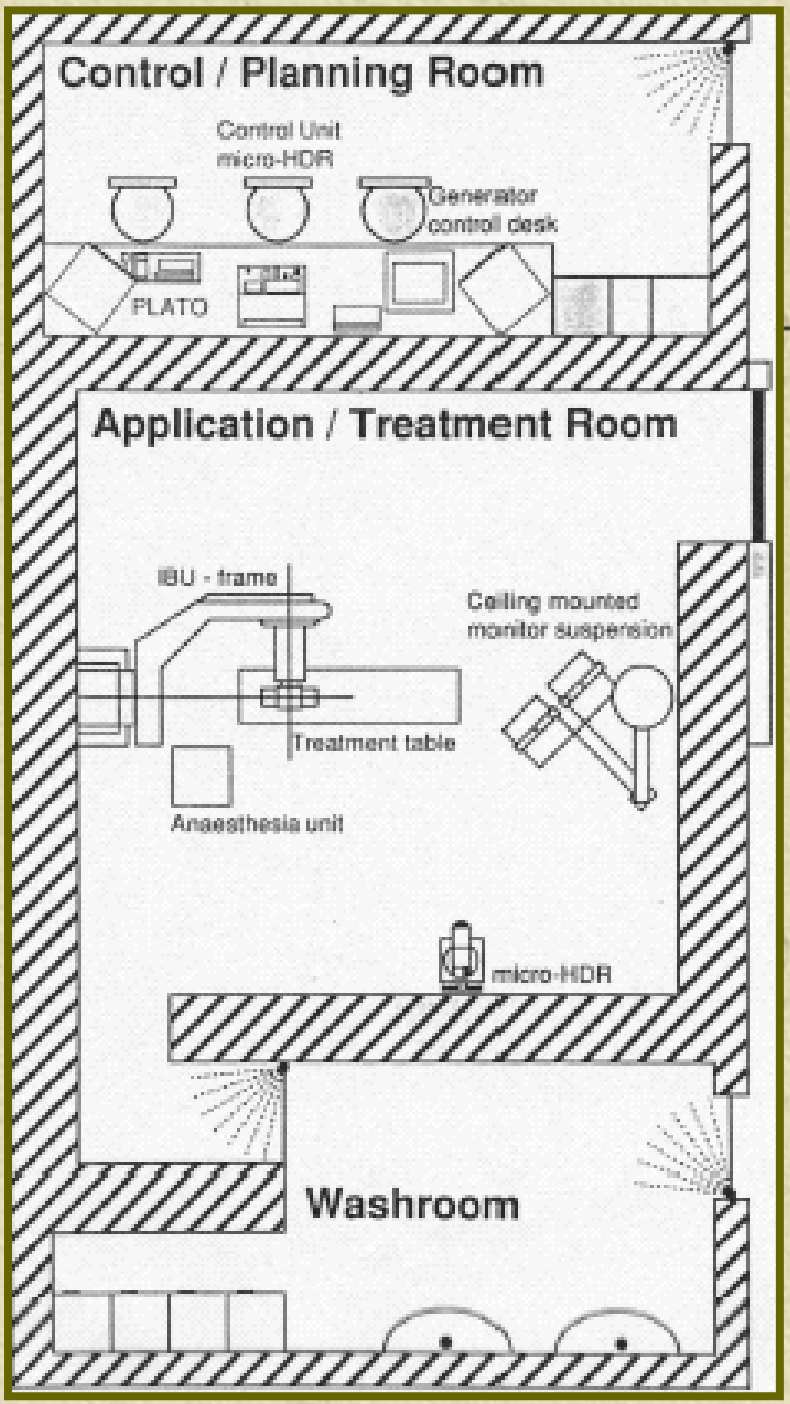
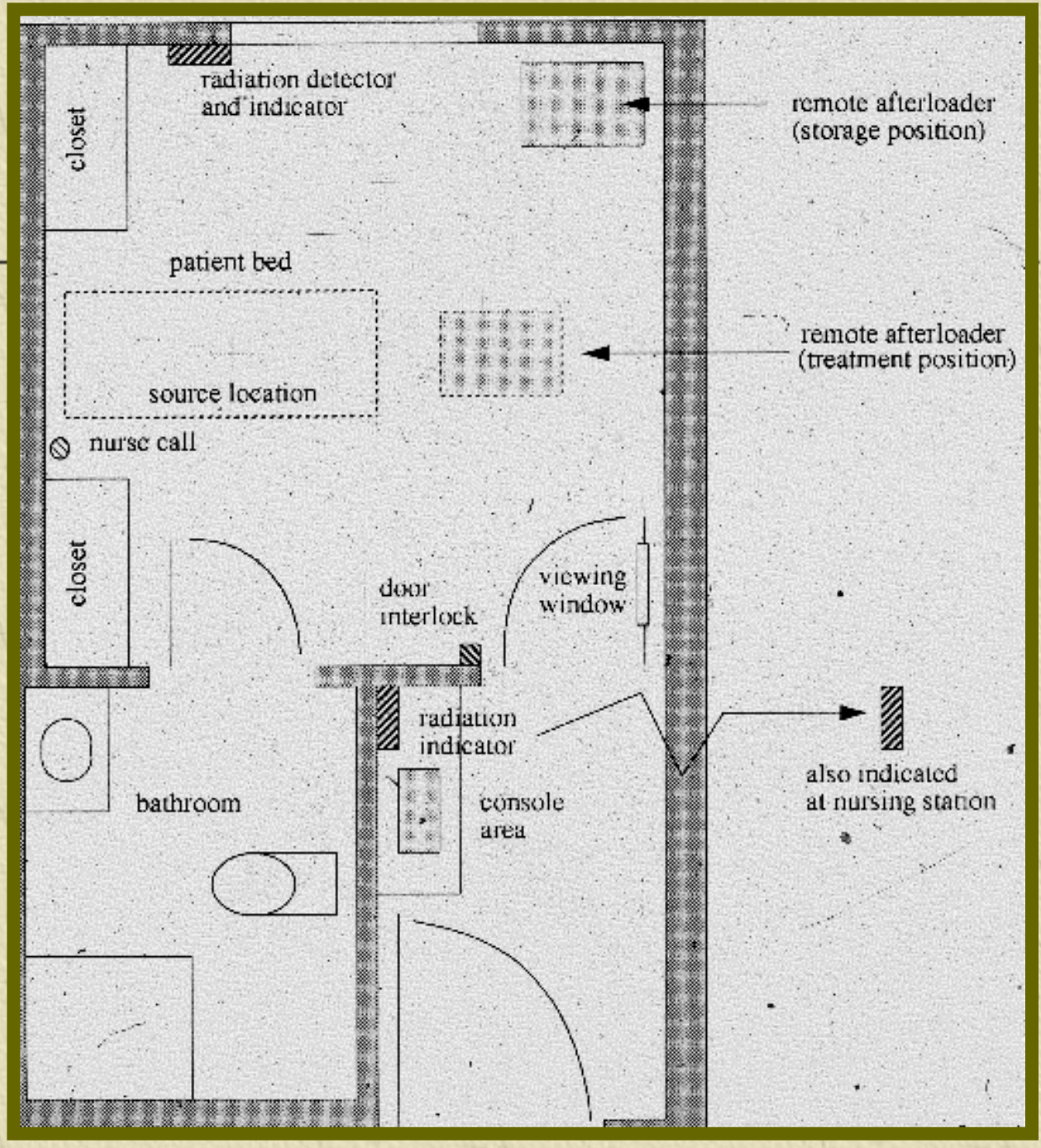
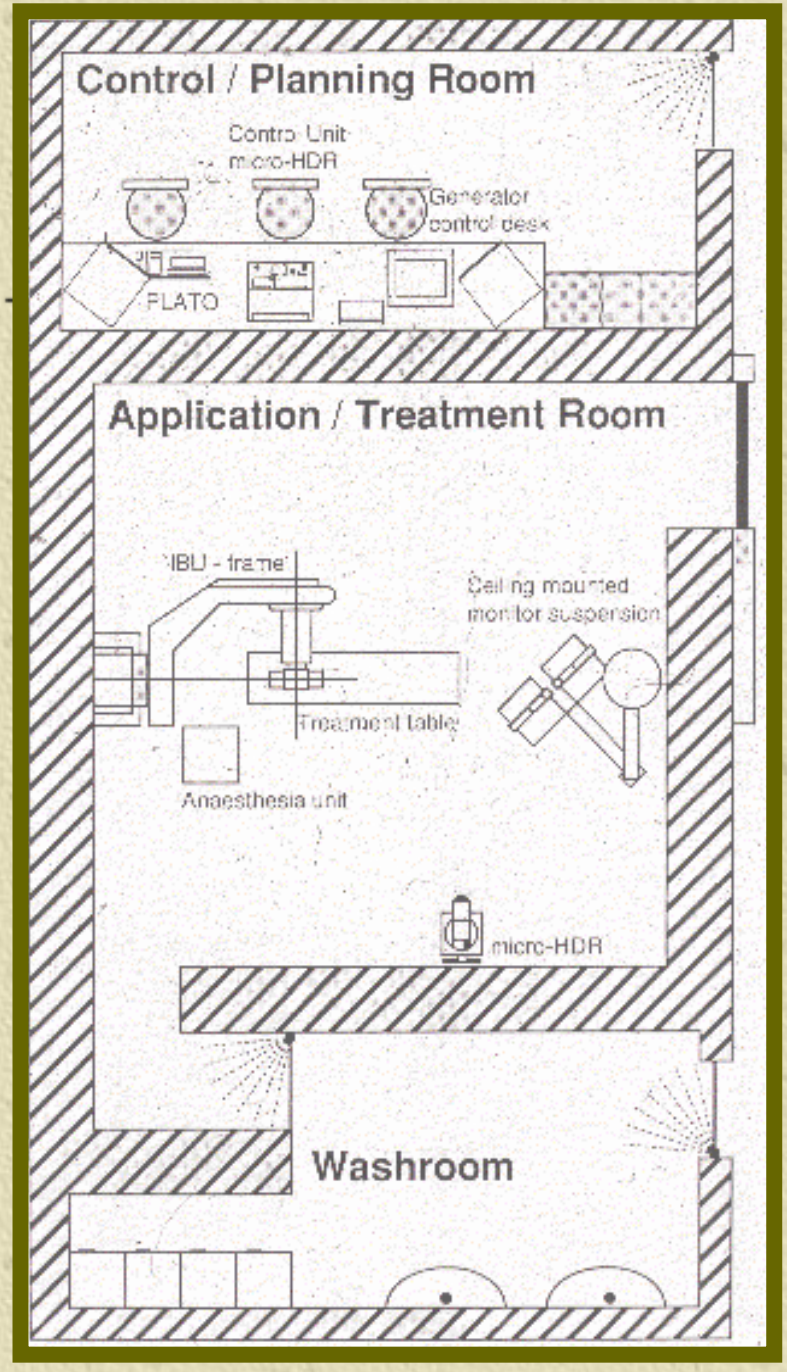


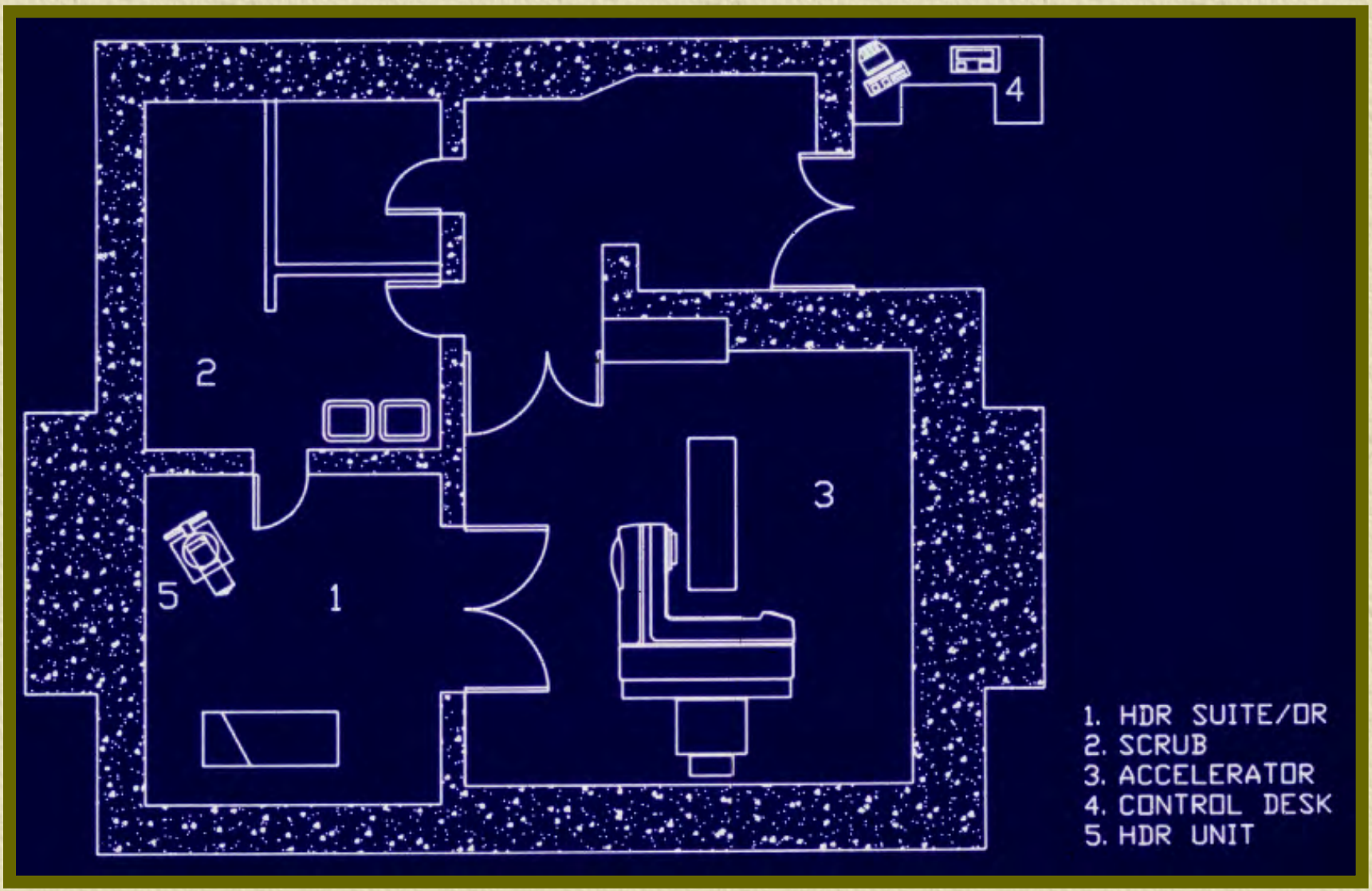
Figure 12. An integrated brachytherapy unit.

(Courtesy, E. van ‘t Hooft, Nucletron International B.V.

EXIT


radiation detector
and indicator
closet
remote afterloader
(storage position)
patient bed
source location
remote afterloader
(treatment position)
nurse call
closet
door
interlock
viewing
window
radiation
indicator
also indicated
at nursing station
bathroom
console
area


Control / Planning Room
Contro Unit micro-HDR
Generator control desk
PLATO
Application / Treatment Room
IBU - frame
Ceiling mounted monitor suspension
Treatment table
Anaesthesia unit
micro-HDR
Washroom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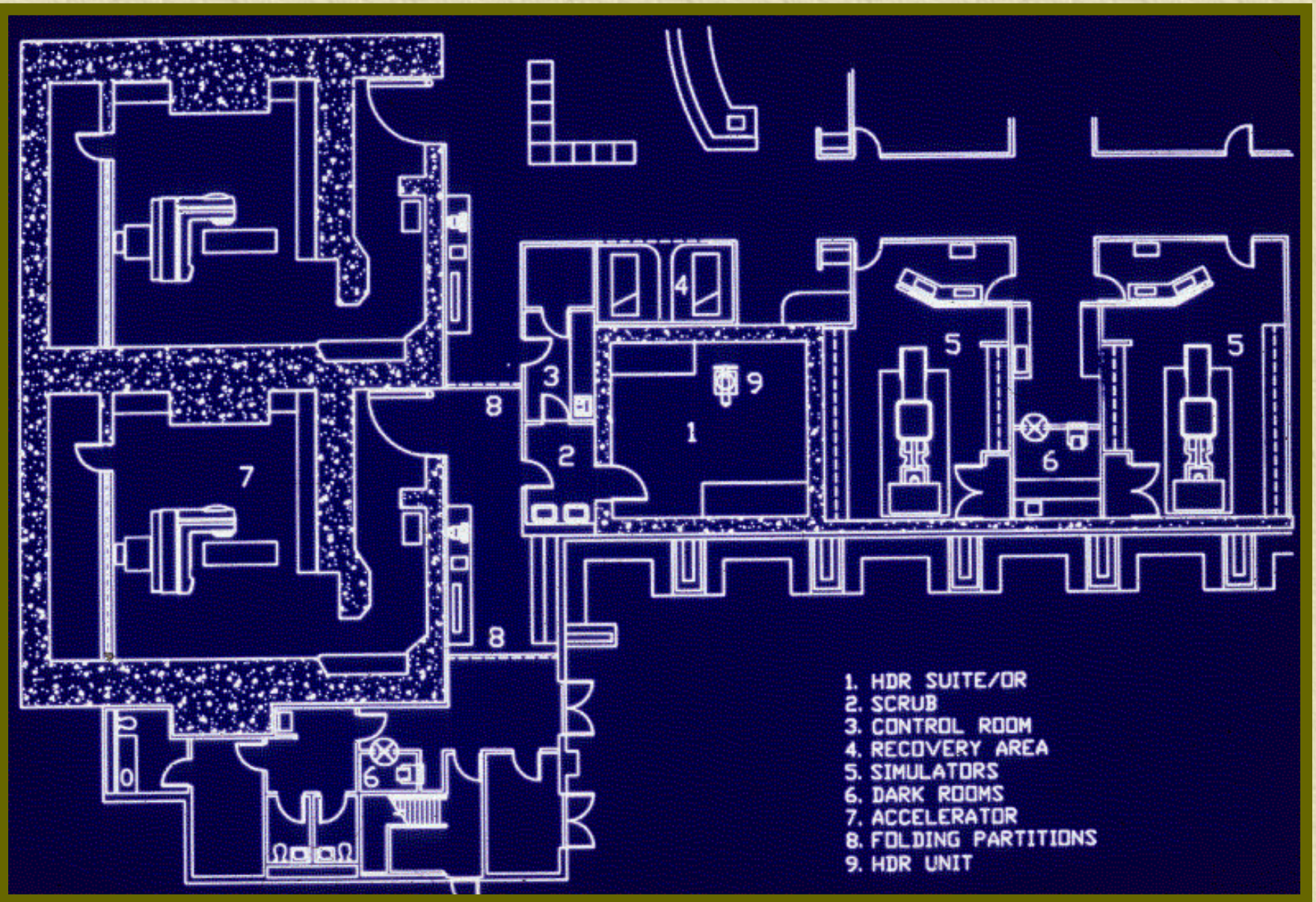
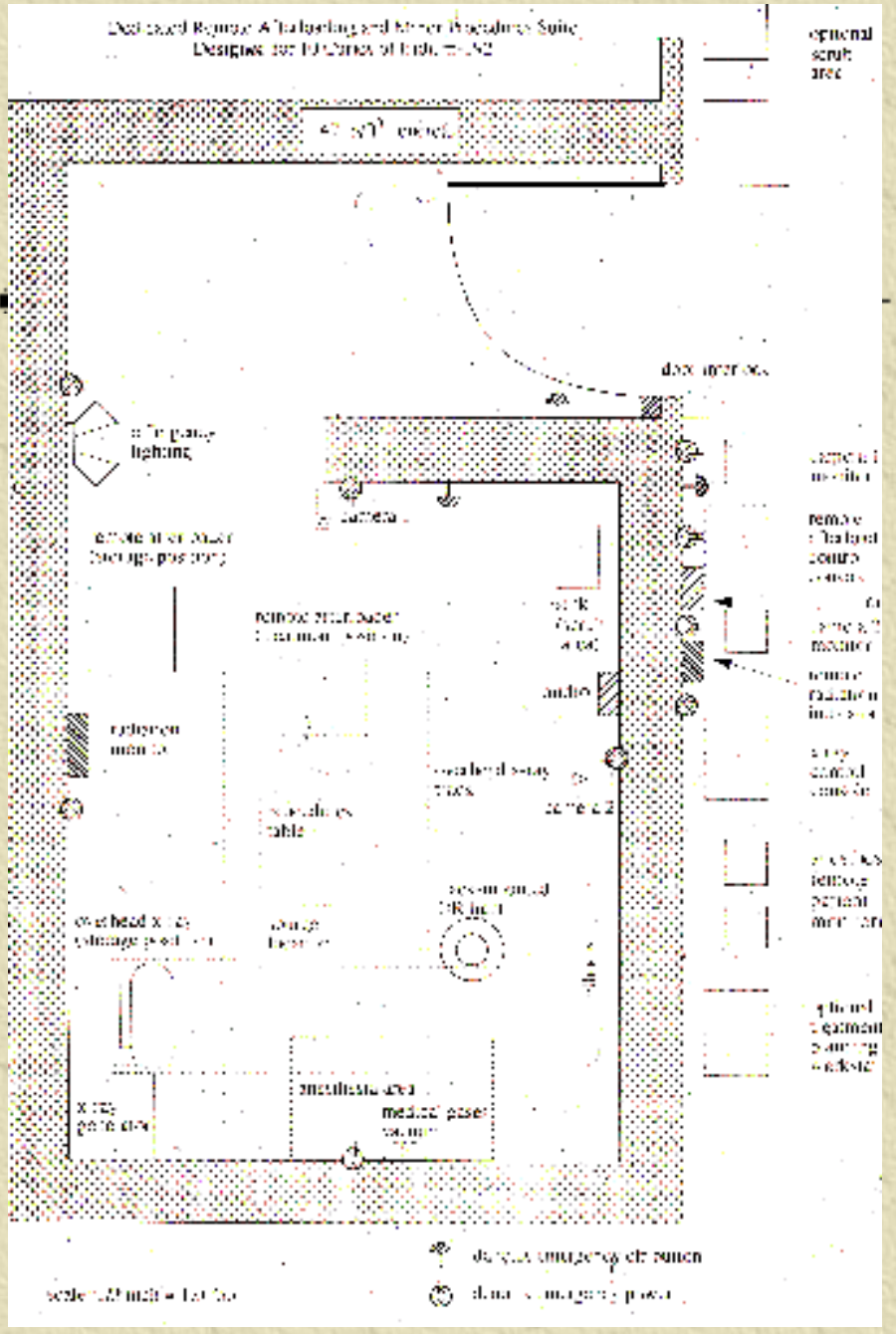
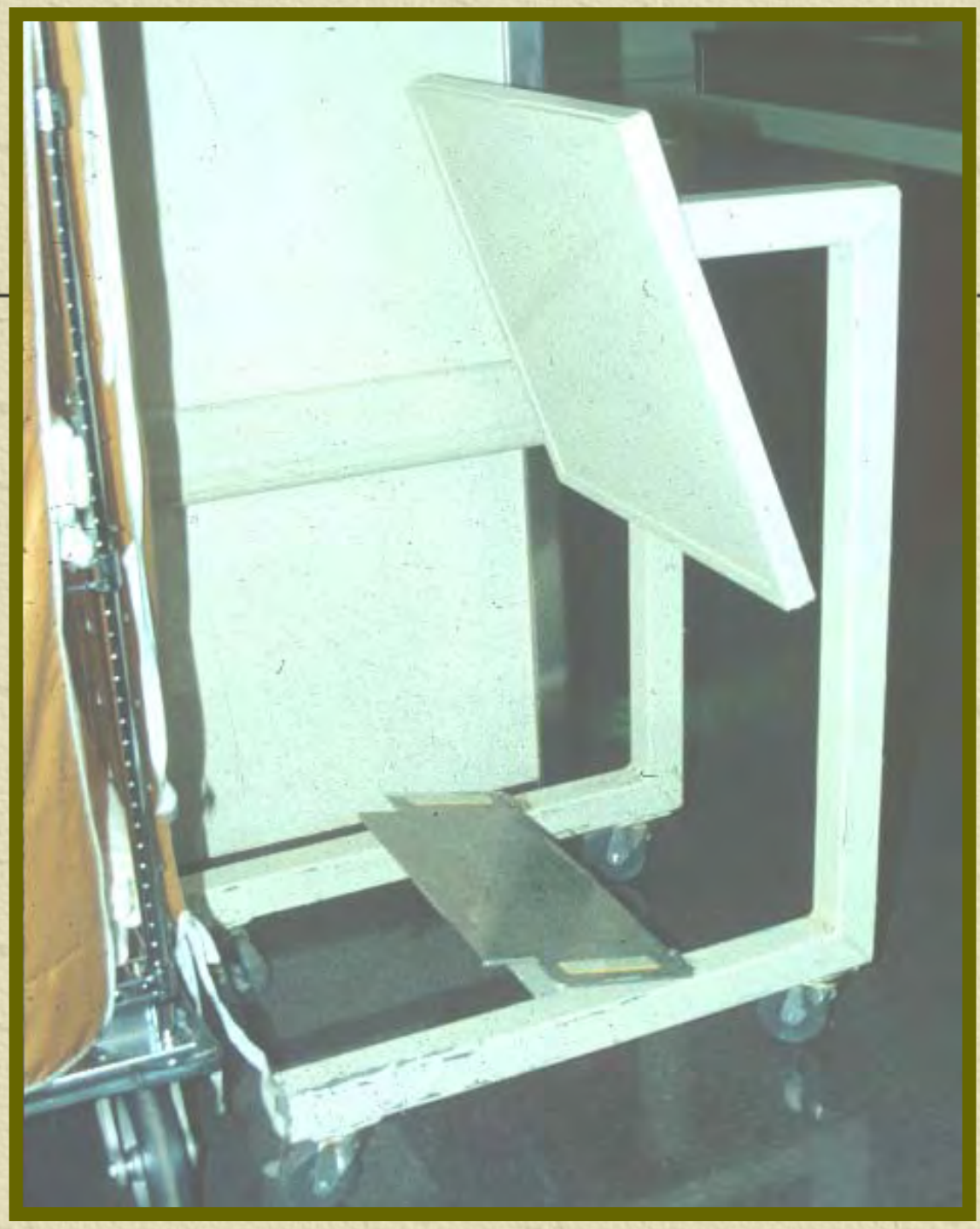
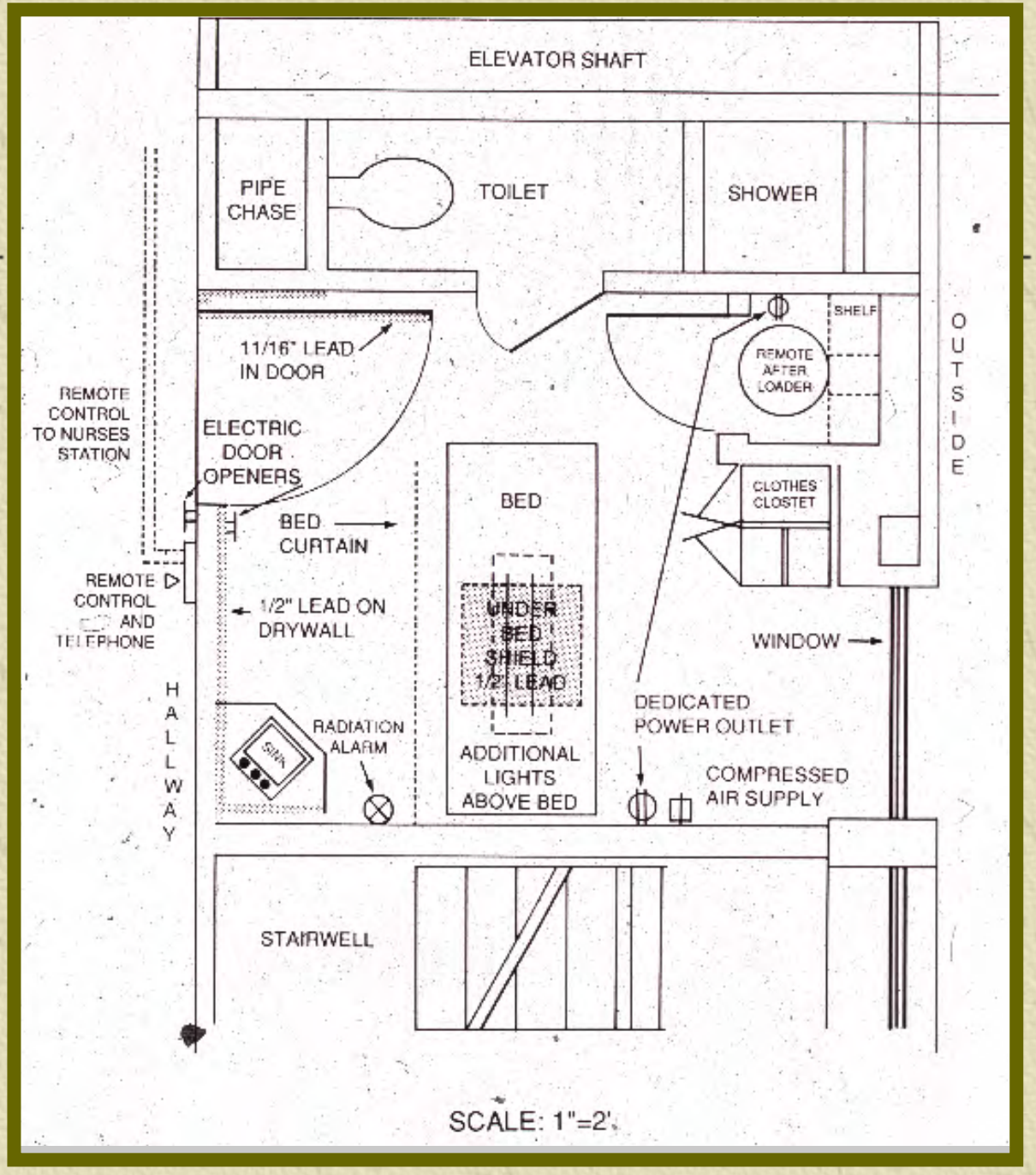
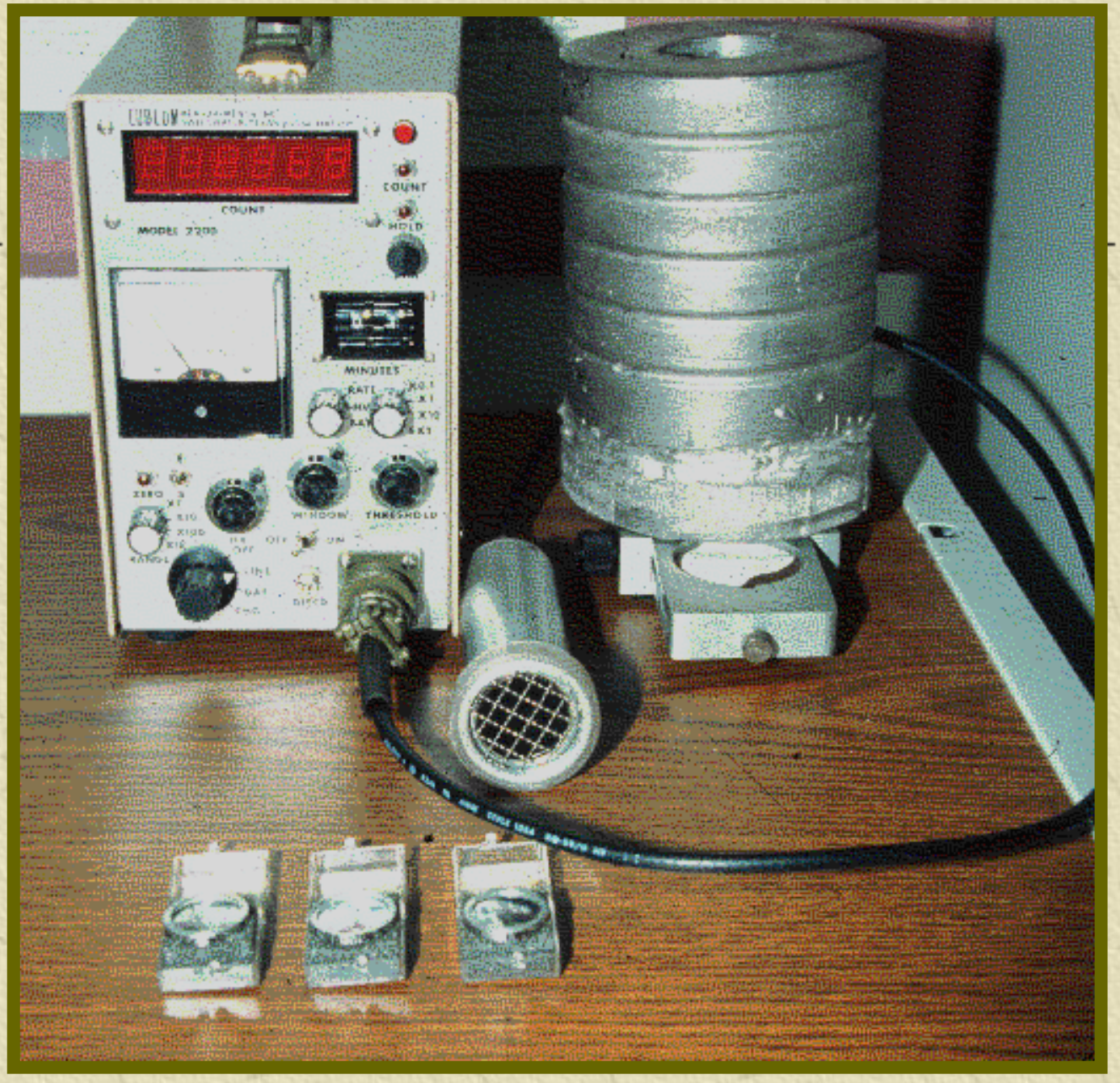
1. HDR SUITE/OR
2. SCRUB
3. ACCELERATOR
4. CONTROL DESK
5. HDR UNIT

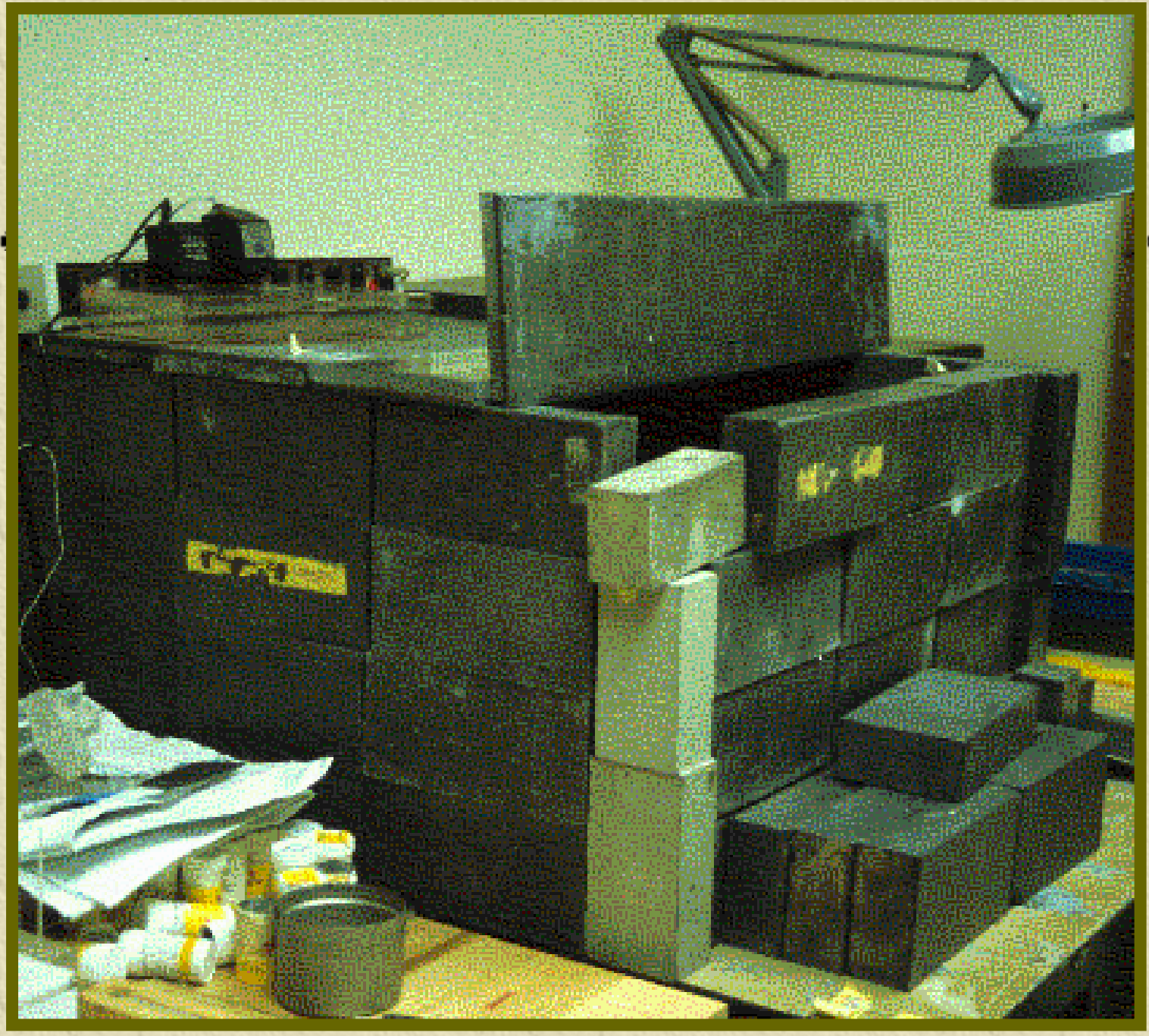

1. HDR SUITE/OR
2. SCRUB
3. CONTROL ROOM
4. RECOVERY AREA
5. SIMULATORS
6. DARK ROOMS
7. ACCELERATOR
8. FOLDING PARTITIONS
9. HDR UNIT

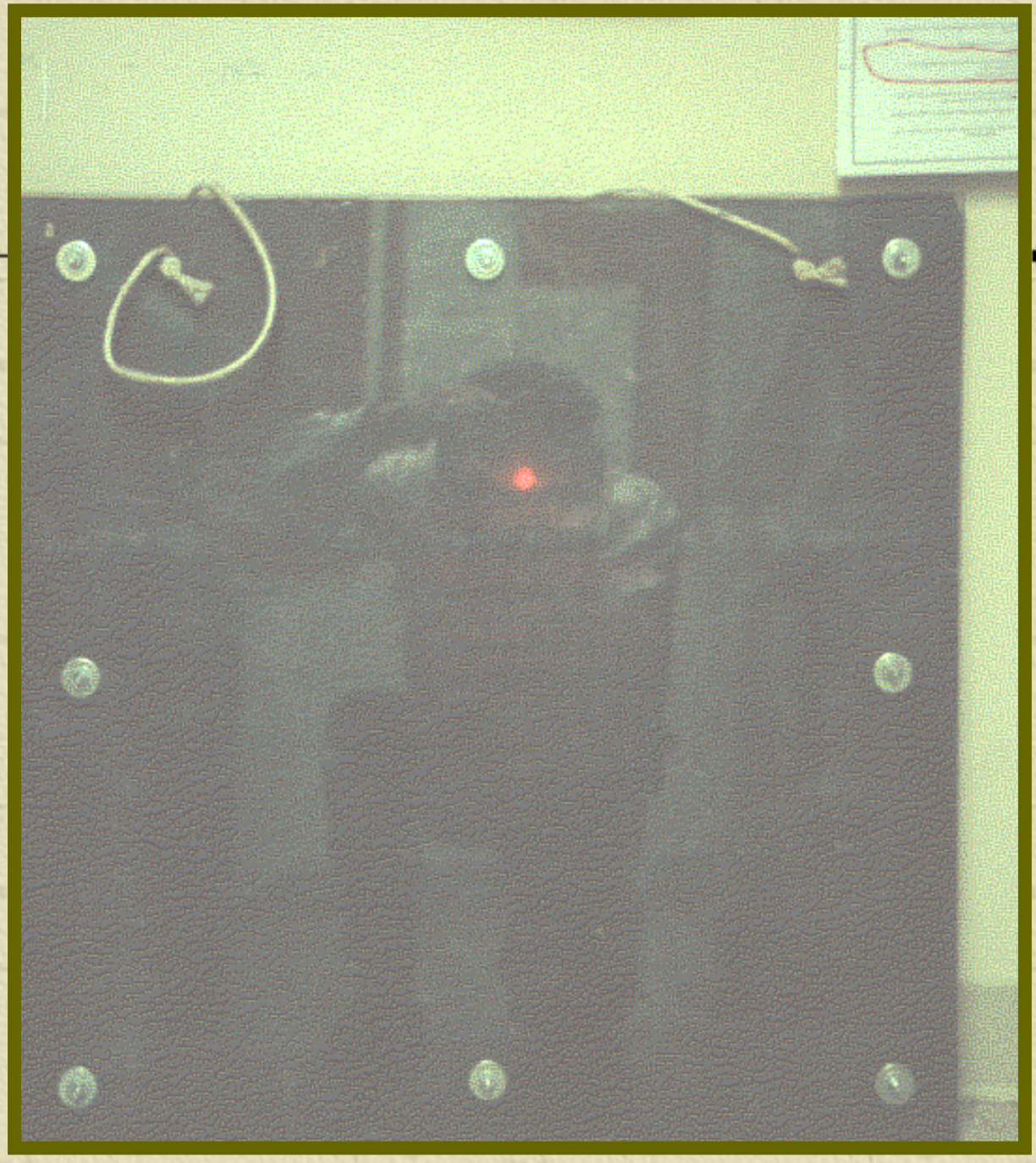


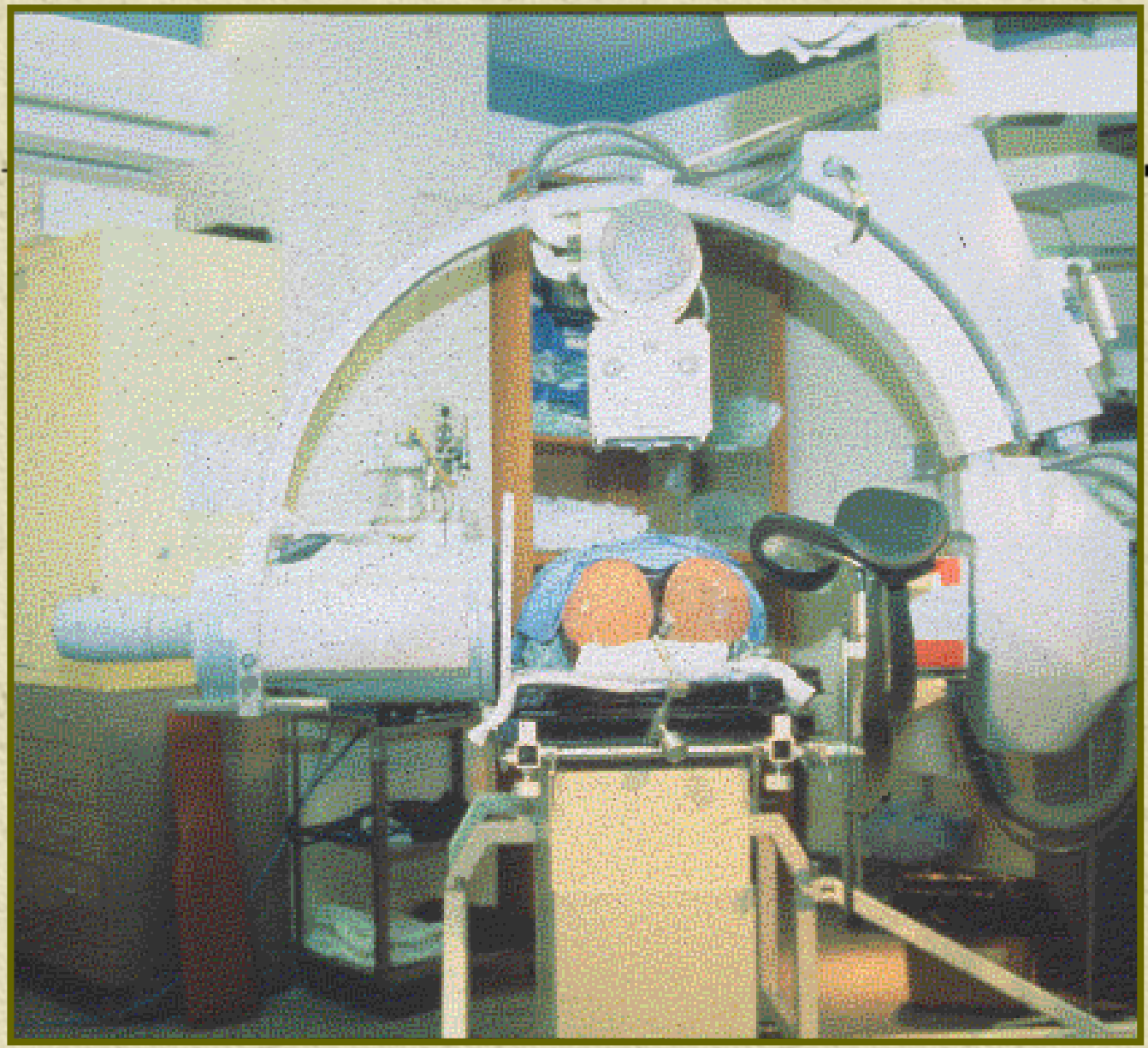



ELEVATOR SHAFT
PIPE CHASE
TOILET
SHOWER
SHELF
REMOTE AFTER LOADER
OUTSIDE
11/16" LEAD IN DOOR
REMOTE CONTROL TO NURSES STATION
ELECTRIC DOOR OPENERS
BED
CLOTHES CLOSTET
BED CURTAIN
REMOTE CONTROL AND TELEPHONE
1/2" LEAD ON DRYWALL
UNDER BED SHIELD 1/2" LEAD
WINDOW
HALLWAY
RADIATION ALARM
SINK
ADDITIONAL LIGHTS ABOVE BED
DEDICATED POWER OUTLET
COMPRESSED AIR SUPPLY
STAIRWELL
SCALE: 1"=2'

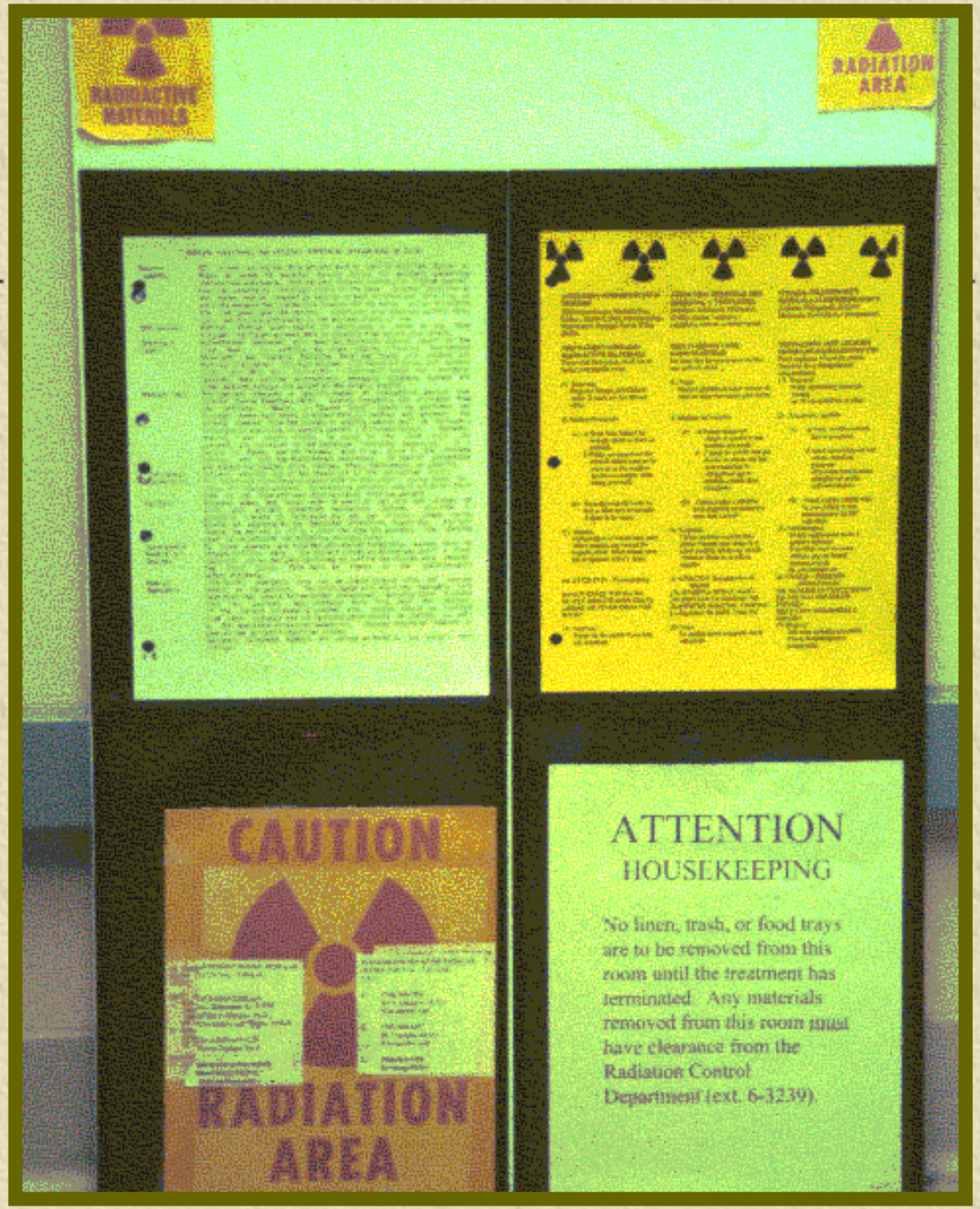

COUNT
MODEL 2200
MINUTES
RATE
WINDOW
THRESHOLD





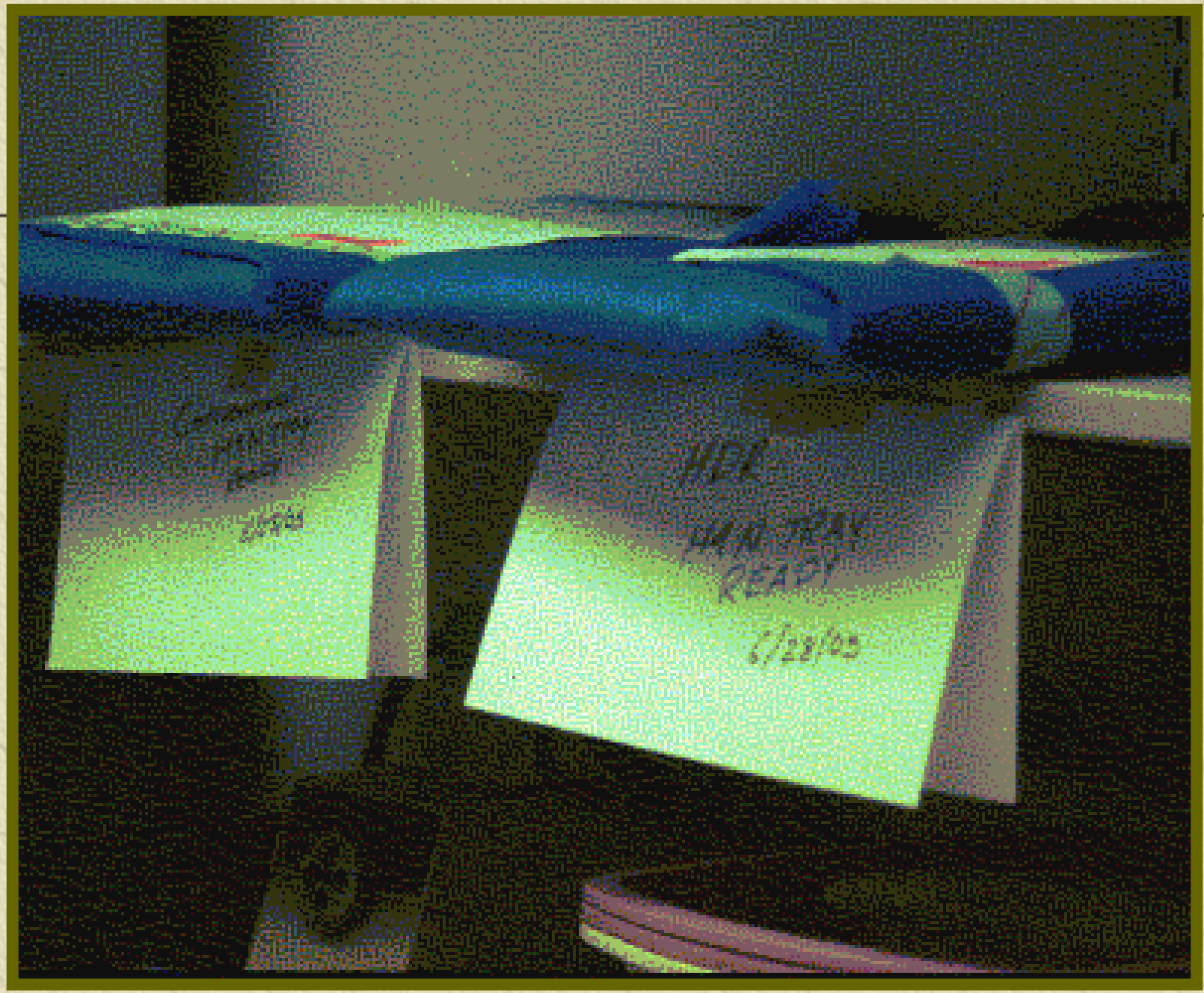


CAUTION
RADIOACTIVE
MATERIAL

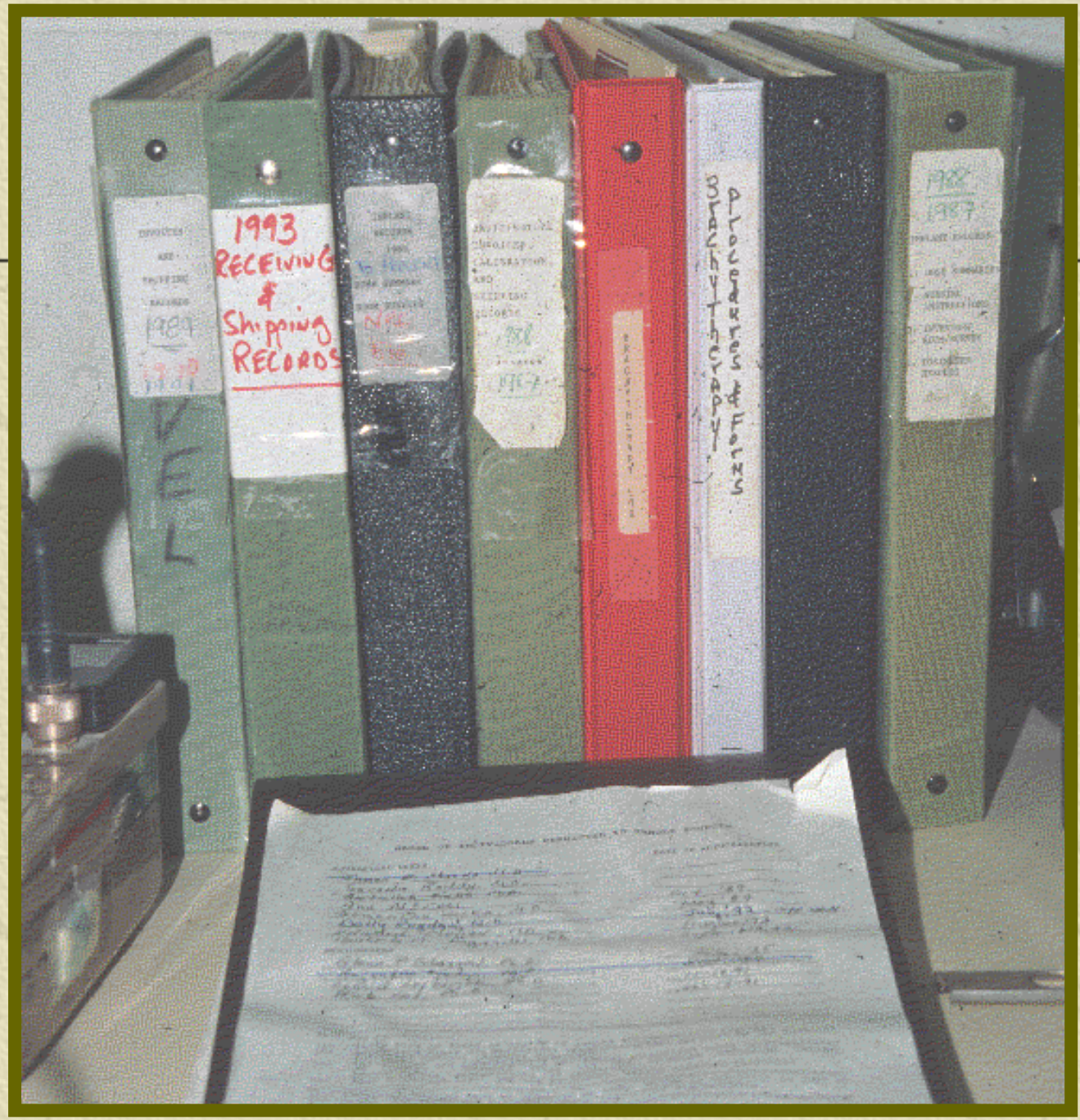

RADIOACTIVE MATERIALS
RADIATION AREA
CAUTION
RADIATION AREA
ATTENTION
HOUSEKEEPING
No linen, trash, or food trays are to be removed from this room until the treatment has terminated. Any materials removed from this room must have clearance from the Radiation Control Department (ext. 6-3239).

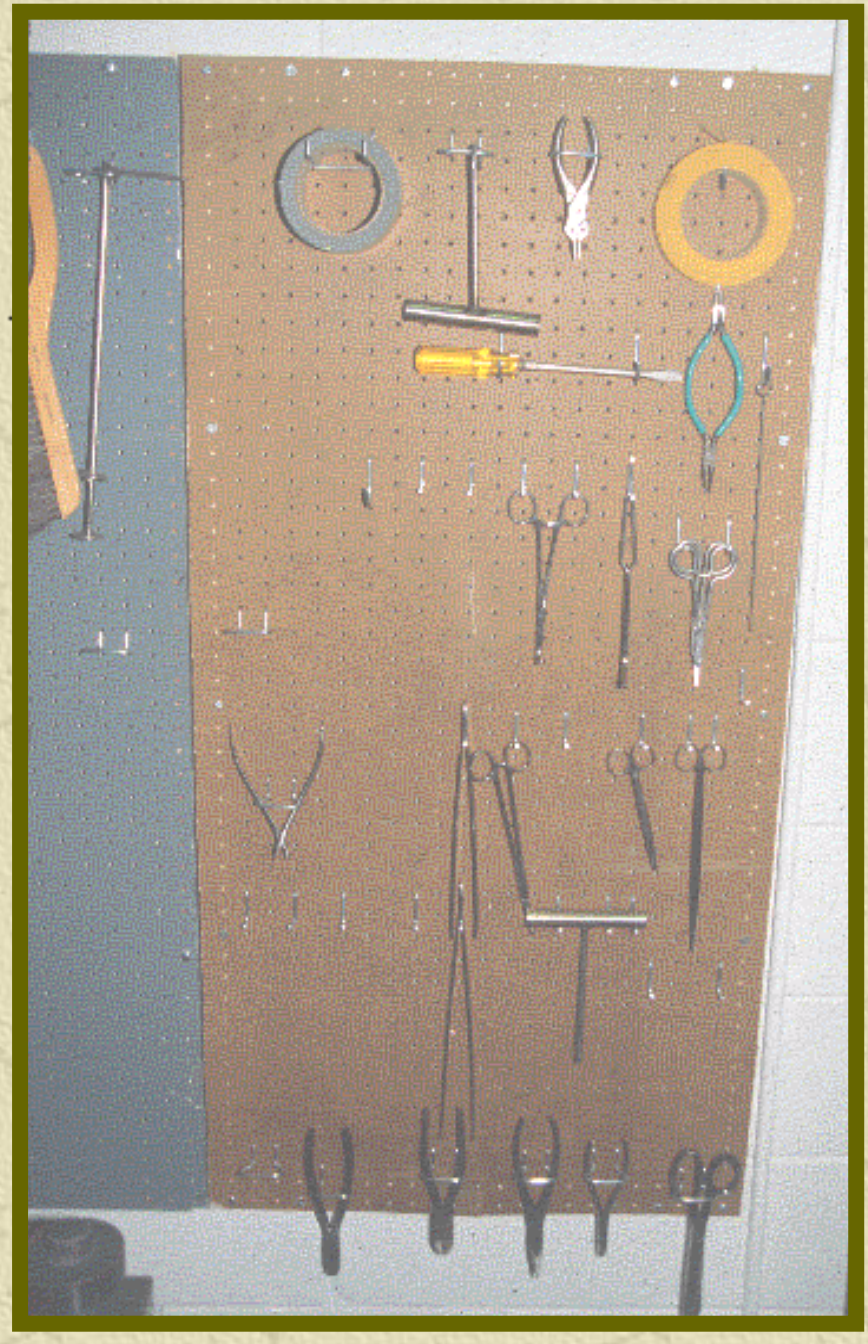
CAUTION
RADIOACTIVE MATERIALS
CAUTION
RADIATION AREA
NOTICE TO EMPLOYEES

ALCOHOL



Compliance Records

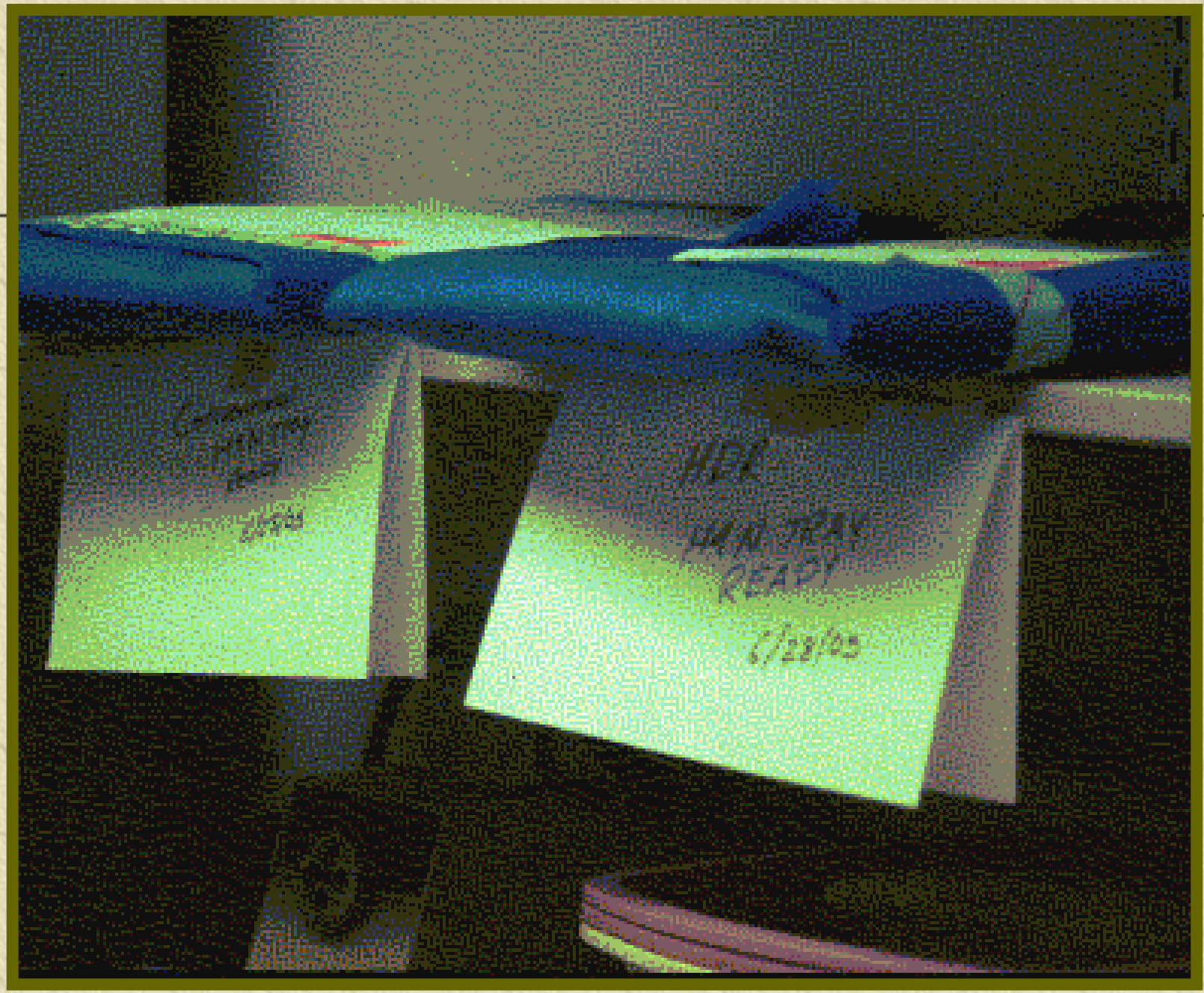

1993
RECEIVING
&
Shipping
RECORDS
PROCEDURES & FORMS
BRACHYTHERAPY



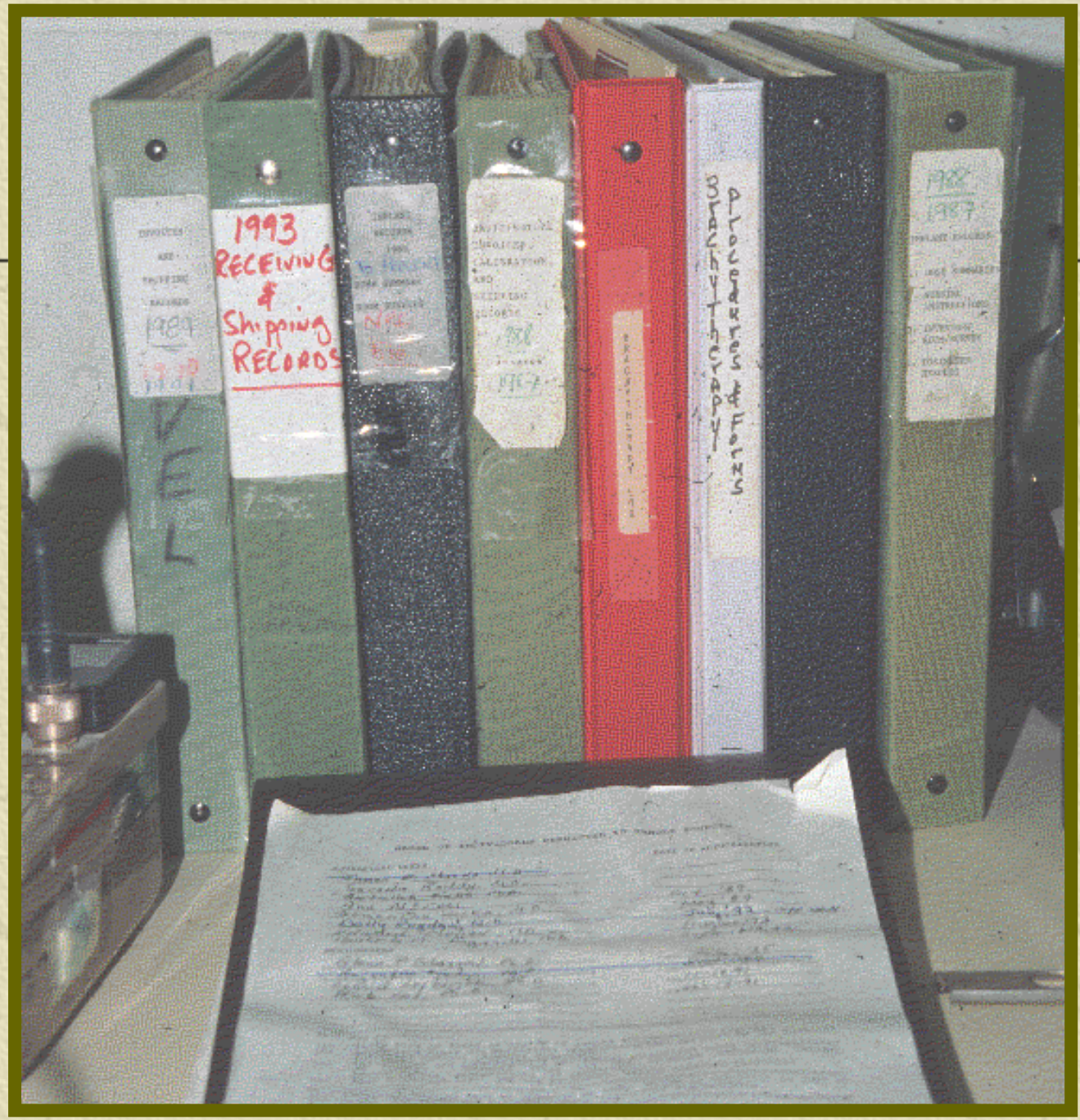
RADIATION
CONTROL
BOARD
CAUTION
RADIOACTIVE
MATERIALS
CAUTION
RADIOACTIVE
MATERIALS
CAUTION

CAUTION
RADIOACTIVE MATERIALS
CAUTION
RADIATION AREA
NOTICE TO EMPLOYEES

ALCOHOL



Compliance Records


1993
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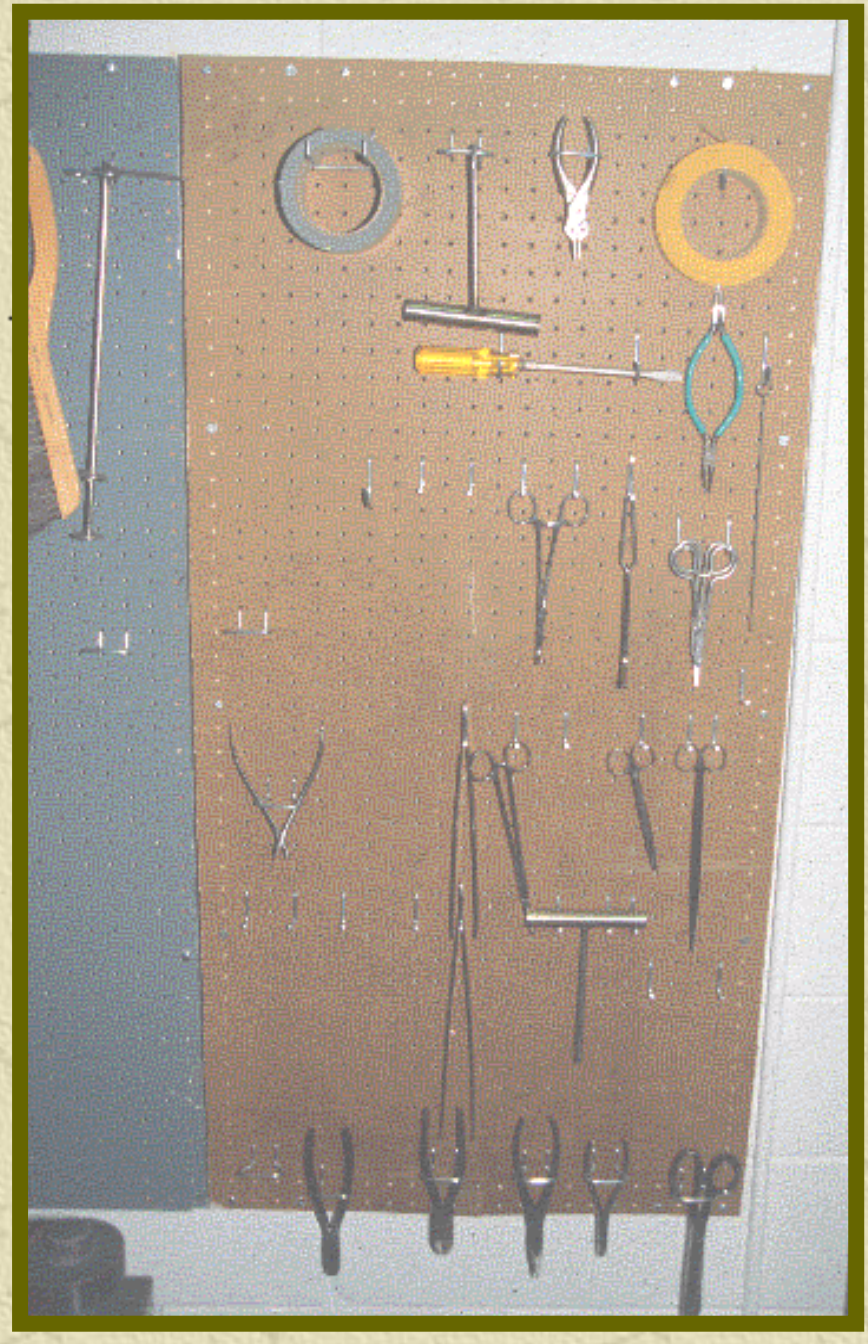
BRACHYTHERAPY



RADIATION
CONTROL
BOARD
CAUTION
RADIOACTIVE
MATERIALS
CAUTION
RADIOACTIVE
MATERIALS
CAUTION

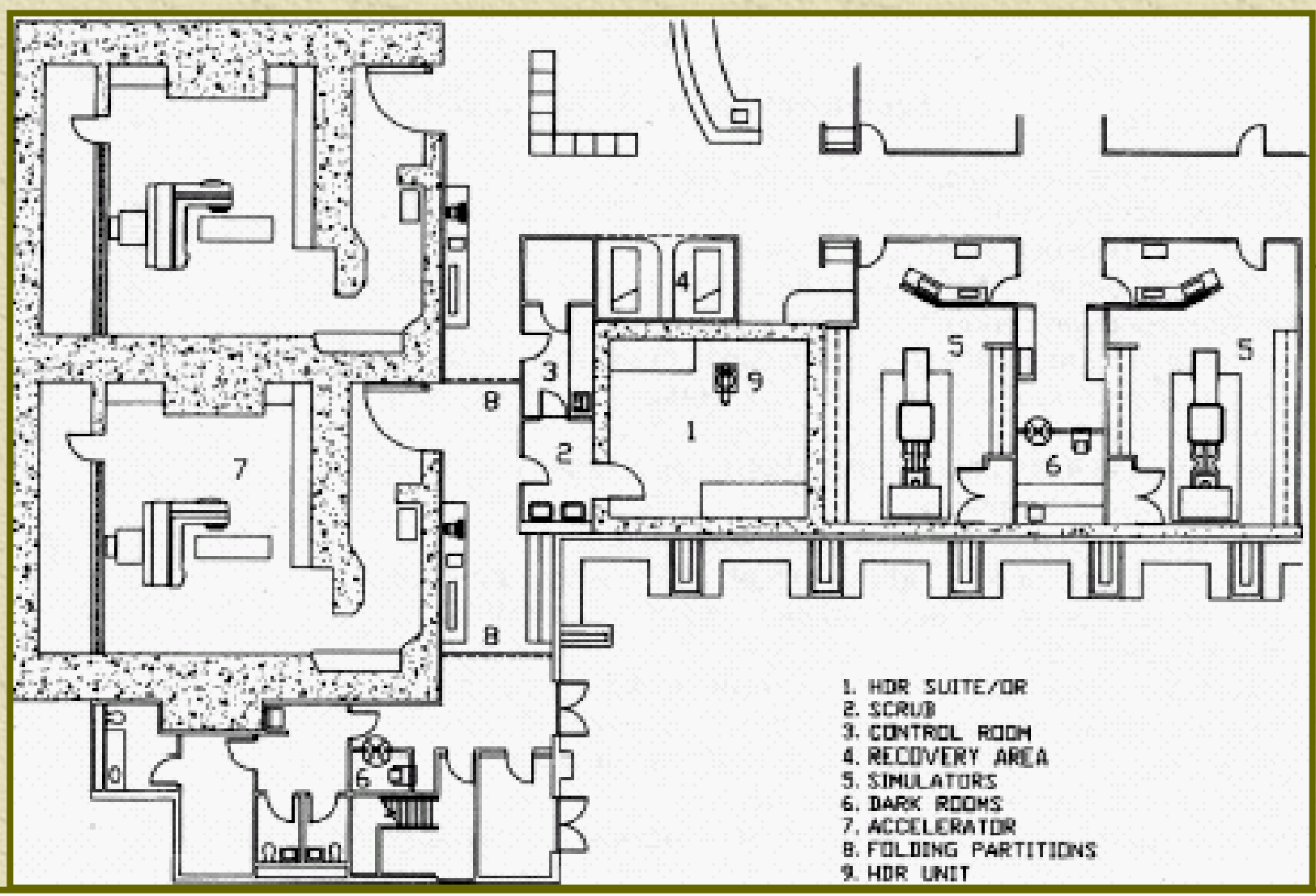


Figure 7. Dedicated HDR brachytherapy suite and OR at the U. of Miami's Sylvester Comprehensive Cancer Center. The suite can be used for intraoperative procedures. [Reprinted from "Design and Implementation of a Program for High Dose Rate Brachytherapy" by P. V. Houdek, G. P. Glasgow, J. G. Schwade, and A. A. Abitbol in *High Dose Rate Brachytherapy: A Textbook*. S. Nag (ed.). Armonk, NY: Futura Publishing Co., © 1994, with permission from Blackwell Publishing.]