You know that you are a Senior Medical Physicist…
When?
• You have calibrated the output of external beam treatment units in terms of Roentgens.
• You remember brachytherapy before remote after loading devices.
• You remember when CT was first introduced in diagnostic radiology.
• You have participated in implants which actually used Ra-226 sources.
• You practiced radiation oncology physics before computers and hand compounded isodose curves.
• You still have a slide rule in your desk.
• Becquerels remain a strange unit of activity.
• The Paterson-Parker rules are second nature to you.
When you can remember these working conditions.
Classic Single Plane Radium Needle Implant from the 1960’s

6 each
Ra-226 needles
3.5 cm active length

Left lateral margin of tongue
Physics:
Units are us.

The ability to convert activity from one isotope (Ra-226) to another isotope (Ir-192), for example, remains an important skill.

\[ X \text{ mg Radium} \times 8.25 \text{ R cm}^2/\text{mg-hr} = Y \text{ mCi (Ir-192)} \times 4.69 \text{ cGy cm}^2/\text{mCi-h} \]
Conversion of Activity

25.5 mg Ra-226
25.5 \times 8.25/4.69
is equivalent to
44.8 mCi Ir-192
Physics
Units are us.

611 mg h (Radium) x
8.25 (Ra-226)/4.69 (Ir-192) =
1,075 mCi h (Ir-192)

Even in today’s practice, the medical physicist must be able to convert using out-dated units into new confusing units.
The Medical Physics Bible
Medical Physics Handbooks 19
Practical Clinical Applications
AAPM Past Summer Schools

BRACHYTHERAPY PHYSICS

Edited by Jeffrey F. Williamson, Bruce R. Thomadson, and Ravinder Nath

American Association of Physicists in Medicine
1994 Summer School
Marie Curie in the winter of her life at her laboratories
Curies, milliCuries, and milligrams

- There are modern units of activity, e.g. the Becquerel.
- There are modern methods of specifying source strength, e.g. air kerma in air and the U.
- This presentation will use old fashion terms, e.g. mCi, and old fashion concepts, e.g. exposure rate constants.
- The excuse for not being modern is that the systems are not modern and the presenter is more comfortable with the older systems.
Ra-226 was important in the UK and the US up until the 1970’s.
Christie Hospital
pioneering the use of Roentgen X-rays for cancer therapy (1901); setting the first international standards for radiation treatment (1932);
The hospital was first opened as the Cancer Pavilion and Home for Incurables in 1892. Nine years later, in November 1901, it was named The Christie Hospital in recognition of the pioneering work of both Mr. and Mrs. Christie.

Every year Christie Hospital sees approximately 11,000 new patients registered; 15,000 in-patient stays; 14,500 day-case stays; and 139,500 out-patient visits. There are approximately 250 in-patient beds, which are intensively used, with an average length of stay of less than six days. Approximately 1,800 staff work on our site, plus around 300 volunteers.
Ralston Paterson, MD, FRCS, FFR
H. M. Parker, M.Sc., F. Inst. P.
The Paterson-Parker or Manchester System for Applicators

The original 1934 Paterson-Parker tables presented the amount of radium in milligram-hours (mg h) required to give a dose of 1000R to the treatment area which is at a distance $h$ from the surface of the applicator, while achieving a $\pm 10\%$ dose uniformity.
External Applicators and Molds

• The Paterson-Parker tables provide values for treatment distances of 0.5 to 5.0 cm at 5 mm increments.

• Classic Paterson-Parker molds have not been common in my experience - 1 in more than 30 years.

• There are distribution rules which depend on the diameter of the circle and the treatment distance.
Johns Example 13-10

• A 6 cm² area is to be treated using sources placed on an equal area 1.0 cm away. To deliver 60 Gy in 5 days, what activity is required?
• Area 6 cm²  Treatment Distance 10 mm
• mg-hr/10 Gy  354
• (60Gy/10Gy)(354 mg-hr/(5daysx24hrs/day))
• = 17.7 mg Ra-226
**TABLE 3: Surface Applicators and Planar Implants**

The table gives $R_A$, the number of mg hr required to deliver 10 Gy to muscle tissue for different areas and treatment distances. Filtration 0.5 mm Pt. The table may be used for planar implants by using a treatment distance of 0.5 cm.

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</tr>
</tbody>
</table>

**Depth:** 10 mm
Single Plane Manchester Implant

- Lateral view
- Anterior view
Paterson-Parker Interstitial Therapy

- The interstitial dose system (1938) was a natural extension of the surface applicator system.
- The definition of ‘stated dose’ is different between the two systems.
- In the interstitial system, the stated dose is defined to be 10% above the minimum dose in the plane of calculation.
Paterson-Parker Interstitial Therapy

- This system supports single and double plane implants and volume implants.
- Single plane implants: The sources are considered to be in the center of a 1 cm slab of tissue and the plane of calculation, which is 5 mm from and parallel to the source plane, is defined by the projection of the sources onto this plane.
- Single plane implants: 10 mm thick
Paterson-Parker Interstitial Therapy

- Double plane implants: 15 mm, 20 mm or 25 mm in thickness
- Single and double planes use the same tables and the same rules.
- Volume implants: > 25 mm thickness
- Volume implants have their own rules and tables.
The Paterson-Parker Rules for Planar Implants

- 1. The needles should be in parallel rows at spacing not greater than 1 cm.
- 2. Crossing needles should ideally cross the active needle ends, but should not be more than 1 cm from the active ends.
- 3. Deduct 10% of the area for each uncrossed end and use the reduced area in the tables.
Areas covered by implants with 1. Two crossed ends  
2. One crossed end and 3. No crossed ends
The Paterson-Parker Rules for Planar Implants

• 4. For implants using small sources (seeds or short needles) the distance between the active ends should not exceed 1 cm.

• 5. If two planes are to be used, the separate planes should be arranged as for single planes, parallel to each other, and if they differ in area, then the average area is used to determine the mg-hrs and the activity is proportioned to each plane.
# The Paterson-Parker Rules for Planar Implants

<table>
<thead>
<tr>
<th>Area</th>
<th>% Activity in periphery</th>
<th>% Activity in the center</th>
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<td>&lt; 25 cm²</td>
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<td>1/3</td>
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<td>&gt; 25 cm² &amp; &lt; 100 cm²</td>
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<tr>
<td>&gt; 100 cm²</td>
<td>1/3</td>
<td>2/3</td>
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</table>
Single Plane Manchester Implant
6 needles - 3.5 cm Active Length, 2.28 mg/needle

• Lateral view

Anterior view

Both ends uncrossed
Single Plane Implant

• Length - 3.5 cm Width 3.0 cm
• Area - 3.5 \times 3.0 \times 0.8 = 8.4 \text{ cm}^2 (0.8 \text{ for 2 uncrossed ends})
• Treatment distance - 0.5 cm
• 225 \text{ mg-h/10 Gy}
• Total milligrams - 13.7 mg
• Dose rate: 1000 \text{ cGy} \times 13.7 \text{ mg/225 mg-h} = 60.9 \text{ cGy/hr}
## Planar Implant

**TABLE 3: Surface Applicators and Planar Implants**

The table gives $R_A$, the number of mg hr required to deliver 10 Gy to muscle tissue for different areas and treatment distances. Filtration 0.5 mm Pt. The table may be used for planar implants by using a treatment distance of 0.5 cm.

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</table>

**Depth:** 5 mm
Single curved plane

- 5 Needles, 2.18 mg/needles, Active length 4.5 cm
- Both ends uncrossed.
Single Curved Plane

• My very old notes indicated that an inside the curve concave area, 5 mm from the curved source plane, was determined. Then the mg-h/10Gy was found for this area.
• The dose rate was also calculated for the outside area at 5 mm from the curved source plane.
Curved source plane

- Inside curved width - 2.8 cm
- Area - 2.8 cm x 4.5 cm x 0.8 = 10.1 cm²
- 250 mg-hr/10Gy
- Inside curved dose rate - 1000 cGy x 10.9 mg/250mg-hr = 43.6 cGy/hr
- Outside curved width - 3.8 cm
- Area - 13.9 cm²
- 306 mg-hr/10Gy
- Outside dose rate - 1000 cGy x 10.9/306 = 35.6 cGy/hr
Double Curved Plane

- This implant used 12 needles in 2 different curved planes. Active length 4.5 cm with 1.5 mg/needle
Paterson-Parker Contribution

• In the time before computers and megavoltage external beam units, a system of dosimetry which included rules of the placement of sources and rules for the distribution of the radiation were a major contribution to the practice of radiation oncology.
Floor of mouth - Double curved plane

- 6 Indian club needles were used in the outer curved plane plus 4 half intensity needles in the inner curved plane.
Double Curved Plane

- Total milligrams: 15.46
- Larger Plane: Area 3 cm x 3.75 cm x 0.9 = 10.13 cm² Activity 9.66 mg
- mg hr/1000 R = 234 (5 mm)
- Dose rate: 9.66 mg x 1000 R x 0.9 rad/R/
  234 mg hr = 37.2 rad/hr
- The dose rate at 10 mm was also calculated using the Manchester tables. 23.3 rad/hr
Double Curved Plane

• Total milligrams: 15.46
• Smaller Plane: Area 1.8 cm x 4.5 cm x 0.8 = 6.48 cm$^2$ Activity 5.8 mg
• mg hr/1000 R = 193 (5 mm)
• Dose rate: 5.8 mg x 1000 R x 0.9 rad/R/ 193 mg hr = 27.05 rad/hr
• The dose rate at 10 mm was also calculated using the Manchester tables. 14.2 rad/hr
Double Curved Plane

- The dose rates from the 2 planes at distances of 5 mm and 10 mm were then added.
- The total dose rate of 5 mm from the smaller plane and 10 mm from the larger plane is 50.35 rad/hr and visa versa from the smaller plane is 51.4 rad/hr.
- (It is fun to note that given the sources if this implant were to be performed today, the dose rates would be the same.)
Two Plane Implant

Example C page 36 Radium Dosage

- The lesion is a flat, plaque-like, solid tumor, just under the skin.
- The size is 5 cm x 6 cm and thickness is 1.5 cm.
- The treatment is a 2 plane implant with the larger plane undercutting the lesion (6 cm x 7 cm) and with a smaller superficial plane (5 cm x 6 cm).
- Dose (in modern units - 60 Gy in 6.5 days)
Radium Dosage The Manchester System

• Published in 1947 by The Williams and Wilkins Company
• Edited by W. J. Meredith (Christie Hospital and Holt Radium Institute, Manchester)
• Compiled from articles by: Paterson, Spiers, Stephenson, Parker, Tod, and Meredith
Two Plane Implant
Example C page 36 Radium Dosage

• Larger plane: 42 cm²
• Smaller plane: 30 cm²
• Average area: 36 cm²
• From Johns table at a depth of 5 mm:
  594 mg-hr/10 Gy for 36 cm²
• 1.5 cm separation factor: 1.25
• Total: 1.25 x 594 = 742 mg-hr/10 Gy
• Total mg-hrs = 742 x 6 = 4452 mg-hrs
Two Plane Implant
Example C page 36 Radium Dosage

• Total mg: 4452 mg-hr/156 hr = 28.5 mg
  This is to be distributed over both planes.
• $42 \text{ cm}^2 + 30 \text{ cm}^2 = 72 \text{ cm}^2$
• $42/72 = 58\% \text{ or } 16.6 \text{ mg}$
• $30/72 = 42\% \text{ or } 12 \text{ mg}$

• Note that both planes are $> 25 \text{ cm}^2$
Two Plane Implant
Example C page 36 Radium Dosage

- Larger Plane needle distribution
  - 8 ea 1 mg needles around the periphery
  - 8 ea 1 mg needles in the center

- Smaller Plane needle distribution
  - 4 ea 1 mg needles + 2 ea 1.5 mg needles around the periphery
  - 4 ea 1.5 mg needles in the center.
Two Plane Implants

• Johns notes that the Paterson-Parker approach of using 5 mm distance and a correction factor is only approximate. Correction factors (1.25 for 1.5 cm, 1.41 for 2.0 cm, and 1.52 for 2.5 cm)

• Johns recommends determining the mg-hr/10 Gy for the center plane.
Double Plane Implant
Active Length: 3.0cm
Width: 4.0 cm
Separation 2.0 cm

Source Plane
Calculation Planes
Source Plane

Johns recommends calculating the dose here.
Volume Implant of Right Posterior Border of Tongue

- 21 needles - 30.5 mg Ra-226 - One uncrossed end
- The calculated dose rate is 79.7 rad/hr.
Paterson-Parker Volume Implants

- New rules and new tables for spheres and for cylinders (Johns Table 13-8)
- Uncrossed ends - 7.5% reduction in volume.
- Sources on each face must be placed as evenly as possible.
- Sources must best be distributed throughout the core and not just at the center.
- Sources on each surface must be spaced evenly and not more than 1.0 to 1.5 cm apart.
### Distribution of Activity for Volume Implants

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<th>Volume Shape</th>
<th>Distribution of Activity</th>
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<th>End B</th>
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<td>1</td>
<td>1</td>
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<tr>
<td>2 ends uncrossed</td>
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<td>2</td>
<td>0</td>
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<tbody>
<tr>
<td>Crossed at needle tips</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1 end uncrossed</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>
Volume Implant Example

Radium Dosage

Tongue and Floor of Mouth

• Area of ulcerated induration of approximately 2 cm x 3 cm on the right side of the floor of the mouth and extending well into the under surface of the tongue.

• To be treated with an elliptical implantation of height 3.6 cm and cross-section 3 cm x 4 cm. Only one end is crossed.
### TABLE 4: Volume Implants

$R_v$ — mg hr to give 10.0 Gy to volume implant: Radium equivalent for filtration of 0.5 mm Pt

<table>
<thead>
<tr>
<th>Volume cm³</th>
<th>$R_v$ mg hr</th>
<th>Distribution Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>106</td>
<td>Volume should be considered as a surface with 75% activity and core</td>
</tr>
<tr>
<td>10</td>
<td>168</td>
<td>with 125%</td>
</tr>
<tr>
<td>15</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>267</td>
<td>Rules for cylinders</td>
</tr>
<tr>
<td>30</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>425</td>
<td>Belt — 50% activity with minimum 8 needles</td>
</tr>
<tr>
<td>50</td>
<td>493</td>
<td>Ends — 12.5% of activity on each end</td>
</tr>
<tr>
<td>60</td>
<td>556</td>
<td>Core — 25% with minimum of 4 needles</td>
</tr>
<tr>
<td>80</td>
<td>673</td>
<td>For each uncrossed end, reduce volume by 7.5%</td>
</tr>
<tr>
<td>100</td>
<td>782</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>979</td>
<td>Diameter</td>
</tr>
<tr>
<td>180</td>
<td>1156</td>
<td>Length</td>
</tr>
<tr>
<td>220</td>
<td>1322</td>
<td>= 1.5%  2.0  2.5  3.0</td>
</tr>
<tr>
<td>260</td>
<td>1479</td>
<td>Increase mg hr</td>
</tr>
<tr>
<td>300</td>
<td>1627</td>
<td>3%  6%  10%  15%</td>
</tr>
<tr>
<td>340</td>
<td>1768</td>
<td></td>
</tr>
<tr>
<td>380</td>
<td>1902</td>
<td></td>
</tr>
</tbody>
</table>

This table was prepared from the original by Meredith (M12) by multiplying his values by $C = 1.064$.

Volume Implant Example
Radium Dosage
Tongue and Floor of Mouth

• Dose (in modern units) 70 Gy in 7 days
• Volume = \( \frac{\Pi}{4} \times 3.6 \times 3 \times 4 = 33.9 \text{ cm}^3 \)
• Effective volume: 33.9 x 92.5% = 31.4 cm³
• mg-h/10Gy (Johns 13-8) = 360 mg-h/10 Gy
• 7 Days = 168 hrs
• 360 mg-h/168 hrs * 70Gy/10Gy = 15 mg
Permanent Volume Implant
Based upon Example in Radium Dosage

• Long ago Radon seed implants were performed. The Ra-222 gas was encapsulated by 0.3 mm gold walls.

• Not so long ago, Au-198 gold seeds were used to replace the Ra-222 gold seeds. The half-life of Au-198 is 2.698 days. The exposure rate constant is 0.238 R m²/h-Ci.
Gold Grain/Seed Applicator

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for ...

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Accommodating 15 grains at one loading, its use provides ease of control in implantation, especially in producing a pre-arranged pattern in a volume implant.

Single grains are expelled by operating the trigger, the next grain being held in position for exposition at the next trigger pull. A numbered scale gives a visible indication of the number of grains used.

Experience has shown that irradiated gold grains produce reactions indistinguishable from those produced by radium seeds. There is less waste than with radium seeds because any unused grains can be reactivated.

1955

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Permanent Volume Implant
Based upon Example in Radium Dosage

• Consider a 4.0 cm diameter sphere, volume 33.5 cm³, which is designed to deliver 65 Gy.
• The Manchester table for 33.5 cm³ yields 376 mg-h/10 Gy.
• \( \frac{65}{10} \times 376 = 2444 \text{ mg-h} \)
• This must now be converted to the appropriate Au-198 activity.
Permanent Volume Implant
Based upon Example in Radium Dosage

• 1 mCi (Au-198) * 2.38/8.25 = 0.288 mg Ra-226

• 1 mCi decayed (Au-198) = 1.445 x 2.698 days x 24 hours/day x 0.288 mg = 26.9 mg-h (Ra-226)

• 2444 mg-hr/26.9 mg-h/mCi = 90.9 mCi Au-198
Permanent Volume Implant
Based upon Example in Radium Dosage

- 90.9 mCi Au-198
- The classic Manchester Rules: 6 parts of the activity (68 mCi) are in the rind and 2 parts (23 mCi) are in the core.
- 12 seeds, 5.7 mCi/seed, should be placed on the surface of the 4 cm diameter sphere and 6 seeds, 3.8 mCi each, should be evenly distributed throughout the volume of the sphere.
Paterson-Parker System

- Is it used today?
- Perhaps very limited use in the US and the UK. Perhaps, not at all.
- Prostate implants are not based upon this system, but reflect some of its heritage, e.g. peripheral loading.
- This system contains some sound basic principles.
Nasal Septum Implant

• 6 each Ir-192 wires, 2.2 cm length
Oncologist placed the sources using best judgement, as opposed to a system. What will be done next time?
Malignant fibrohistiocytoma of right upper extremity

- 15 catheters, Ir-192 wire, 45 Gy in 76 hours

How did the oncologist decide on source spacing?
Robert Heinlein: A generation which ignores history has no past and no future.