STANDARD IMAGING — ADVANCING RADIATION QA™

Ionization Chamber Construction

Theory • Design • Assembly • Test

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Mar 1995 – Nov 2000 • Exradin, Inc.

Nov 2000 – current • Standard Imaging, Inc.

sclaimer

This presentation contains non-specific information about general ionization chamber theory, design, assembly and testing.

- Detailed design information is considered confidential and proprietary within the industry.

ypes of Ionization Chambers

Spherical

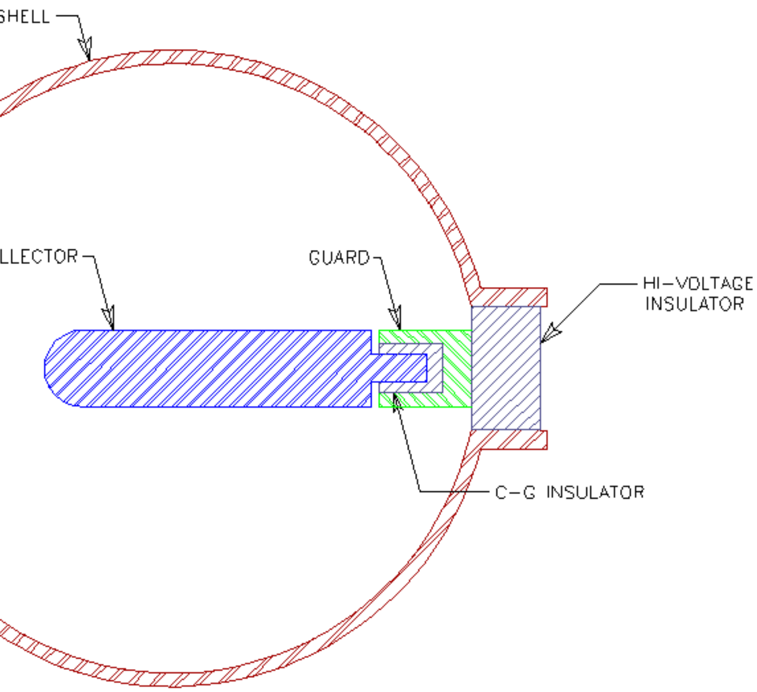
Thimble (a “stretched” Spherical chamber)

Parallel Plate

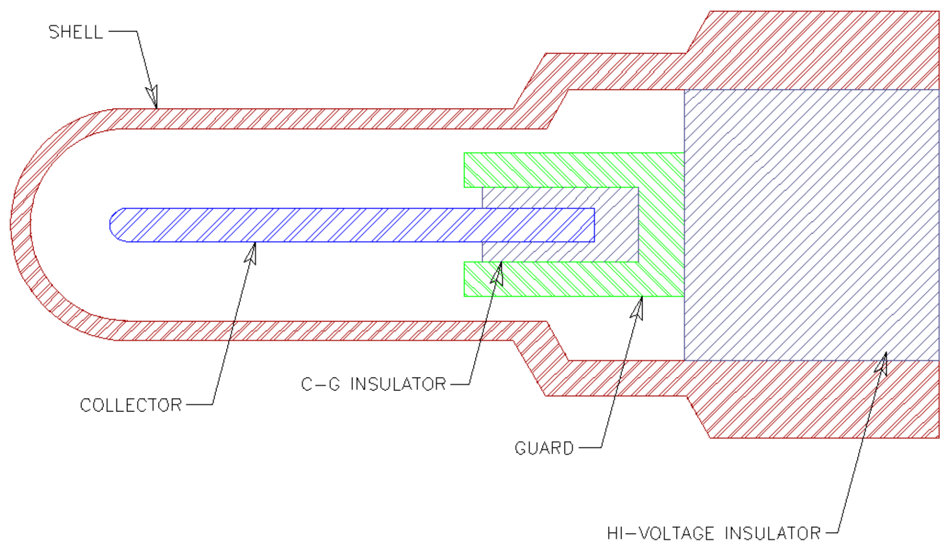
Well (a “deformed” Parallel Plate chamber)

Each type has its own set of pros/cons for specific applications (AAPM/IAEA protocols, etc.)

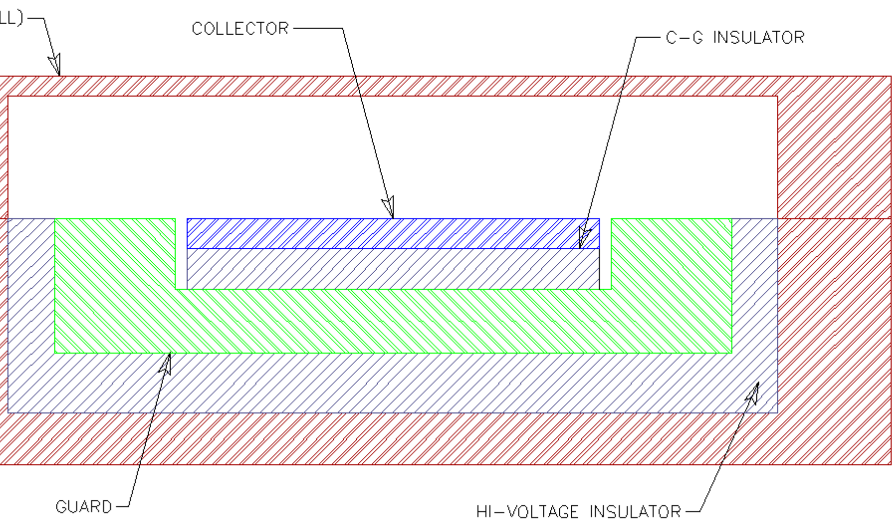
Spherical



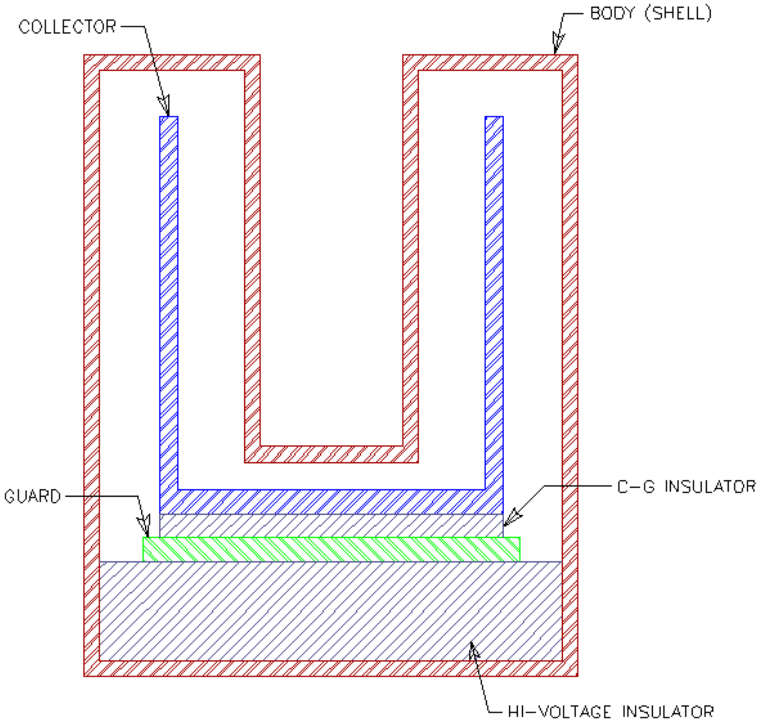
Thimble



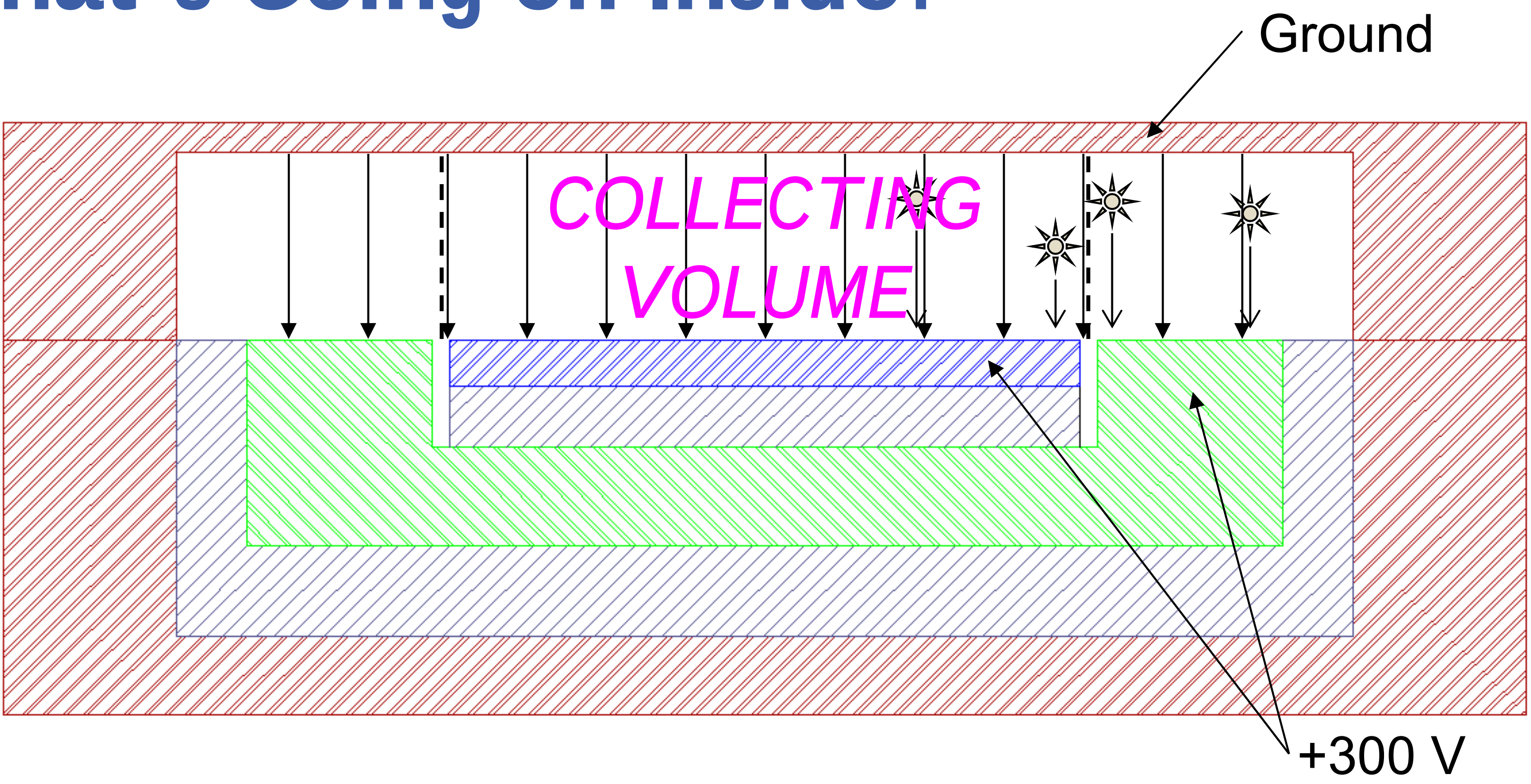
Parallel Plate



Well

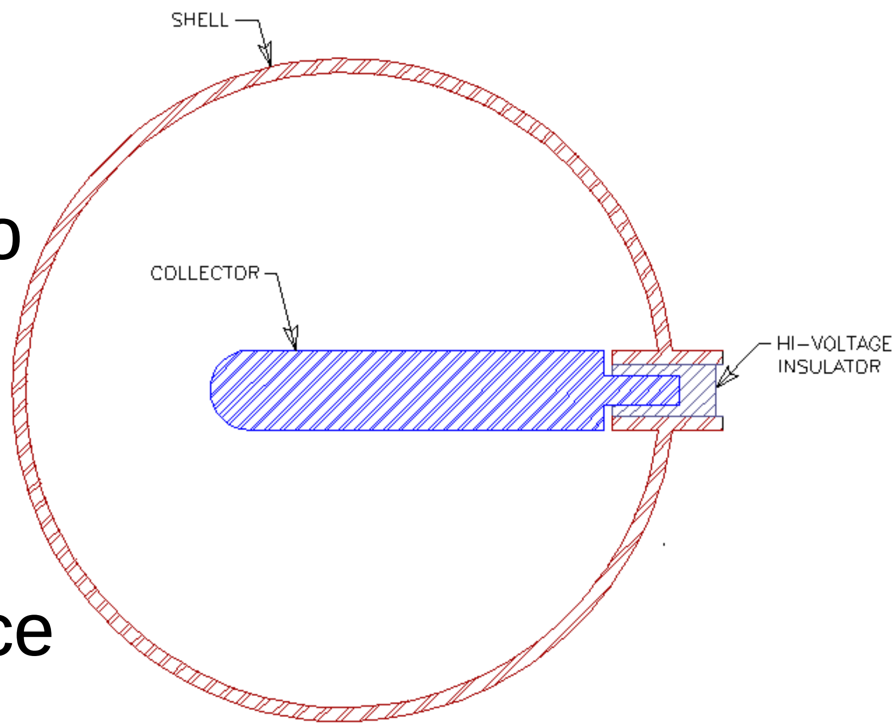


hat's Going on Inside?

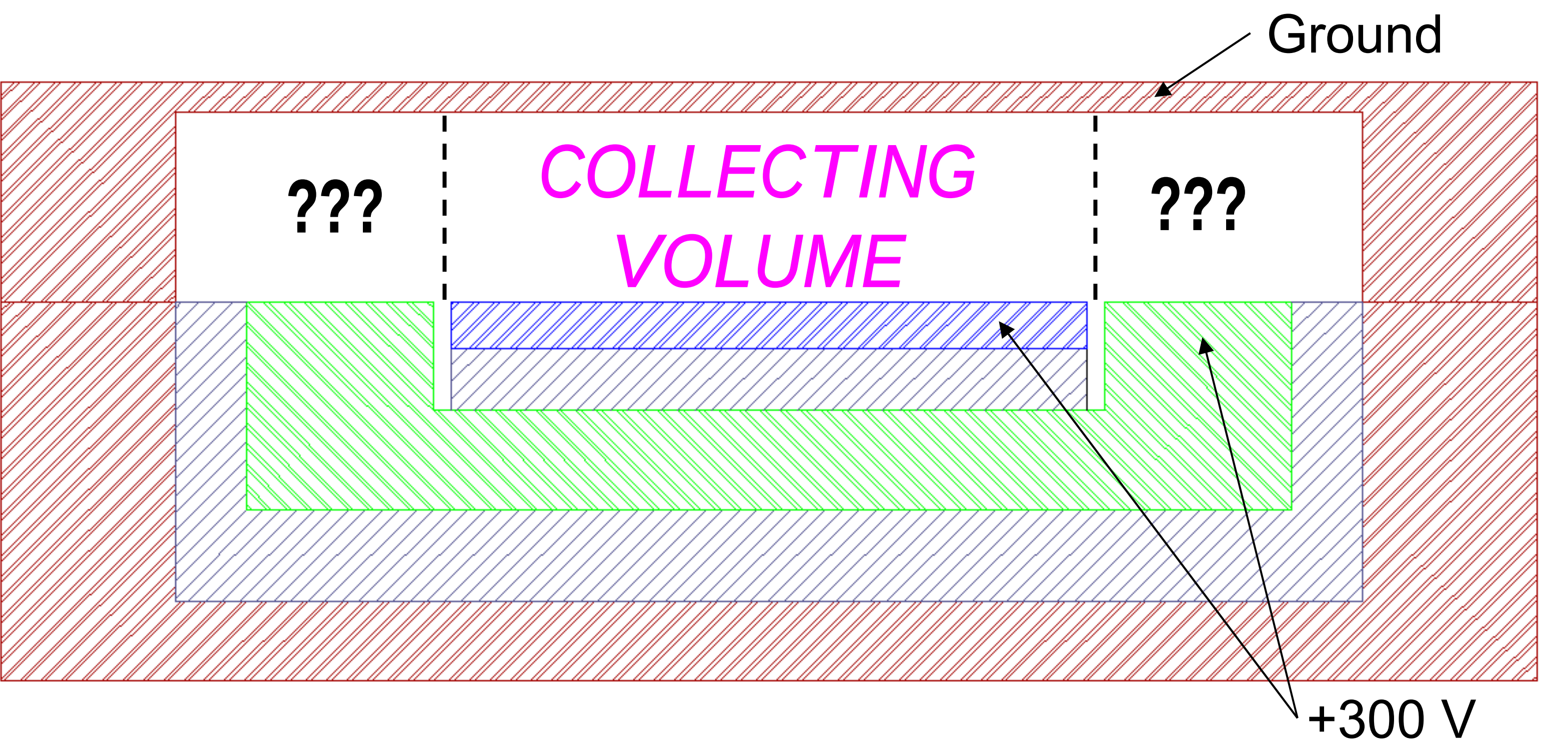


uard Theory

- An ionization chamber does not need a guard to operate correctly
- But having a guard provides wonderful benefits and performance enhancements



uard Theory cont.



uard Theory cont.

There are actually *two* distinct "collecting volumes" inside any guarded ionization chamber:

- Collector's Volume ("collecting volume"; cal. factor)
- Guard's Volume

The Guard's Volume is part of the HV bias circuitry.

- The C-G Insulator prevents this signal from corrupting the Collector's Volume signal.

uard Theory cont.

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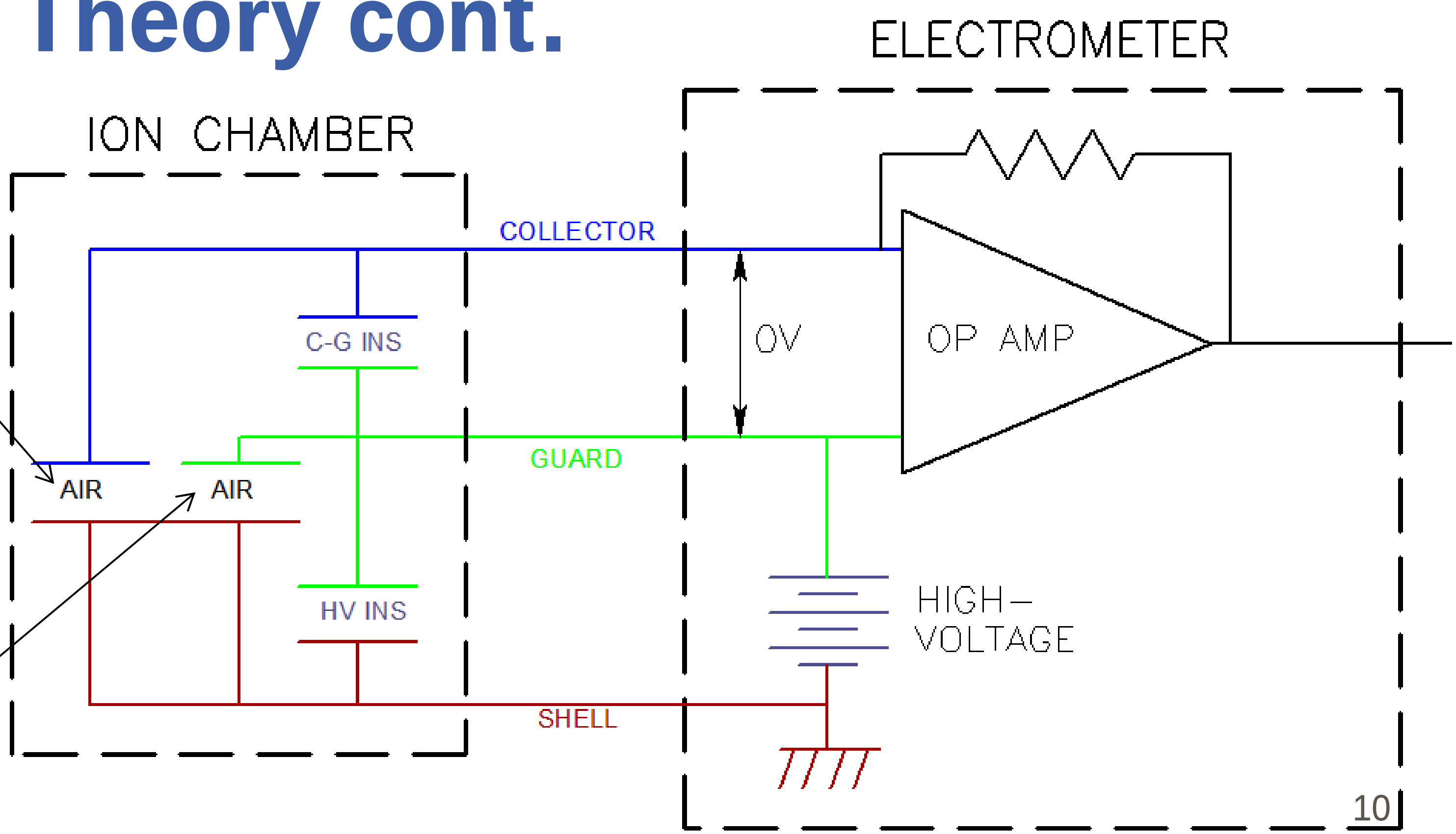
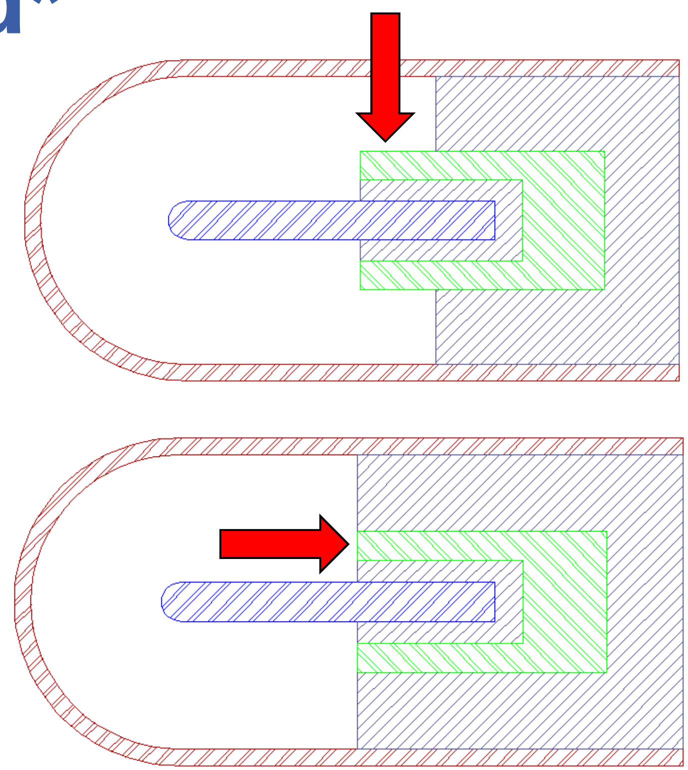


Fully Guarded" Defined*

FULLY GUARDED is when the uard extends *beyond* the HV nsulator to complete the ollecting volume.

PARTIALLY GUARDED is when he guard is *flush* with the HV nsulator and *does not extend* nto the chamber's airspace.



et al, Chapter 6 in Clinical Dosimetry Measurements in Radiotherapy, pp 181-204, D.W.O. Rogers and Joanna Cygler, ed, 2009

ummary of Guard’s Responsibilities

Electrically shields the collecting volume’s signal (current) inside the chamber, along the triaxial cable, thru the connectors and onto the electrometer’s circuit board, into the A/D.

(By virtue of inherent triaxial cable & connector design.)

It completes the shape of the collecting volume not defined by the shell.

sign Considerations for Parallel Plates

Entrance window – thick or thin (film)?

- Thin windows are necessary for X-rays and electrons, but will require a waterproof cap.

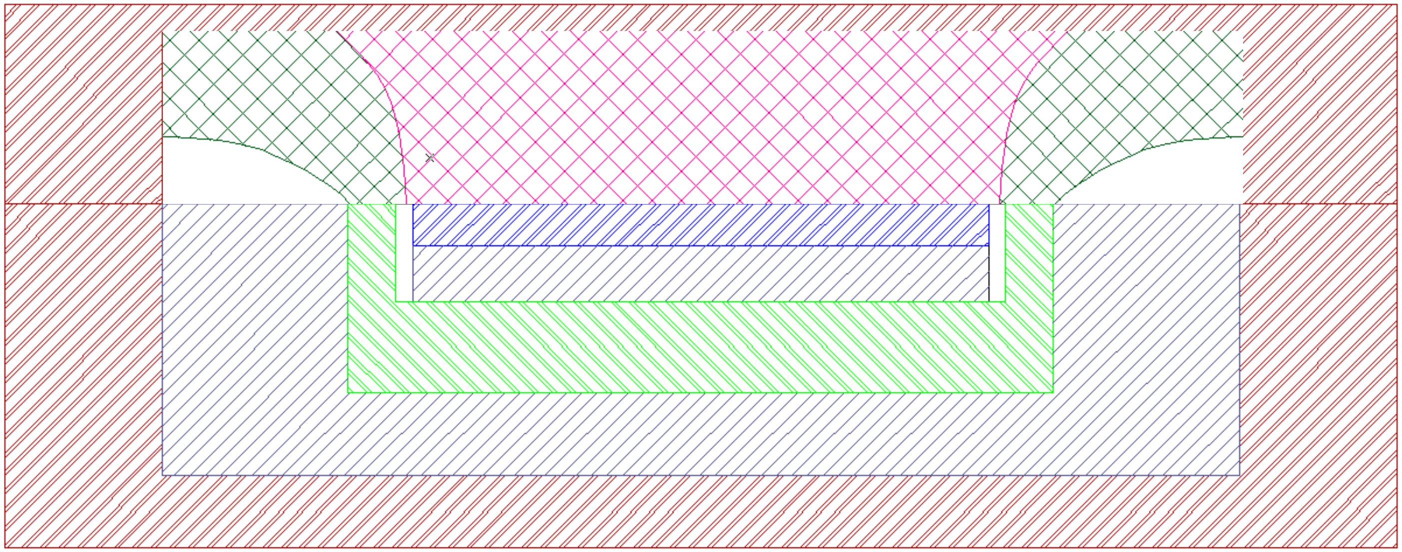
Size of collecting volume and collector.

General rule of thumb for guard design:

$$\frac{Guard\ Ring\ Width}{Collector/Window\ air\ gap} > \frac{2}{1}$$

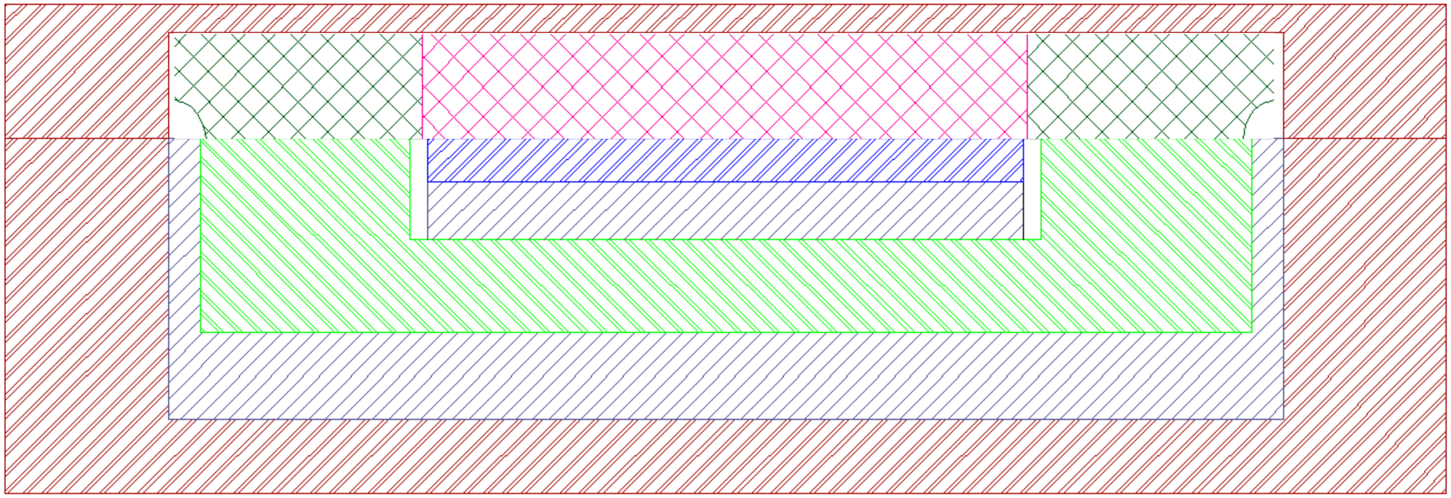
#1: Guard Ring/C-W Air Gap Ratio

Ratio < 2:1



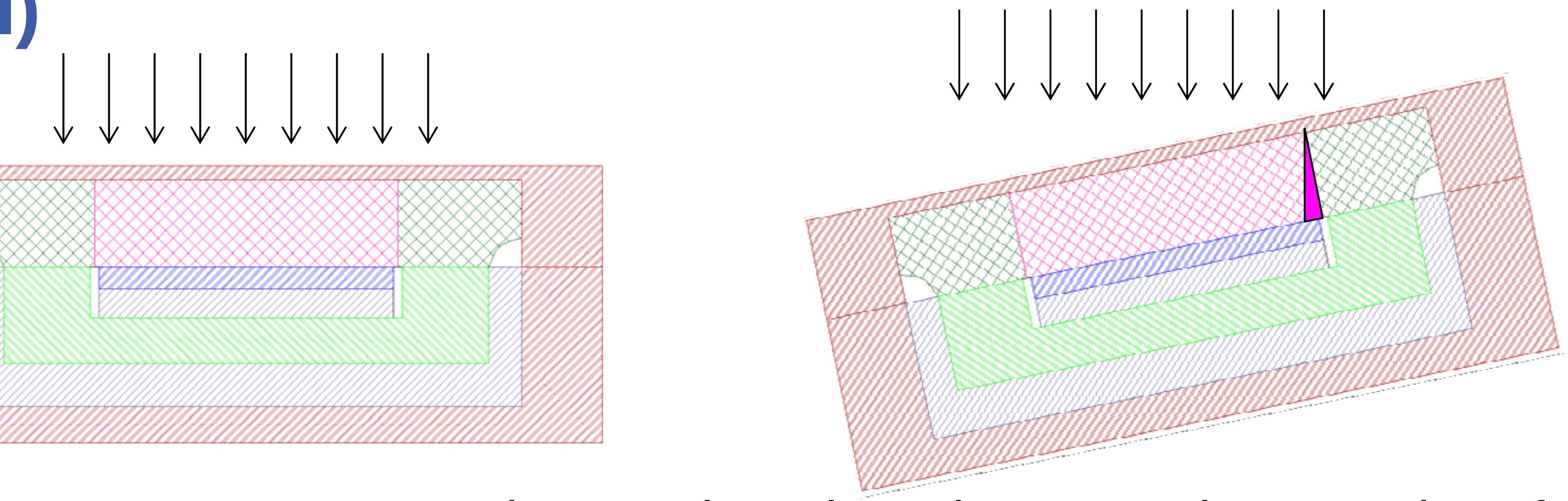
#2: Guard Ring/C-W Air Gap Ratio

Ratio > 2:1



(Guard ring has large impact on chamber's diameter)

tational Dependence of Parallel Plates
l)



The Guard’s Volume is attenuating a portion of the Collector’s Volume (in 3D, it doesn’t take much to lose a measurable portion of the signal).

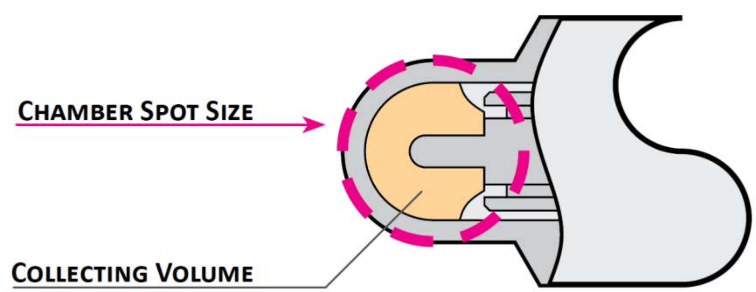
sign Considerations for Thimbles

Thimbles are by far the most versatile/popular chamber type.

- Physical considerations – material/machining limitations; assembly nuances of small parts.
- Short stem for water scanning or long stem for in-air fixturing/solid phantom use?
- Waterproof? (must internally vent to ambient)
- Thin or thick walled? (possible low energy use?)

v. Design Considerations for Thimbles

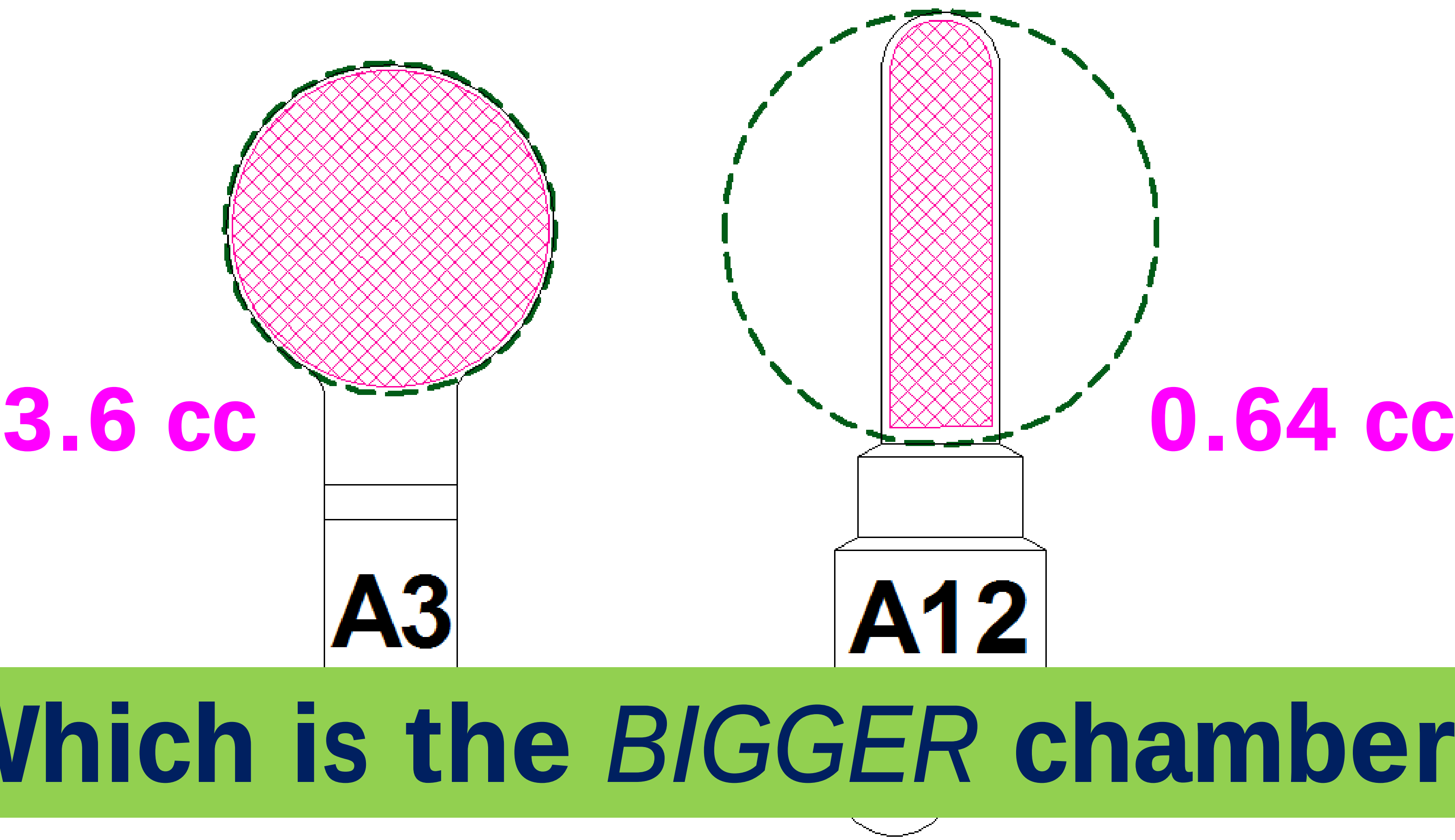
- ize of collecting volume.
- xpected signal magnitude.
  - Can an appropriate signal-to-noise ratio easily be maintained?
- hamber "Spot Size"
  - Shape of volume - cyl? sph?
  - This shape is dependent on its the intended use.



v. Design Considerations for Thimbles cont.

Is it really the "Collecting Volume" or the "Spot Size" that should define the size of a chamber?

- Its *marketing* vs *reality*
  - Our A3 spherical has a smaller "Spot Size" than our A12 farmer-type – but it has 6x the volume.
  - 6x the volume = 6x the signal!



Which is the *BIGGER* chamber?

ot Size vs Collecting Volume Specifier

“Spot Size” is not to be confused with the chamber’s “Minimum Field Size.”

- Isodose lines of small fields.
- Repeatable positioning/fixturing of chamber.

Spot Size is the “pixel size” of the chamber’s volume.

- L x W

nally – Let’s Build One!

Cleanliness is a must! (But how clean?)

- Make your mother jealous...but proud!

Internal parts cannot shift.

- Shifted parts can result in an altered volume and calibration factor(s).

“Some assembly required”......and......

Good Luck! ☺

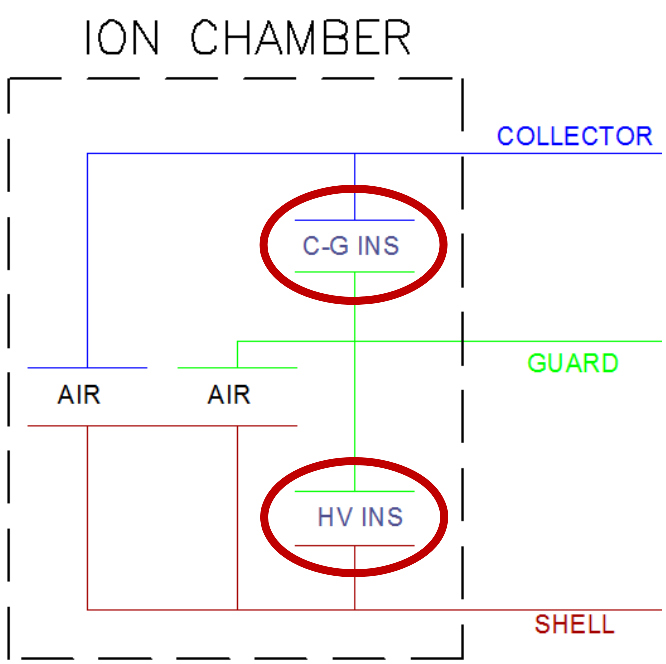
zation Chamber Production Tests

G-C Insulator

- Ensures Guard Volume's signal stays out of Collector Volume's signal.

HV Insulation

- Ensures HV bias is stable to create chamber's field lines.
- Unstable bias = unstable e-field lines = unstable response ☹



kage – It Hides Everywhere

Leakage sources aren't just *inside* the chamber:

- Triaxial cable (kinks, sharp bends)
- Connector (dust, moist breath) **USE DUST CAPS!**

Extension cables:

- Kinks, sharp bends
- Pinched in bunker door, rolled over by a chair, recently unspooled (triboelectric effect)
- Connectors **DUST CAPS! DUST CAPS!**

ecting Volume Analysis

\ range of chamber's collecting volume is to be expected:

- Machined part tolerances
- Assembly of nested parts ("stack-up tolerances")

\ simple analysis of the max/min tolerances yield nax/min collecting volumes.

Chamber volume is inversely proportional to it's alibration factor.

ecting Volume Analysis cont.

.gg-Gray Theory: $D_{air} = \frac{Q}{M}\left(\frac{\overline{W}}{e}\right)_{air}$

becomes....

$$N_k * Volume = \frac{\left(\frac{\overline{W}}{e}\right)_{air}}{\rho_{air\,@\,22^\circ}} = \text{constant}$$

$$N_k * Volume = 28{,}404{,}672\,\frac{\text{Gy}}{\text{C}}\,cm^3$$

ecting Volume Analysis cont.

neoretical Case Study (farmer-type thimble)

Volume		N_k *(22°C)*
Theor = 0.600 cc	→	4.73E+07 Gy/C
Max = 0.618 cc	→	4.60E+07 Gy/C
Min = 0.585 cc	→	4.86E+07 Gy/C

(Remember….inverse relationship)

ecting Volume Analysis cont.

- very Air Kerma cal factor will be within this cceptable range if:
  - parts are within spec.
  - it was assembled correctly.
- f its not – disassemble it and figure out why.

"he Proof is in the Pudding"

Every thimble and parallel plate chamber is irradiated in-house:

- Serves as a great final QC test prior to shipping.
- Provides a factory calibration.
- Gives wonderful legacy data if it ever comes in for service.

IMAGING. ADVANCING RADIATION QA™

Thank you!

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