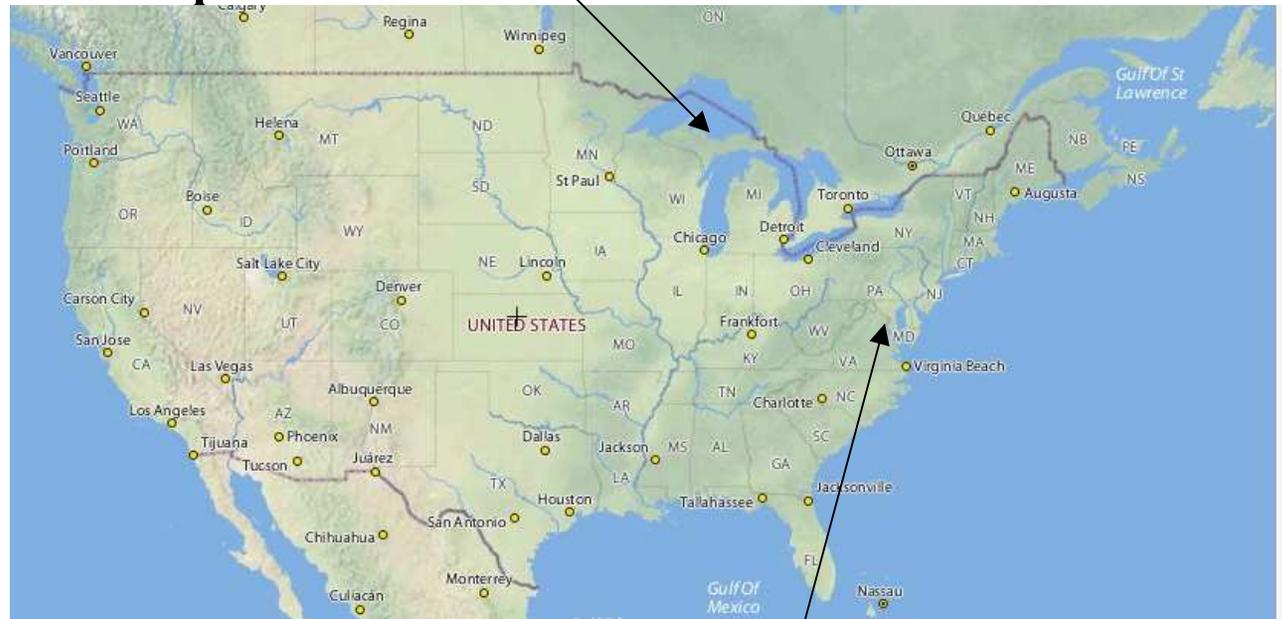


# Fast Real Time Calibration of a Varian 2100 (High Energy) series LINAC

Kenneth Chu, Ph.D., D.A.B.R., P.Eng.

Marquette General Hospital

Marquette, MI



And

Shidong Tong, Ph.D., D.A.B.R.

Inova Alexandria Hospital Cancer Center,  
Alexandria, VA

# Purpose

To describe how to adjust the output of a Varian linac in REAL time to  $1.000 \pm 0.002$  cGy/MU



# Background

- Many physicists adjust the dose rate by an iterative process of turning the MU1 potentiometer followed by an ion chamber measurement. However, this can take several minutes. When the measured output is close enough ( $\pm 0.5\%$ ) to 1cGy/MU, the process is generally accepted.
- However, few physicists realize that this process can be performed *REAL TIME* and is quite simple to do
- The drawback of having a simple technique is that you may be tempted to recalibrate the LINAC monthly

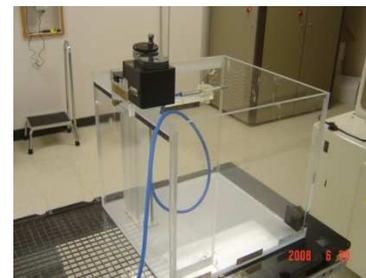
# WARNING

- Do NOT be tempted to recalibrate your linac monthly!
- It is better to recheck the output next day or using a different system
- Varian LINAC's generally do not drift by more than 2 % per year.
- An output drift upward of approximately 1% per month in all energies indicates the sealed Varian ion chamber may be leaking
- If you have to adjust the output (cGy/MU) by more than 2% in any one month, please check
  - Previous months output for a trend
  - Field size (especially after electrons were used)
  - Blank electron insert is in place
  - SSD and chamber depth
  - Chamber fully inserted
  - Electrometer settings
  - Pressure and Temperature (of solid water...not just room)

# Materials



- Varian 2100c (high energy) series LINAC
- Flat head screw driver (tweaker)
  - for turning potentiometer
- Electrometer and ion chamber system
  - with plastic water (or water filled tank)
  - thermometer and barometer



# Methods: Preparation

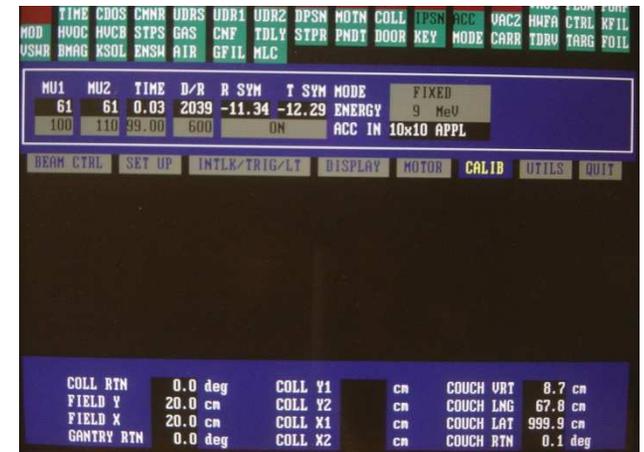
## LEGEND

[ ] keystroke

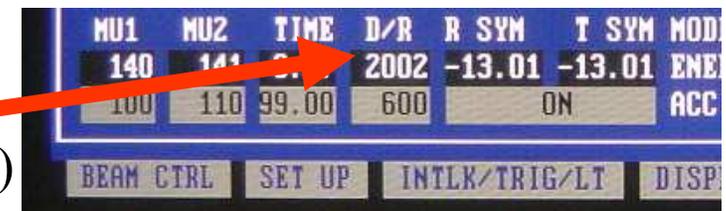
( ) Potentiometer

< > Display reading

ent = enter



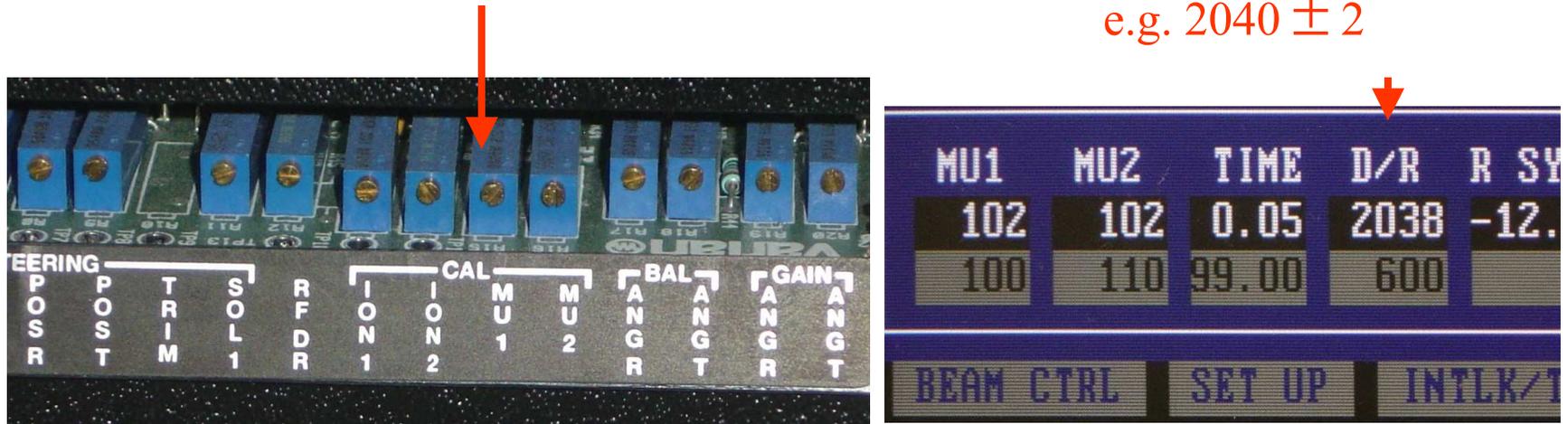
1. We assume you are familiar with service mode and over-rides
2. Determine output of your LINAC (cGy/MU) e.g 1.019 cGy/MU
3. In service mode, press Calibrate, Calibrate, Integrate [C][C][I] and record the value under <D/R> on the screen.
  - e.g. 2002 for 2100C/D, EX, iX, Trilogy (used in this poster)
  - e.g. 1050 for older C series LINAC



# Methods: Potentiometer (MU1)

- Multiply your output (in step 2) with the value found in step 3. Record this product. e.g:  $1.019 \times 2002 = 2040$
- Press [C][C][I] and adjust pot (MU1) until the <D/R> number equals the product you just calculated  $\pm 2$  units.

e.g.  $2040 \pm 2$



- Integration lasts 6 seconds, if more time is needed to adjust pot (MU1), use other hand to continuously press [ent][ent][ent] to keep integration cycle active
- Note which direction you moved the pot (MU1) and by how much

## Methods: Potentiometer (MU2)

8. Prepare to run beam by pressing  
[esc] [S][D] [100 mu] [enter] [I][D]...to clear interlocks
9. Run beam [B] [Y] and check output on electrometer  
...it is now 1cGy/MU
10. Observe display of <MU2> after beam is finished...we need to make it = <MU1>
11. Move potentiometer (MU2) by exactly the *same amount and in the same direction* as you did for pot (MU1)
12. Run beam [S][D] [100 mu] [B] [Y]
13. When beam is finished, display <MU2> should be close to <MU1> ...within  $\pm 1$
14. If not, adjust pot (MU2) by a small amount
15. Repeat steps 12, 13, and 14 if necessary until display <MU2> = <MU1> ...within  $\pm 1$

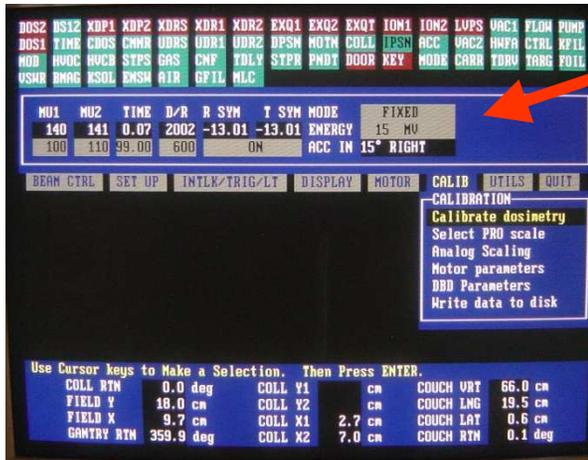
...e.g. both should read 100 when 100MU is selected

## Methods: Potentiometers (ION1 & ION2)

16. Press [C][C][I] and adjust potentiometer (ION1) in *REAL TIME* to make <D/R> read  $2000 \pm 2$ .... (we just set it to 2040 earlier in step 5 of example)
17. Continuously Press [ent][ent][ent] with other hand to keep integration active while adjusting potentiometer (ION1)
18. Adjust pot (ION2) the *same amount and direction* as in step 16.
19. Press [ent][ent][ent], and *wait* until it integration finishes; make sure the display of <MU2> = <MU2> = 200 ( $\pm 1$  unit of each other)
20. Otherwise tweak potentiometer (ION2);
22. Repeat steps 19 and 20 until display <MU2> = <MU2> = 200  
(Note: for C series linacs <MU1>=<MU2>=105)

**Warning:** Although steps 8 to 15 can be simplified under perfect conditions, we chose to give this example in this poster. From experience, steps 8 to 15 are vital to prevent interlocks when running in clinical mode when MU1 and MU2 were not properly adjusted before you started. NOTE: if the output adjustments are greater than 2% you may have to over-ride some of the dose interlocks in service mode to perform steps 8 to 15.

# HINTS



Be sure to select the correct energy as on the screen.

The red LED indicates the energy programmed.



Warning: If you have to turn the potentiometer more than 1/4 turn and nothing responds, you probably have the wrong circuit board!



[enter][enter][enter] = [C][C][I] after the first [C][C][I]

# Simplified Theory

1. Assume the LINAC should delivery 1cGy/MU but is actually 1.02cGy/MU to your calibration point
2. Pressing CCI delivers a reference current from ION1 to the integrator board to simulate what happens when the beam is on
3. D/R displays the reference dose rate from ION1 (e.g 2000MU/min)
4. But actual measured D/R is 1.02 times higher (as this is what the physicist determined)
5. Thus turn MU1 pot in real time adjust the gain in the integrator circuit to display  $2000 * 1.02 = 2040$  MU/min
6. Now when you run beam (e.g.100MU), the current from the LINAC's ion chambers deliver the same current as before but it is multiplied by 1.02, so the LINAC will reach 100 MU 2% earlier in time, and beam off at 1.000 MU/cGy
7. ION1 is used for the cal-check cycle (CCI), and adjusting it resets the reference current value back to D/R to 2000 MU/min (mid point in interlock range for D/R)
8. MU2 and ION2 pots are part of a back up system, and can be done iteratively in the CCI mode after the integration is completed (6 seconds/iteration).

# 1 Page Summary Instructions (clinac software vers. 5.4 to 6.2)

Measure linac dose rate output, e.g., output = 1.02 cGy/MU

- [C][C][I] to watch *current* <D/R>, e.g., 2000 (or 1050 for 2100C linac)
- Calculate *desired* <D/R> = *current* <D/R> 2000 × *current output* 1.02 = 2040

## Adjust (MU1)

- [ent][ent][ent] and adjust POT (MU1) in REAL TIME to get *desired* <D/R> 2040
- Now linac output = 1.00 cGy/MU

## Adjust (MU2)

- [Esc][S][D][100][enter] to set dose, [I][D] to clear interlocks, [B][Y] to run beam
- Iteratively adjust POT (MU2) to make <MU2> = <MU1> after running beam
- Repeat above until <MU2> = <MU1>

## Adjust (ION1)

- [C][C][I]
- [ent][ent][ent] and adjust POT (ION1) in REAL TIME to get <D/R> to read 2000 (or 1050 for 2100C)

## Adjust (ION2)

- [ent][ent][ent] and wait for end of integration to see if <MU2> = <MU1> = 200 (or 105 for 2100C)
- Iteratively adjust POT (ION2) to make <MU2> = <MU1> after running integration
- Repeat until <MU2> = <MU1>

## Verify linac dose rate output

- [Esc][S][D][100][enter] to set dose, [I][D] to clear interlocks. Reset electrometer,
- [B][Y] to run beam and check output!

Note: [ent][ent][ent] = [C][C][I] only after the first [C][C][I]

# 1 Page Summary Instructions (clinac software version 6.3 or higher)

Measure linac dose rate output, e.g., output = 1.02 cGy/MU

- [C][C][I] to watch *current* <D/R>, e.g., 2000 (or 1050 for 2100C linac)
- Calculate *desired* <D/R> = *current* <D/R> 2000 × *current output* 1.02 = 2040

## Adjust (MU1)

- [C][C][E] and adjust POT (MU1) in REAL TIME to get *desired* <D/R>
- [C][C][I] to stop integration.

## Adjust (MU2)

- [Esc][S][D][100][enter] to set dose, [I][D] to clear interlocks, [B][Y] to run beam
- Iteratively adjust POT (MU2) to make <MU2> = <MU1> after beam is finished
- Repeat to see if <MU2> = <MU1> ...tolerance ±1

## Adjust (ION1)

- [C][C][E] and adjust POT (ION1) in REAL TIME to get <D/R> to read 2000±2,  
(or to read 1050±2 for 2100C LINAC).
- [C][C][I] to stop integration.

## Adjust (ION2)

- [ent][ent][ent] and wait for end of integration to see if <MU2> = <MU1>
- Iteratively adjust POT (ION2) to make <MU2> = <MU1> after integration cycle
- Repeat until <MU2> = <MU1> ...tolerance ±1

## Verify linac dose rate output

- [Esc][S][D][100][enter] to set dose, [I][D] to clear interlocks. Reset electrometer,
- [B][Y] to run beam and check output!

(Note: [C][C][E]=[C][C][I] [ent][ent][ent]...for extended integration; Press [C][C][I] to stop [C][C][E] )

# 1 Page Summary only if before calibration display <MU1>=<MU2> (for clinac software vers. 5.4 to 6.2)

Measure linac dose rate output, e.g., output = 1.02 cGy/MU

- [C][C][I] to watch *current* <D/R>, e.g., 2000 (or 1050 for 2100C linac)
- Calculate *desired* <D/R> = *current* <D/R> 2000 × *current output* 1.02 = 2040

## Adjust (MU1)

- [ent][ent][ent] and adjust POT (MU1) in REAL TIME to get *desired* <D/R> 2040
- Now linac output = 1.00 cGy/MU

## Adjust (MU2)

- [ent][ent][ent] and wait for end of integration to see if <MU2> = <MU1>
- Iteratively adjust POT (MU2) to make <MU2> = <MU1> after running integration
- Repeat above until <MU2> = <MU1>

## Adjust (ION1)

- [C][C][I]
- [ent][ent][ent] and adjust POT (ION1) in REAL TIME to get <D/R> to read 2000 (or 1050 for 2100C)

## Adjust (ION2)

- [ent][ent][ent] and wait for end of integration to see if <MU2> = <MU1> = 200 (or 105 for 2100C)
- Iteratively adjust POT (ION2) to make <MU2> = <MU1> after running integration
- Repeat until <MU2> = <MU1>

## Verify linac dose rate output

- [Esc][S][D][100][enter] to set dose, [I][D] to clear interlocks. Reset electrometer,
- [B][Y] to run beam and check output!

Notes: [ent][ent][ent] = [C][C][I] only after the first [C][C][I]  
if <MU1> does not equal <MU2> before calibration, you will run into problems in clinical mode.  
In this case choose, either of the previous 2 pages...they have never failed me.

# Conclusions

- Varian high energy LINACs can be calibrated to  $\pm 0.2\%$  in real time in service mode
- Potentiometers MU1, MU2, ION1 and ION2 can be adjusted in a few minutes.
- The authors take no responsibility if you calibrate the LINAC incorrectly

# Recommendations

- Double check that each energy works in clinical mode
- After recalibration, check your diodes, daily QA devices, monthly QA reference factors, etc.
- When a new LINAC is installed, it is generally within 10%
- Obtain independent TLD readings from RPC, and/or an independent system (e.g. diodes) from another LINAC or facility
- Go to <http://medphysfiles.com> to down load this poster after August 1, 2008

# References

- Verbal Communications with
  - Jeff Chen, Eugene Wong, Craig Lewis, Kevin Jordan, John Taylor and the Bio-engineers at London Region Cancer Center, London, Ontario Canada
  - Marty Shapiro, OnTech, LLC
  - Keith Burton, Varian Medical Systems
- Varian Customer Service Bulletin CTB-CN-282b.pdf
- Varian Clinac iX tech ref.pdf