Radiographic Unit

Learning Outcome: Evaluate the standard performance of a radiographic unitaccording to Safety Code 35 requirements.

Objectives 3.1-3.6

In a Quality Control Program, there are three main components

- Visual inspection
- Environmental inspection
- Performance testing

Visual Inspection (Test 1) – Papp 6th Edition pg 101-102

- Includes checking main components of equipment for safety, proper function andmechanical condition
- Should be performed annually (at minimum), with a checklist for documentation.
- Components that must be included:
    - Control panel
        - Contains all the selectors for controlling x-ray production (mA, time, kVp)
        - Must verify proper function of all meters/switches that monitor operationof the generator
        - Must have:
            - Sign warning of x-ray emission – conspicuous, permanent, highlyvisible stating unauthorized use is prohibited
            - Controls/meters must be marked for function
            - Indicator lights – ready for exposure and x-ray emission
                - i.e., Green light/donut when ready for exposure and yellow/orange light sign when exposing
        - Proper function of heat sensors and overload backup timers
        - Ensure a clear line of sight into the x-ray room through the window, thereshould be no obstructions
        - Also need to have an updated technique chart for each room
    - Overhead tube crane
        - This is the bracket that holds the x-ray tube over the x-ray table
        - Items to evaluate are:
            - High voltage cables and wires
                - Is there any discoloration or damage?
            - Condition of the cable brackets, tie downs
                - Are they intact and functioning? Are they too tight/loose?Do they

affect motion of the tube?

- Stability of the system

        - When moving, is there excessive drift/vibration?
    - Détentes and Locks
        - Are they working effectively?
        - Interlocks – anything that stops the machine from workingfor the safety of the machine/operator
            - i.e., overhead tube may not be activated in a fluoroscopy room if the fluoroscopic tower is notlocked in place
    - Lights
        - Is the collimator light bright enough?
        - Collimator and centering laser, is it accurate?
    - SID indicator
        - Needs to be accurate within 2% (more details later)
- Radiographic table
    - As this piece of equipment is usually in contact with the patient, needs tobe kept clean and safe
    - Need to inspect:
        - Condition of the surface – is it clean, uniform? Are there any deepscratches or debris?
        - Power top/angulation if applicable (i.e., fluoroscopy tables)
        - Stability – should only move when it is supposed to, should movesmoothly
        - Bucky tray/cassette locks
        - Footboards, shoulder braces, handles – how is the condition?
- Lead apparel
    - Tested and inspected annually, but every 6 months is preferable
    - Looking for proper labelling and storage
    - Items should be clean and when not in use, hung properly to preventcracks and damage
    - Testing can be done fluoroscopically or radiographically
    - Check for the correct amount of lead equivalency as per the SC 35
- Miscellaneous equipment (i.e., sponges, miscellaneous equipment.)
    - Sponges – Are they clean, free of contrast? Condition? Are thereenough?
    - Immobilization devices
        - i.e., pigg-o-stat – are the brakes and holder functional? Is it clean?Any damage?
    - Step stools, stools – Are they stable? Locks functional? Clean?
    - Calipers – typically in areas where manual techniques used with technique charts
    - IV stands – Are they stable? Are there enough?

Environmental Inspection – Papp 6th Edition pg. 102-103

- Should be performed annually (at minimum)
- The visual inspection focuses more on the main components of the x-ray equipment, theenvironmental inspection is primarily checking for mechanical and electrical safety
- Often performed at the same time as the visual inspection
- Some items included in this inspection are:
    - High tension cables
        - Check the coverings on the outside of the cables.
            - If there is discoloration, this can indicate internal heat and a potential short circuit
            - Particularly vulnerable areas are where the wire/cables bend
            - If discoloration is present, must contact a biomed engineer, physicist or call a service technician.
    - Tube tracks/counterweights
        - Mechanical condition
        - Are there any areas that require maintenance, lubrication?
        - Is the tube moving smoothly along the tracks?
    - Electrical safety
        - Critical for all involved – user and patients
        - All equipment should be properly grounded and all connections intact

Performance Testing – Papp 6th Edition pg. 103

- This is for evaluating the performance of the x-ray generator and x-ray tube using testtools
- It is common for sites to have a QC technologist or physicist perform these tests, but radiographers should know how these tests are performed, and how to interpret the results
- All the tests, aside from the visual inspection, fall into this category.

Reproducibility (Test 2) – Papp 6th Edition pg. 104-105, SC 35 pg. 24: 2.5.2 #1

- Consider the name of this test, it is important for an exposure to be reproduced accurately. Why does this matter? If an exposure is taken using a specific technique (kVp and mAs), it is imperative that the expected radiation output is produced. If this is not the case, it is impossible to control how much radiation a patient receives, and therewill not be any consistency with exposures. Radiation output will be unpredictable.
- Also known as the repeatability test – because each exposure is repeated with the sameexposure factors and should produce the same amount of radiation each time.
    - Note: this test cannot be performed on a falling load generator, as the exposuretime cannot be kept constant with that type of generator.
- This test is commonly the first generator test performed, before all other tests
    - Performed annually, after any calibrations/repairs to generator, or if there is anyreason to suspect exposures are not consistent
- Purpose of this test: To confirm that the same dose (mR) is received from exposure toexposure when a constant mA, time and kVp are used.
    - If this is inconsistent, radiographic density, contrast, and patient dose areaffected
    - Consistent exposures decrease repeat images caused by exposure factors –ultimately reducing patient dose
- Coefficient of variation
    - What is it? It is a statistical measurement that tells us how variable or consistentthe measurements are
    - Describes the spread or distribution of a data set
    - Also, were the results founded on chance? If the C≤ 0.05, there is littleprobability that these results occurred purely by chance alone
- Troubleshooting Considerations
    - If the test fails, further investigation is required
        - Variations in parameters
        - Timing issue? Were all the exposures done within one hour?
        - Possible issues with x-ray tube operation
        - Dosimeter issues? Was it warmed up, was it reset?
        - Electrical power variations
            - Can we tell what the issue is? mA, time or kVp?
            - NO – need further testing (service engineer) to determine cause.

- Refer to the QUAL 370 Procedures manual for the equipment and sample procedure toperform this test and analyze results.

- Use the following sample data results to perform the calculations. Formulas andcalculation sheets are provided in the QUAL 370 Procedures manual.

Reproducibility			
Exposure	mR	Time (ms)	kVp
1	60.03	99.87	79.23
2	60.05	99.90	79.29
3	60.03	99.87	79.23
4	60.03	99.87	79.23
5	60.05	99.90	79.29
6	60.06	99.92	79.28
7	60.02	99.84	79.20
8	60.03	99.87	79.23
9	60.04	99.88	79.26
10	60.03	99.87	79.23

***This guided calculation is for **mR**. Please ensure all calculations for the full data set are completed.*

To determine the mean value of mR, add up all the mR values and divide by 10.

Mean mR = 60.037 mR

Calculate the % difference between the mean and the maximum value of the 10 measurements.

$$\frac{(\text{MAXIMUM VALUE} - \text{MEAN VALUE})}{\text{MEAN VALUE}} \times 100 = \quad \%$$

$$\frac{[60.06\ mR - 60.037\ mR]}{60.037\ mR} \times 100 = 0.038\%$$

Calculate the % difference between the mean and the minimum value of the 10 measurements.

$$\frac{(\text{MINIMUM VALUE} - \text{MEAN VALUE})}{\text{MEAN VALUE}} \times 100 = \quad \%$$

$$\frac{[60.02\ mR - 60.037\ mR]}{60.037\ mR} \times 100 = -0.00028\%$$

Compare the results to the standard in SC 35 p. 24

- Each of the 10 radiation exposures measured must be within +/- 15% of themean value of the 10 measurements.

Based on results, mR = PASS

Reproducibility Worksheet

STEP 1 Subtract each reading from the mean value.

(60.037– 60.03) + (60.037- 60.05) + (60.037- 60.03) + (60.037- 60.03) + (60.037- 60.05) + (60.037- 60.06) + (60.037- 60.02) + (60.037- 60.03) + (60.037- 60.04) + (60.037- 60.03)

STEP 2 Square each result, and add them up.

$(0.007)^2 + (-0.013)^2 + (0.007)^2 + (0.007)^2 + (-0.013)^2 + (-0.023)^2 + (0.017)^2 + (0.007)^2 + (-0.003)^2 + (0.007)^2$

0.000049+0.000169+0.000049+0.000049+0.000169+0.000529+0.000289+0.000049+0.000009 +0.000049 = 0.00141

STEP 3 Divide the result from Step 2 by 9.

0.00141 / 9 = 0.000156666

STEP 4 Take the square root of the result in Step 3.

$\sqrt{}0.0001516666 = 0.012516655$

STEP 5 Divide the result from Step 4 by the mean value.

0.012516655 / 60.037 = 0.000208482

Compare the results to the standard in the SC 35 p.24

- The coefficient of variation must be less than 0.05

Based on results, mR = PASS

Please ensure all calculations are completed in full for mR, time (ms) and kVp. Check your answers for accuracy.

Mean Value

Time: 99.879 ms *kVp: 79.247 kVp*

% Difference – Maximum and Mean

Time: 0.0410 % *kVp: 0.0543 %*

% Difference – Minimum and Mean

Time: -0.039% *kVp: -0.0593%*

Coefficient of Variation

Time: 0.000224 *kVp: 0.000390*

kVp Accuracy (Test 3) – Papp 6th Edition pg. 106-107, SC 35 pg. 25 : 2.5.2 #6

- Review: What is affected by kVp?
  - Potential difference across tube
  - Energy of photons in the beam (penetrability)
  - Radiographic contrast, optical density and patient dose
- Due to the number of factors affected by kVp, it is important that the generator producesthe kVp that is set on the console
- Small changes/variances in kVp can affect dose and image quality
- kVp can drift over time as the tube ages
- Purpose of this test: to confirm that the x-ray generator is producing the same kVp asindicated on the control panel
  - If kVp is inconsistent, it will be difficult to predict contrast/density, which will inturn affect patient dose and reproducibility
- Testing is done on acceptance, annually, before/after any generator service, or when there is any reason to suspect the generator is not functioning well. Typically performedbefore mA or timer tests – because it can affect other measurements and test results.
- Troubleshooting Considerations
  - If the test were to fail, need to investigate a bit further
    - Variations in the line voltage supplying the generator
    - Faulty high voltage cables
    - Problems with selector circuitry

- Refer to the QUAL 370 Procedures manual for the equipment and sample procedure toperform this test and analyse results.
- Use the following sample data results to perform the calculations. Formulas andcalculation sheets are provided in the QUAL 370 Procedures manual.

kVp Accuracy

Set mA: 100	Set Time (ms): 100	SID (cm): 110

Set kVp	Focal Spot	Actual kVp	% diff	PASS	FAIL
50	Large	49.28			
60	Large	59.50			
70	Large	69.09			
80	Large	79.13			
90	Large	89.15			
100	Large	98.35			

This guided calculation is for **50 kVp. Please ensure all calculations for the full data set are completed.*

$$\% \text{ Difference} = \frac{(\text{Actual kVp}) - (\text{Set kVp})}{(\text{Set kVp})} \times 100$$

% Difference = (49.28 kVp – 50 kVp) x 100
(50 kVp)

% Difference = -1.44%

Compare the results to the standard in SC 35 pg 25.

- The measured kVp shall have a value within +/- 10% of the selected kVp value.

***Based on results,** 50 kVp = PASS*

Please ensure all calculations are completed in full for the remaining kVp settings. Check youranswers for accuracy.

% Difference

60 kVp: -0.83%
70 kVp: -1.3%
80 kVp -1.088%
90 kVp: -0.94%
100 kVp: -1.65%

mA Linearity (Test 4) – Papp 6th Edition pg 109-110, SC 35 pg 25 : 2.5.2 #2

- Review: How does the mA affect the x-ray tube?
  - Regulates the temperature of the filament
    - Controls how many electrons are boiled off and in the thermionic cloud
  - Quantity of x-ray photons in the beam, direct relationship with optical density
- Linearity
  - Sequential increases in mA or mAs should produce the same proportionalincrease in the exposure
    - i.e. if 70 kVp and 5 mAs produce 20 mR of exposure, technically 70 kVpand 10 mAs should produce 40 mR (double mAs = double mR)
  - Why is this test important?
    - Reciprocity law: Any combination of mA and time should produce thesame exposure as long as the total mAs is the same
      - This allows techniques to be adjusted as needed
        - i.e. pediatrics, difficult patients, breathing techniques
- Purpose of this test: To confirm that any two consecutive mA settings can produceaverage exposure ratios within the acceptable tolerance and that mA is linear withexposure.
  - This is what allows the reciprocity law to work, if there is too much variance in theoutput,

there will be too much variation in the resulting exposure, making technique adjustments very difficult.

- Testing is done on acceptance, annually, before/after any generator service. Typicallyperformed after reproducibility and kVp accuracy.
- Troubleshooting Considerations
    - If the test were to fail, need to investigate a bit further
        - Problems with mA selector
        - Timer issues
        - Rectifier failure

- Refer to the QUAL 370 Procedures manual for the equipment and sample procedure toperform this test and analyze results.
- Use the following sample data results to perform the calculations. Formulas andcalculation sheets are provided in the QUAL 370 Procedures manual.

mA Linearity

Set kVp: 80	Set Time (ms): 100	SID (cm): 110

Set mA	Set mAs	Focal Spot	Exposure	mR	Avg. mR	mR/mAs
50		Large	1	28.21		
			2	28.15		
100		Large	1	56.49		
			2	56.61		
125		Large	1	70.57		
			2	70.54		
160		Large	1	90.13		
			2	90.15		

***This guided calculation is for the **50 and 100 mA** stations. Please ensure calculations for the full dataset are completed.*

Step 1: Calculate the set mAs

50 mA x 100 ms = 5 mAs

100 mA x 100 ms = 10 mAs

Step 2: Calculate the average mR of Exposure 1 and 2

50 mA: 28.21 mR + 28.15 mR = 56.36 mR / 2 = 28.18 mR

100 mA: 56.49 mR + 56.61 mR = 113.1 mR / 2 = 56.55 mR

Step 3: Determine the mR/mAs – take the average mR and divide it by the set mAs

50 mA: 28.18mR / 5 mAs = 5.636 mR/mAs
100 mA: 56.55 mR / 10 mAs = 5.655 mR/mAs

***Note... look at the values for mR/mAs – they should be similar for every mA setting. In essence, forevery 1 mAs set, there should be_____mR. The proportion of mR to mAs should not vary by much.*

*Recommendation – do these steps for all the mA settings first before moving onto the linearityworksheet. Enter all the values into the data table for easier reference.

mA Linearity Worksheet

Use the mR/mAs for consecutive mA settings. If the statement is true, then it is a pass.

Absolute value – only positive values, no negatives

x_1 @ 50 mA x_2
@ 100 mA

$$|x_1 - x_2| \leq 0.10(x_1 + x_2)$$

$$|(5.636 - 5.655)| \leq 0.10(5.636+5.655)$$

$$0.019 \leq 1.1291$$

This is a true statement, 0.019 is less than or equal to 1.1291

PASS X FAIL ____

Compare the results to the standard in SC 35 pg. 25.

- The average mR/mAs values obtained at any two consecutive mA settings shallnot differ more than +/- 0.1 times their sum.

Based on results, linearity between 50 and 100 mA = PASS

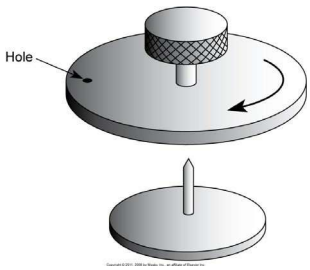
Please ensure all calculations are completed in full for the remaining mA settings. Check youranswers for accuracy.

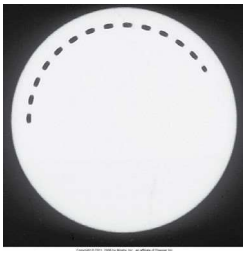
100 mA and 125 mA: 0.0106 < 1.12994
125 mA and 160 mA: 0.01065 < 1.127815

Timer Accuracy (Test 5) – Papp 6th Edition pg 108-109, SC 35 pg 25 : 2.5.2 #6

- Exposure time – why does it matter?
  - The total quantity of radiation produced is directly related to exposure time
  - Need to ensure that the generator is producing the exposure time that is set
  - Affects patient dose and radiographic density
- Several methods to test timer accuracy
  - Spinning top test tool
    - Oldest method – manually spin the top, then take the exposure
    - Top is counterweighted to maintain a constant speed of rotation
    - For single phase units only (pulsed), does not work well on 3 phase/high frequency units because the x-ray production is constant.

- Each pulse creates a dot, which should correspond to the setting





- Wisconsin Timing Test tool/ Synchronous timer
  - For 3 phase and HF generators, motor driven top used instead
  - Top rotates at a constant speed of 1 rps. After 1 second, a 360 circle ismade
  - For each exposure, measure the arc with a protractor
  - Actual exposure time = Arc size in degrees/360
- Digital timing test tool
  - Easiest method of evaluation – used in modern departments, this is themethod we will use.
  - Utilizes a solid-state detector,
  - After the exposure is taken, the test tool will display the exposure time

- Purpose of this test: To confirm that the x-ray generator is producing an exposure for theamount of time set on the control panel.
- Testing is done on acceptance, annually, before/after any generator service. Also ifimages are over/under exposed, inconsistent EI values between similar exposures.

- Refer to the QUAL 370 Procedures manual for the equipment and sample procedure toperform this test and analyze results.
- Use the following sample data results to perform the calculations. Formulas andcalculation sheets are provided in the QUAL 370 Procedures manual.

Timer Accuracy

Set mA: 100		kVp: 60		SID (cm): 110	
Set Time (ms)	**Focal Spot**	**Result (ms)**	**Acceptable Range**	**PASS**	**FAIL**
40	Large	35.13			
50	Large	45.19			
60	Large	59.23			
80	Large	77.31			
100	Large	98.35			

***This guided calculation is for the **40 ms** time setting. Please ensure all calculations for the full data setare completed.*

(0.1 x Set Time) + 1 =_____ms Set Time +_____= max limit

Set Time -_____= minimum limit

(0.1 x 40 ms) + 1 = 5 ms

40 + 5 = 45 ms (max limit)

40 – 5 = 35 ms (minimum limit)

Acceptable Range: ***35-45 ms*** Lab result = 35.13 ms

Compare the results to the standard in SC 35 pg. 25.

- All exposure times must be accurate to +/- 10% + 1ms of that set on the x-raygenerator control panel

Based on results, the 40 ms setting = PASS

Please complete calculations for the remaining time settings. Check your answers for accuracy.

50 ms: 44 - 56 ms

60 ms: 53 - 67 ms

80 ms: 71 – 89 ms

100 ms: 89 – 111 ms

Leakage Radiation Compliance (Test 6)– SC 35: pg 24

- Leakage radiation is defined as any photons that escape from the tube housing, exceptthose exiting from the port
  - Tube housing is typically only lined with lead at the cathode end because of thedirection of the photons being emitted from the anode
- Why is this important? It contributes to everyone's dose!
- This can be tested in several ways:
  - Paddle/radiation probe (most commonly used method)
    - Please refer to the QUAL 370 Procedures manual for a sample procedure
  - Cassette Method
    - Place a lead sheet on the table under the collimator, close the collimatorshutters and lower tube onto the lead sheet
    - Surround the x-ray tube with cassettes, labeling each one with a markerto note the location (i.e., anode side, cathode side, etc.)
    - Take a large exposure, process the cassettes and look for exposed areas
    - Repeat the same exposure with a dosimeter 1 m away from the area thathad an exposure
- To evaluate leakage radiation, there is a formula (**needs to be memorized)
  - % leakage = $\frac{\text{Leakage mR}}{\text{Primary mR}} \times 100$

Example: What is the percentage of leakage if the intensity of the primary beam is 145 mR andthe leakage is 0.08 mR?

$$\frac{0.08\ \text{mR}}{145\ \text{mR}} \times 100 = 0.055\ \%$$