Evaluation of the Quality Control and Quality Assurance in Mammography mobile Unit

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Abstract

The aim of this study was to undertake a comprehensive evaluation of selected mammography unit. The materials used mammography machine Philips, multi-electrometer, target and filter combinations W/Rh, Mo/Rh and Mo/Mo and Aluminum layers. The quality control assessment was performed on the selected machine. The assessment was done included kV accuracy and reproducibility and Half Value Layer measurement. The results obtained confirmed that the machine is working correctly and was within acceptable performance criteria. The results of the physical parameters indicated a deviation of tube potential for the examined tube from the nominal values with the standard deviation (± 5%), except the few values exceeds this levels, and the conclusion is that some adjustments showed be done and the have value layer at the nominal tube potential (28kV) was in agreement with the published values.

Key words: Mammography, QC/QA, accuracy and reproducibility, HVL, kilovoltage, machine current.

1. Introduction

Breast screening depends on diagnostic procedure to discover cancer in its early stages thanks to little changes in tissue composition. Like any examination that features x-rays, there's invariably little random risk of causing cancer. It's so necessary to judge the danger from the dose delivered to the patient throughout the screening method, in alternative words, to stay the dose as low as moderately accomplishable (**Dance et al., 2000**). Mammography needs prime quality standers since the distinction between traditional and pathological areas within the breast is extraordinarily low.

X-ray examinations remain the foremost oftentimes used radiation in medication, constituting the foremost important simulated supply of radiation exposure for the planet population. However, the increasing use of x-ray in hospitals has created a very important source of radiation within the population collective dose. In diagnostic radiology, periodic dose assessments ought to be created to encourage the improvement of the radiation protection of the patients. Dose measurements are needed any to check completely different imaging techniques and to go with some international tips and rules (**Suliman et al., 2007**). Mammography needs a highest image quality for all procedures whereas keeping the radiation dose delivered to the breast, as low as attainable. This can be solely doable by mistreatment optimum instrumentality and safe procedures. Also, like any medical checkup managing radiation, there's continually at any low risk of random impact inducement cancer. Therefore, it's important to make sure that the diagnostic procedure units used is functioning accurately and also the radiation dose delivered to the breast and ascertain whether or not it falls at intervals international references levels, (**Marianne & Bengt, 2008**).

QA programs as recommended by AAPM and AERB should be carried out periodically to ensure safety in breast cancer screening. This work points to the importance of the regulation and effective compliance and also help in both improving the QA and reduce the glandular dose received by the patients **(Selvan and Sureka 2017)**. Digital imaging allows automation of the image quality analysis, which can potentially improve repeatability and objectivity compared to a visual evaluation made by the users. To develop an automatic image quality analysis software for daily mammography quality control in a multi-unit imaging center (**Sundell et al., 2019)**.

2. Materials and Methods

2.1. Materials

The materials used for this study are one selected mammography mobile units were Philips, Aluminum layers and kV and current and effective dose dosimeter.

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Figure (2.1): Mammography equipment, Philips

The dosimeter used for measurement in this study was the calibrated multi-electrometer. Manufactured by RTI electronics AB, it was used to measure the voltage in kV, current in mAs, Exposure in mR, exposure time measurements in seconds. Multi-electrometer or dosimeter is shown in figure (2.2).

Figure (2.2): Multi-electrometer Model4000M. Figure (2.3): Thin layers of Aluminum filters

We used number of Target and filter combinations such as W/Rh, Mo/Rh, Mo/Mo, and Rh/Rh built-in mammograms and we used number of Aluminum sheets to measure the effective Half Value Layer (HVL) materials shown in figure (2.3).

2.2. Methods

QC tests were carried out on the mammography systems to verify whether they were performing with internationally accepted criteria. The QC tests performed included: tube voltage kV accuracy and reproducibility, HVL, image quality tests and compression.

2.2.1. Quality Control Tests

Quality control (QC) tests are carried out to evaluate the performance level radiographic systems in order to ensure that users are provided with best achievable image quality while keeping patient doses as law as reasonably achievable.

The following QC tests were performed for both patient dose measurements and clinical image quality evaluation had been carried out; Reproducibility and accuracy of kV and HVL determination.

a) Kilovoltage kV measurement

Image quality and patient dose are dependent on any variation in the generator kilo voltage (kV) of the X-ray set. Therefore an accurate kV calibration is required (**IAEA, 2009**).

Methods of KV accuracy and reproducibility measurement:

- Select number of kV settings commonly used in the clinical practice range from 25 to 32 kV.
- Position the measuring instrument (kV meter) on the breast support table.
- Set the mammography unit in the manual mode and carry out three exposures at each kV to four types of target filter combination at tube current (50 / 100 mAs) according to mammography unit selected.
- Carry out a single exposure for the other kV setting selecting and note the values measured on the data to determine the kV accuracy, calculate the percentage deviation between the nominal value and the measured kV value for each selected kV.

Deviation % = 100 (kVnom. – kVmeas.) / kVnom.

Limiting value of accuracy: ±5%

To determine the kV reproducibility, calculate the measurement percentage difference using the following formula:

Reproducibility = 100 (Max. reading – Min. reading) / Min. reading

Limiting value of reproducibility: diff. ≤ 5%

b) **Half value layer determination**

The half value was measured to all three target / filter combination for all x-ray units under investigation. Since the estimation of accurate dose required an assessment of half value (**IAEA, 2009**). The Half Vague Layer (HVL) can be assessed by adding thin aluminum (Al) filters to the X-ray beam and measuring the attenuation.

- Position the exposure detector on top of the bucky.
- Place the compression multi electrometer on top of the bucky.
- Place the compression device have way between focal spot and detector.
- Select 28 kV tube voltage and an adequate focal spot charge (mAs-setting) and expose the detector directly.
- The filters can be positioned on the compression device and must intercept the hole radiation field.
- Use the same mAs setting and expose the detector through each filter.
- Note limiting value for 28 kV Mo/Mo the HVL must be over 0.3mmAl equivalent.

3. Results and Discussion

Quality assurance applied to the radio diagnostic practice is intrinsically related to medical ethics. It’s primary is goal to guarantee the fulfillment of three basic criteria: a) Be necessary and appropriate to solve the clinical problem; b) Be able to produce images with enough information to solve the clinical problem; and c) Be optimized, in order that the screening or diagnostic examination results in the lowest possible radiation exposure, lower costs, and inconvenience to the patient. Results for equipment testing, presented in Table I, shows correspondence with adopted tolerances for most quality control tests, except for irradiation geometry and AEC tests. Radiation from routine mammography poses significant cumulative risk of initiating and promoting breast cancer (**Suliman et al., 2007, Modupe et al., 1999, Olivera et al., 2005,)**.

Contrary to conventional assurances that radiation exposure from mammography is trivial--and similar to that from a chest X-ray or spending one week in Denver, about 1/1,000 of a rad (radiation-absorbed dose)--the routine practice of taking four films for each breast results in some 1,000-fold greater exposure, 1 rad, focused on each breast rather than the entire chest (**Olivera et al., 2005**). Thus, premenopausal women undergoing annual screening over a ten-year period are exposed to a total of about 10 rads for each breast. As emphasized some three decades ago, the premenopausal breast is highly sensitive to radiation, each rad of exposure increasing breast cancer risk by 1 percent, resulting in a cumulative 10 percent increased risk over ten years of premenopausal screening, usually from ages 40 to 50 (4); risks are even greater for «baseline» screening at younger ages, for which there is no evidence of any future relevance.

3.1. Quality Control Tests

Quality Control (QC) tests are carried out to evaluate the performance level of radiographic systems in order to ensure that users are provided with the best achievable image quality while keeping patient doses as low as reasonably achievable. The following QC tests were performed of clinical image quality evaluation had been carried out; Accuracy and Reproducibility of kV and HVL determination. The quality control tests methods used, as well as the criteria for scoring the results, were in full agreement with those specified in the European Protocol for the Quality Control of the Physical and Technical Aspects of Mammography Screening.

3.1.1. Tube voltage accuracy and reproducibility

The reproducibility and accuracy of the tube voltage are essential in mammography. They guarantee a constant quality of image when repeating the exposure at same settings. This allows the practitioner to precisely select the appropriate kV value for the examination. The tube voltage (KV) used during medical examination in mammography fall within the range (25-32 kV); thus this range were studied using calibrated test device and the kV values for each nominal tube voltage are measured. The relation between the nominal and the measured values of tube voltage are represented in table (3.1) and as shown in figure (3.4) for the mobile unit. From this figure it is clear that the measured tube voltage has an acceptable deviation from the nominal values table. The results of KV accuracy and reproducibility of Philips mobile unit for all target filter combinations were as shown in tables (3.4 - 3.6).

Table (3.1): Values of nominal kV and measured kV for mobile unit with 100 mAs and W/Rh

Nominal kV	**Measured kV**
25	27.72
26	28.08
27	28.28
28	28.75
29	29.34
30	30.02
31	30.9
32	31.95

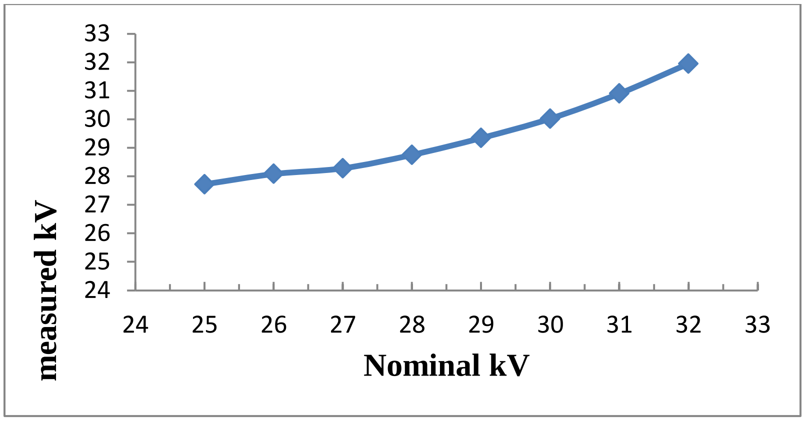

Figure (3.1): Values of nominal kV and measured kV for mobile unit Philips with 100 mAs and target filter combination W/Rh.

Table (3.2): Values of nominal kV and measured kV for mobile unit Philips with Pre-set tube load 100 mAs and target filter combination Mo/Rh

Nominal kV	Measured kV
25	26.8
26	27.1
27	27.77
28	28.51
29	29.29
30	30.1
31	31.08
32	31.94

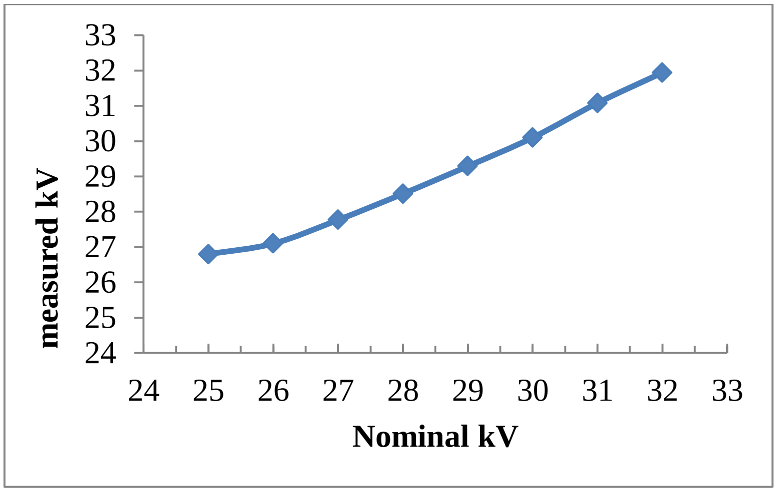

Figure (3.2): Values of nominal kV and measured kV for mobile unit Philips with Pre-set tube load 100 mAs and target filter combination Mo/Rh

Table (3.3): Values of nominal kV and measured kV for mobile unit Philips with Pre-set tube load 100 mAs and target filter combination Mo/Mo

Nominal kV	**Measured kV**
25	27.46
26	27.84
27	28.13
28	28.74
29	29.04
30	29.74
31	30.61
32	31.55

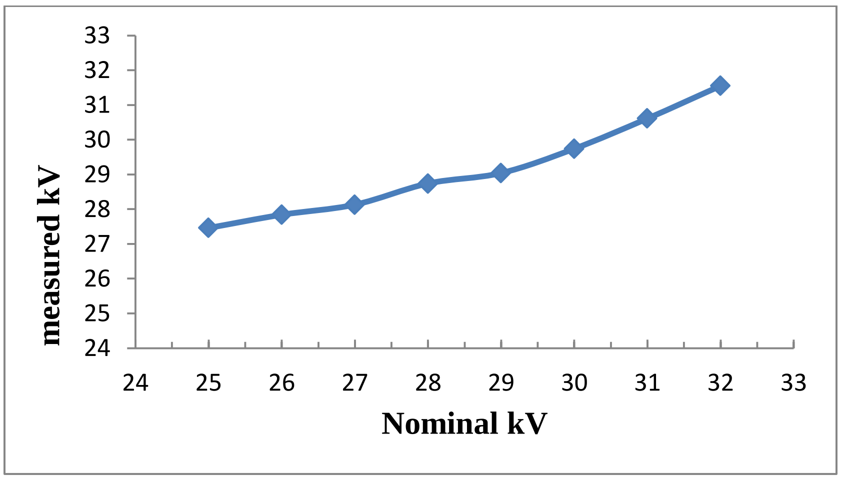

Figure (3.3): Values of nominal kV and measured kV for mobile unit Philips with Pre-set tube load 100 mAs and target filter combination Mo/Mo

Table (3.4): Values of nominal kV and measured kV for mobile unit Philips with Pre-set tube load 100 mAs for W/Rh Target filter combination

Nom. KV	25	26	27	28	29	30	31	32
Measured	27.33	27.74	28.0	28.49	29.1	29.81	30.76	31.77
Deviation %	-9.32	-6.44	-3.7	-1.75	-0.3	0.63	0.77	0.72
Reproducibility	0.01	0.01	0.01	0.003	0.001	0.01	0.002	0.002

Table (3.5): Values of nominal kV and measured kV for mobile unit Philips with Pre-set tube load 100 mAs for Mo/Rh Target filter combination

Nom. KV	25	26	27	28	29	30	31	32
Measured	26.15	26.64	27.39	27.91	29.38	29.89	30.89	31.81
Deviation %	- 4.6	- 2.46	- 1.44	0.32	- 1.31	0.37	0.35	0.59
Reproducibility	0.01	0.002	0.02	0.002	0.04	0.001	0.001	0.001

Table (3.6): Values of nominal kV and measured kV for mobile unit Philips with Pre-set tube load 100 mAs for Mo/Mo Target filter combination

Nom. kV	25	26	27	28	29	30	31	32
Measured	27.0	27.54	27.78	28.1	28.78	29.52	30.37	31.38
Deviation %	- 8	- 5.92	- 2.9	- 0.36	0.76	1.6	2.03	1.9
Reproducibility	0.01	0.01	0.001	0.003	0.005	0.004	0.003	0.001

As for the accuracy of the tube voltage, deviations greater than ± 5% over the range of the available kV of the machine 25 kV and 26 kV for W/Rh and Mo/Mo target filter combination are to be considered as an unacceptable and need to be fixed. The results of KV accuracy for target filter combination showed that deviations were less than ± 5% over the range of the available KV sets (27-32kV) of the machine are to be considered as acceptable values. The results of KV reproducibility indicated that, the difference percentage were less than 5%for the range of KV nominal and this indicates that the unit is in good work condition. The results of KV accuracy and reproducibility of the unit for all target filter combinations were shown in tables (3.4-3.6). The results of KV accuracy for Mo/Rh combination showed that deviations were less than ± 5% over the whole range of the available KV sets of the machine are to be considered as acceptable values. The results of KV reproducibility indicate that, the difference percentage were less than ±5%for the range of KV setting (25kV-32kV).

For W/Rh target filter combination, the data showed that, greater deviation than the recommended limiting values at certain tube voltage at 25 and 26 KV, the deviation were -9.32% and -6.44% respectively. These deviations percentage indicate that there is a problem in this unit for this target filter combination and need to be readjusted as shown in table (3.4).

The results of KV accuracy for Mo/Rh combination showed that deviations were less than ± 5% over the whole range of the available KV sets of the machine are to be considered as acceptable values as shown in table (3.5) and the results of KV reproducibility indicate that, the difference percentage were less than 5% for the range of KV nominal which indicates that the unit is in good work condition.

For Mo/Mo target filter combination the data showed that, greater deviation than the recommended limiting values at certain tube voltage, at 25 and 26 KV, the deviation were -8.0% and -5.92% respectively. These deviations percentage indicate that there is a problem in this unit for Mo/Mo target filter combination and need to be readjusted as shown in table (3.6).

3.1.2. Half value layer (HVL)

In diagnostic x-ray tubes, the half value layer (HVL) plays an important role to qualify the beam and unnecessary radiation exposure. In this study, the half value layer (HVL) was evaluated in the kilovoltage range of interest for Philips mobile unit by adding thin aluminum filters to the

X ray beam and measuring the transmission (attenuation) in ‘good geometry’ i.e. for narrow beam conditions to minimize the influence of scattered radiation and it was calculated

Table (3.7): Variation of the thickness of Al filter with the exposure (mR) of mobile unit, for clinically most relevant 28 KV with 100 mAs and **W/Rh** target filter combination

Al Thickness in mm.	0.0	0.1	0.2	0.3	0.4	0.5	0.6
Exposure (mR)	425.5	368.7	320.9	280.7	246.8	218.0	192.9
Transmission %	100	86.7	75.4	65.9	58.0	51.2	45.3

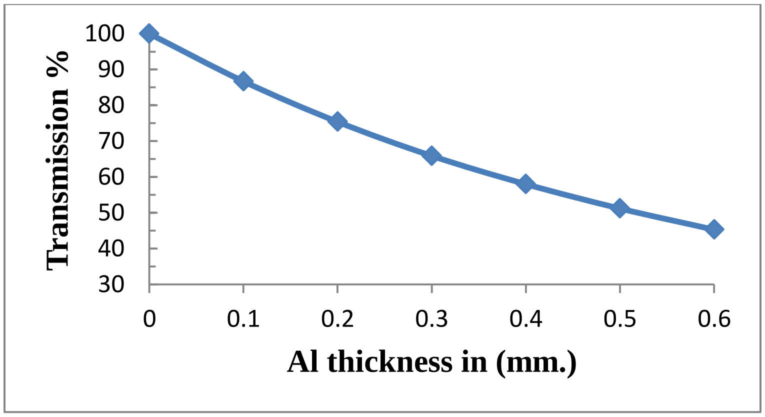

Figure (3.4): Variation of the thickness of Al filter with the exposure (mR) of mobile unit, for clinically most relevant 28 KV with 100 mAs and W/Rh target filter combination

Table (3.8): Variation of the thickness of Al filter with the exposure (mR) of mobile unit, for clinically most relevant 28 KV with 100 mAs and **Mo/Rh** target filter combination

Al Thickness in mm.	0.0	0.1	0.2	0.3	0.4
Exposure (mR)	1058	879.5	735.2	635.5	531.1
Transmission %	100	83.1	69.49	60.1	50

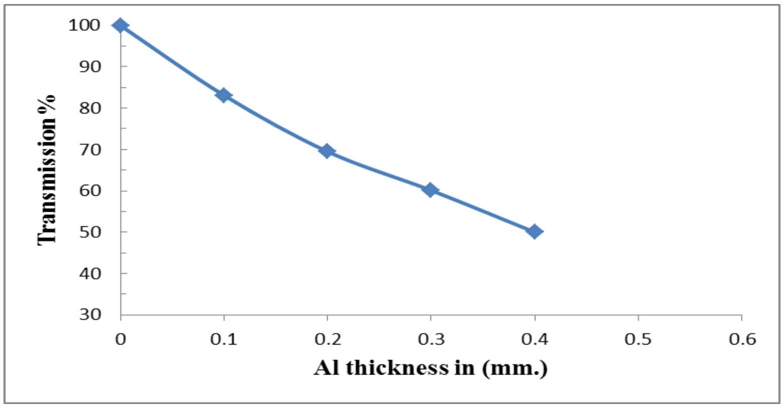

Figure (3.5): Variation of the thickness of Al filter with the exposure (mR) of mobile unit, for clinically most relevant 28 KV with 100 mAs and Mo/Rh target filter combination

Table (3.9): Variation of the thickness of Al filter with the exposure (mR) of mobile unit, for clinically most relevant 28 KV with 100 mAs and **Mo/Mo** target filter combination

Al Thickness in mm.	0.0	0.1	0.2	0.3	0.4
Exposure (mR)	1416.0	1133.0	921.5	761.2	635.8
Transmission %	100	80.0	65.0	54.0	45.0

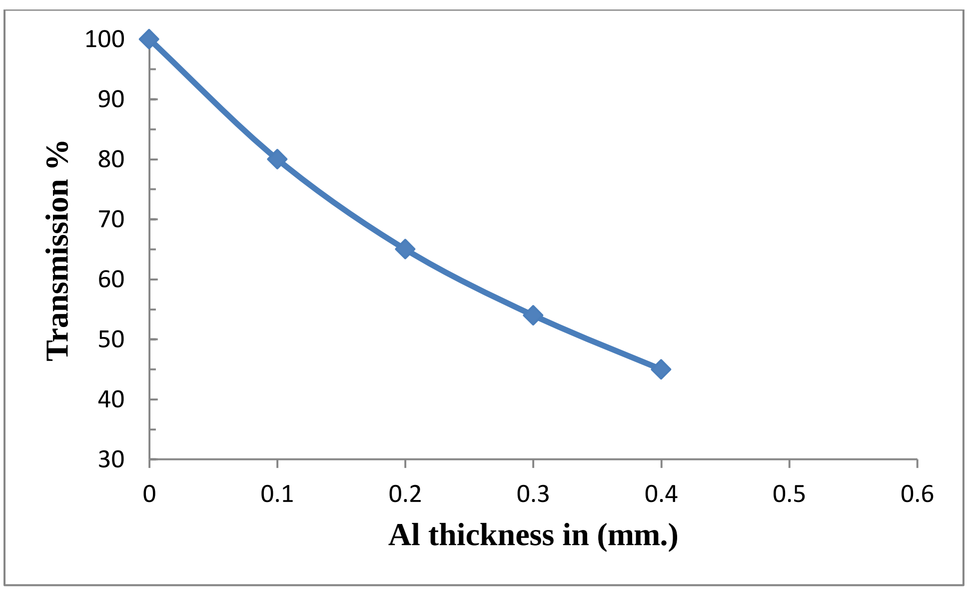

Figure (3.6): Variation of the thickness of Al filter with the exposure (mR) of mobile unit, for clinically most relevant 28 KV with 100 mAs and Mo/Mo target filter combination.

For the selected mobile unit, HVL was measured for the three target filter combinations and shown in table (3.7). The value of the HVL for W/Rh in this study was in the order of 0.488 and 0.4 mm Al for Mo/ Rh and 0.278 for Mo/Mo selected kilovolt 28 kV as shown in tables (3.7 –3. 9) and figures (3.4-3.6).

Conclusion

The quality control assessment was performed on the mammography machine selected. The assessment done included kV accuracy and reproducibility and Half Value Layer measurement and the results obtained confirmed that the machine is working correctly and were within acceptable performance criteria. The results of the physical parameters indicated a deviation of tube potential (kV) for the examined tube from the nominal values with the standard deviation (±5%), except a few values exceeds this levels, indicated that some adjustments showed be done. The Have Value Layer (HVL) at the nominal tube potential (28kV) was in agreement with the published values.

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الملخص باللغة العربية

"تقييم مراقبة الجوده وضمان الجوده فى وحدة تصوير الثدى بالاشعة"

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الهدف من هذه الدراسة إجراء تقييم شامل لوحدة مختارة من التصوير الاشعاعي للثدي. المواد المستخدمة آلة التصوير الاشعاعي للثدي فيليبس، الكترومتر متعدد الاغراض ، ومجموعة المرشحات W / Rh، Mo / Rh وMo / Mo وطبقات الألومنيوم. تم إجراء تقييم مراقبة الجودة على الجهاز المحدد. وقد أُجري التقييم بما في ذلك دقة kV وقابلية التكرار وقياس طبقة نصف القيمة. وأكدت النتائج التي تم الحصول عليها أن الجهاز يعمل بشكل صحيح وكان ضمن معايير الأداء المقبولة. وأشارت نتائج العوامل الفيزيائية إلى انحراف في إمكانية الأنبوب الذي تم فحصه عن القيم الاسمية مع الانحراف المعياري (± ٥٪)، باستثناء القيم القليلة التي تتجاوز هذه المستويات، والاستنتاج هو أنه يجب القيام ببعض التعديلات وأن طبقة نصف القيمة (HVL) للأنبوب (٢٨ كيلو فولت) متفقة مع القيم المنشورة.