Suggested Revision of NEMA Standards

Ralph Adams

Loma Linda University Medical Center, Loma Linda, California

The purpose of the NEMA Standards is to "eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting the proper product for its particular need" (NEMA Bylaw Art. V, Sec. 1). The sections on count-rate performance, however, have caused considerable misunderstanding of NEMA specifications by salespersons and users, many of whom fail to distinguish between input and observed count rates and between intrinsic and system (extrinsic) performance. The "maximum count rate" is shown to be an unreliable index of camera performance at useful count rates, and is misconstrued by some users to mean the maximum clinically useful count rate. The sections on count-rate performance can be made more meaningful to users by substituting "observed count rate" for "input count rate," by deleting the section on "maximum count rate," and by adding a section on system count-rate performance.

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The NEMA standards publication of Performance Measurements on Scintillation Cameras is intended to provide a uniform criterion for measurement and reporting (*1*). It is specifically "designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need." (NEMA Bylaw Art. V, Sec. 1) Clearly the need of the purchaser is to estimate camera performance in his own clinical tests. Of the several camera performance parameters tested, the count rate usually exhibits the most divergence numerically between intrinsic and system (extrinsic) performance. The author has observed considerable misunderstanding of NEMA specifications by salespersons, purchasers, and users who fail to distinguish between input and observed count rate and between intrinsic and system performance. The purpose of this article is to suggest revision in the NEMA Standards to reduce misunderstanding by users who are not primarily physicists or engineers, and to make the Standards more nearly relevant to the clinical environment.

NU 12.34 intrinsic count-rate performance. Five parameters are now measured and reported:

1. Input count rate for a 20% count loss.
2. Maximum count rate.
3. Typical incident compared with observed count-rate curve (class standard).
4. Intrinsic spatial resolution at 75,000 cps (observed).
5. Intrinsic flood-field uniformity at 75,000 cps (observed).

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For reprints contact: Ralph Adams, Nuclear Radiology, Loma Linda University Med. Ctr., Loma Linda, CA 92354.

Input count rate for a 20% count loss. No definition of "input count rate" appears under NEMA General Definitions (Part 1). A suggested definition:

The input count rate is the counts per unit time resulting from gamma events incident on the detector as determined from the camera's scaler or count-rate indicator and corrected for dead-time loss.

Unlike the observed count rate (R_{obs}), which can be read directly from the scaler, the input count rate (R) must be calculated indirectly:

$$R = R_{obs}e^{R\tau}$$

where τ is the dead time as measured by NEMA protocol NU 1-2.34 B. The unknown R in the exponent prevents direct evaluation of this expression, and it is calculated by sequential approximation, a tedious procedure unless a computer or programmable calculator is available. The results of such calculations are not commonly included in manufacturers' specifications. The author has observed that the "input count rate for 20% count loss" is almost invariably confused by salespersons with the observed count rate. Unfortunately, the distinction between intrinsic and system (extrinsic) performance is rarely made. A NEMA specification of $R_{-20\%}$ of 100,000 cps would nearly always be unintentionally misconstrued to mean that the camera could be operated under clinical conditions of scatter at 100,000 cps, as read right off the camera's scaler, with loss of only 20% of the data.

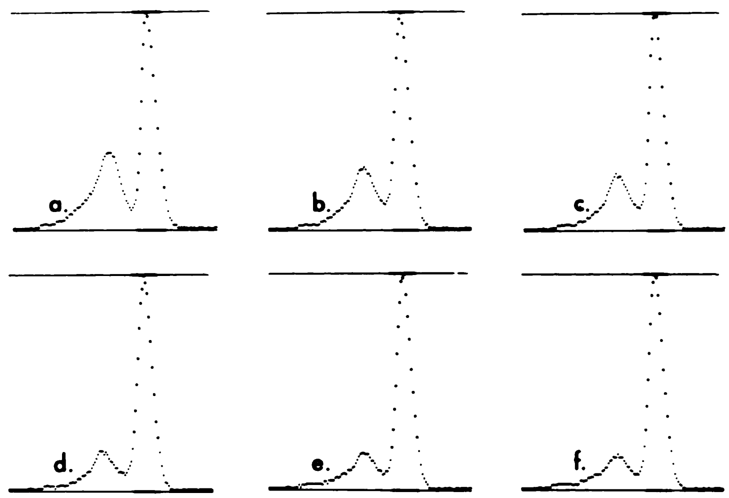

FIG. 1. Tc-99m spectra observed with multichannel analyzer of Ohio-Nuclear 120 camera. (a) Open source on floor. (b) Open source on plaster wall. (c) Open source 10 cm from plaster wall. (d) Open source on light foam pad 22 cm above deck and 35 cm from plaster wall. (e) Open source on light foam pad, 22 cm above wood tray table in open doorway. (f) Open source suspended on tape in open doorway. Significant scatter is evident at all positions.

Let us analyze realistically the performance of this typical camera:

NEMA specification: $R_{-20\%}$ 100,000 cps

The observed count rate incurring 20% data loss is 80,000 cps, not 100,000 cps. The corresponding intrinsic deadtime is obtained from:

$$\tau = \frac{0.2231}{R_{-20\%}} = 2.23\ \mu\text{sec [See NEMA NU 1-2.34 B (}2\text{)]}$$

The system paralyzing deadtime of the same camera (including the effects of collimator and scatter) would be typically about 4 μsec. The observed or system count rate incurring 20% data loss ($R_{obs\text{-}20\%}$) would be calculated from:

$$R_{obs\text{-}20\%} = \frac{0.8}{\tau} \ln \frac{10}{8} = \frac{0.1785}{4\times 10^{-6}} = 45{,}000 \text{ cps}$$

A misunderstanding of 100,000 cps for 45,000 cps is cause for some concern.

The selection of an optimum trade-off between statistical quality and radiation to the patient must be made by the operator. When count rates incur 27% data loss, a 2% increase in administered activity is required to generate a 1% increase in the observed count rate. Many clinicians would consider any further increase in administered activity to be a misuse of radiation. A knowledge by the operator of the system count-rate performance is essential for him to make an intelligent choice of camera equipment or to use an existing camera to best advantage in first-pass cardiac studies.

The foregoing sources of confusion can be avoided if the NEMA standard NU 1-2.34 B is revised to specify observed rather than input count rate and if a section is added on system count-rate performance. This section would be similar to NU 1-2.34 except that the collimator would be in place and the sources measured in a scattering phantom (*2-5*).

The present NEMA protocol NU 1-2.34 B (*3*) specifies "suspending" the sources near the crystal axis at greater than 1 m distance. Unfortunately, such an unshielded source produces considerable scatter from the floor, walls, ceiling, etc., which varies significantly with location and building materials (Fig. 1). A clean, scatter-free spectrum is easily available from a small Tc-99m source in a lead pot and filtered with copper, as shown in NEMA Fig. 2-2 (Figs. 2, 3). Additional filtration beyond 5 mm copper has no further effect on the spectrum but offers convenient adjustment of the count rate. The deadtime as measured with this source configuration is not affected by the room environment and usually measures about 15% less than by the present NEMA protocol. Such a source configuration would also provide more consistent data for intrinsic energy resolution measurements, revising NU 1-2.31 B, which now requires an unspecified point source at 5 UFOV diameter.

Maximum count rate. When the scintillation camera is operated at excessive count rates near foldover, the maximum intrinsic observable count rate may be affected by a number of unpredictable phenomena and does not necessarily indicate the camera performance at lower input rates. A few camera models faithfully follow paralyzable performance up to foldover, and the maximum rate is consistent with $1/e\tau$, where τ is the dead time as measured by NEMA Standards NU 1-2.34B. Much more commonly, however, cameras achieve maximum count rates that differ considerably from the predicted value. Other physicists with whom the author has discussed this measurement agree that it is a quick and simple test but not a reliable index of camera performance. Furthermore, the author has observed that most users interpret "maximum count rate" to mean the maximum clinically useful count rate. Therefore, a case can be made for deleting the Maximum Count Rate from the NEMA Standards as both irrelevant and misleading.

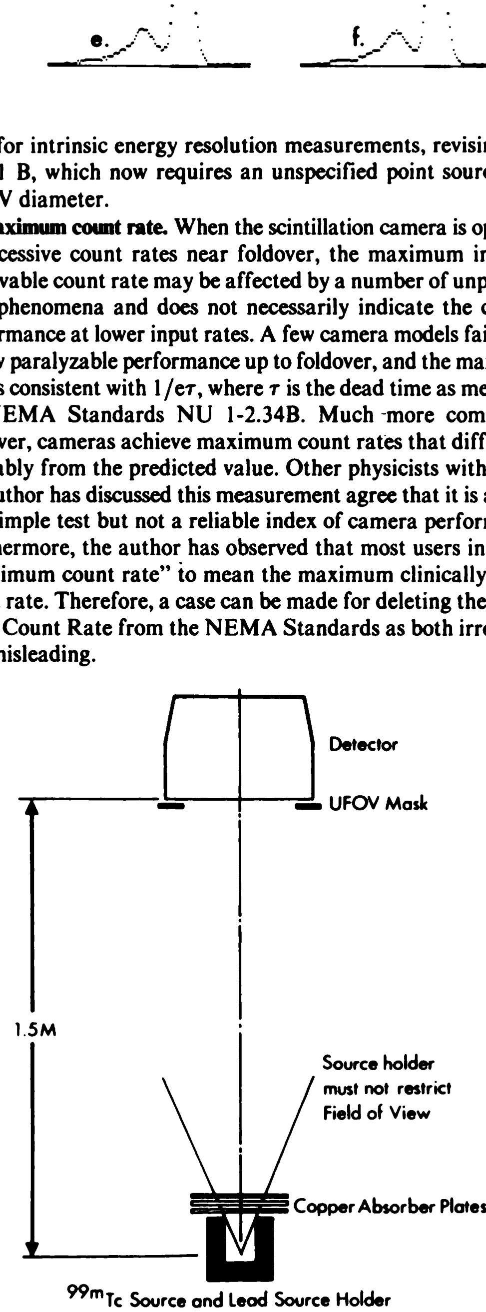

FIG. 2. Arrangement of source and lead holder with copper filters (From NEMA publication, Fig. 2-2).

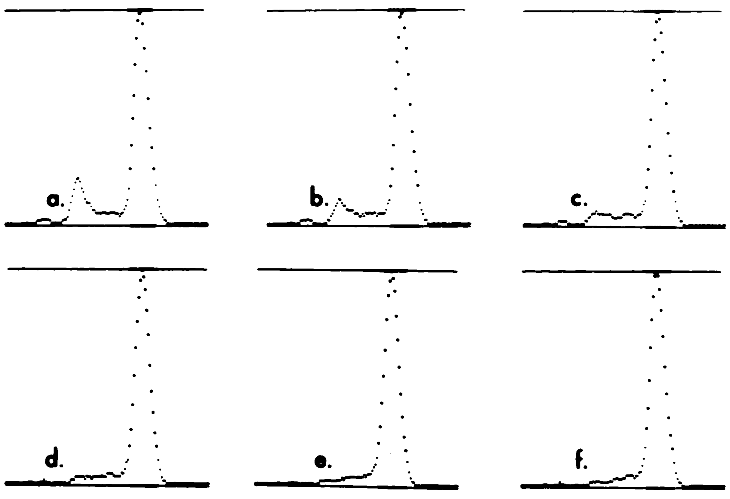

FIG. 3. Tc-99m spectra observed with multichannel analyzer of Ohio-Nuclear camera from source configuration shown in Fig. 2. (a) No filter. (b) 1 thickness. (c) 2 thicknesses. (d) 3 thicknesses. (e) 4 thicknesses. (f) 5 thicknesses. Each filter is 0.05 inch copper (1.28 mm); 5 mm or more of copper filter produces a clean scatter-free spectrum, which is not altered by additional thicknesses of copper.

Typical incident compared with observed count/rate curve. The NEMA Standards definition of "incident rate" is the "independently measured or calculated rate of gamma events entering the scintillation camera detector." The "incident rate" concerns events before interaction with the crystal; the "input count rate" comes afterward and is affected by detection efficiency. Clearly the intent of this section is to measure the "observed count rate" as a function of the "input count rate," as previously defined, and not as a function of the "incident rate."

CONCLUSIONS

Suggested revisions.

1. NU 1-1 Include a definition of "input count rate."
2. NU 1-2.34B (*2*) Replace "input" count rate with "observed" count rate. Revise the equation as previously shown.
3. NU 1-2.31B and NU 1-2.34B (*3*) Use shielded sources filtered with copper, rather than unshielded sources.
4. NU 1-2.34B (*4*) Report the "observed" count rate for 20% loss, rather than the "input" count rate.
5. NU 1-2.34C. Delete the section on Maximum Count Rate.
6. Add a section on system count-rate performance, analogous to NU 1- 2.34B but with collimator in place and using sources in a scattering phantom.
7. NU 1-2.34D. Change "incident" to "input" in title and text.

REFERENCES

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