NISTIR 6092

Analysis of Proposals for Compliance and Enforcement Testing Under the New Part 431; Title 10, Code of Federal Regulations

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January 1998

U.S. DEPARTMENT OF COMMERCE
William M. Daley, Secretary
TECHNOLOGY ADMINISTRATION
Gary Bachula, Acting Under Secretary for Technology
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Raymond G. Kammer, Director

Executive Summary

This report was prepared at the request of the Office of Codes and Standards of the U.S. Department of Energy (DOE). It analyzes two proposals for establishing compliance with the average efficiency levels prescribed by section 342(b)(1) of the Energy Policy and Conservation Act of 1975, as amended (EPCA): The Department of Energy's Proposed Rule for Electric Motors, at 10 *Code of Federal Regulations* Part 431, sections 431.24 and 431.127, published in the *Federal Register*, November 27, 1996; and the April 18, 1997, "Proposal for the Method of Determining Compliance and Enforcement for Electric Motors under the Efficiency Labeling Program of DOE, 10 CFR Part 431," submitted by the Motor and Generator Section of the National Electrical Manufacturers Association (NEMA).

Under section 431.24 of the DOE's Proposed Rule for compliance with EPCA, the manufacturer would determine the average full-load efficiency of each basic model of electric motor either by testing or by application of an Alternative Efficiency Determination Method (AEDM). Under section 431.127 of DOE's Proposed Rule for enforcement of EPCA, the DOE would ascertain, through an enforcement sampling plan, the accuracy of information disclosed in the labeling and the marking of the electric motor to indicate its energy efficiency, and whether the motor complies with EPCA standards.

During the public comment period, NEMA raised issues concerning the DOE's proposed sampling plans for compliance and enforcement. According to NEMA, the compliance criteria in the Proposed Rule are inconsistent with NEMA Standards Publication MG1-1993, "Motors and Generators," and place a high burden on manufacturers. Moreover, NEMA contends that the Proposed Rule would require that electric motors covered by EPCA be engineered to exceed the average full-load efficiency levels prescribed by EPCA.

This report evaluates the operating characteristics of the DOE's and NEMA's proposals within the context of EPCA: Compliance with the energy efficiency levels for motors prescribed by section 342(b)(1) of EPCA appears to be satisfied when the true mean full-load efficiency of the population of each basic model of electric motor equals or exceeds the applicable nominal full-load efficiency.

Contents

Analysis of Proposals for Compliance and Enforcement Testing Under the New Part 431; Title 10, Code of Federal Regulations

Introduction

This report was prepared at the request of the Office of Codes and Standards of the U.S. Department of Energy (DOE). It analyzes various criteria and sampling plans proposed for establishing compliance with the nominal full-load efficiency levels prescribed by the Energy Policy and Conservation Act (EPCA), 42 U.S.C. 6313(b)(1) [1].[1] The report discusses, in detail, two proposals: (1) the Notice of Proposed Rulemaking (NOPR) for electric motors published in the *Federal Register* on November 27. 1996 [2]; and (2) a proposal prepared by the National Electrical Manufacturers Association (NEMA), Motor and Generator Section [3], which was submitted in response to the call for public comment given in the NOPR.

This report evaluates the operating characteristics of these proposals in the context of the EPCA requirements. Section 342(b)(1) of EPCA requires that each electric motor manufactured (alone or as a component of another piece of equipment) have a nominal full-load efficiency of not less than the prescribed level. This report assumes that the energy efficiency requirement of the legislation is satisfied if the mean full-load efficiency of the entire population of motors of each basic model covered by the legislation equals or exceeds the applicable nominal efficiency.

Under the NOPR, efficiency testing is required in three contexts:

1. compliance testing,
2. substantiation of Alternative Efficiency Determination Methods (AEDM), and
3. enforcement testing.

The statement submitted by the NEMA, Motor an Generator Section [3], raises significant issues regarding the NOPR:

1. The electric motor manufacturers maintain that the NOPR compliance criteria (1) are inconsistent with NEMA Standard MG 1-1993 [4], (2) place a high burden on manufacturers in that the risk of false determination of noncompliance can be as high as 50 percent for motors in compliance with the NEMA labeling guidelines, and (3) in effect, ensure compliance with the EPCA energy efficiency levels for electric motors by requiring that covered equipment be engineered to *exceed* the average full-load efficiency levels established by EPCA.
2. The electric motor manufactureres maintain that the methods proposed for compliance and enforcement testing by the NOPR are not harmonized.

This report seeks to clarify such issues.

Methods

This report compares the NOPR and NEMA proposals through model calculations of their operating characteristics, i.e., an estimated probability of demonstrating compliance for a population of motors having a specific mean efficiency and standard deviation. Modeling the operating characteristics of the NOPR and NEMA proposals requires detailed information about the distribution of motor efficiencies. Ideally, such model calculations would be based on energy efficiency data gathered from extensive testing; in the absence of such data, however, this report must infer information from the energy efficiency labeling guidelines established by NEMA Standard MG 1-1993. Such guidelines were developed by consensus among motor manufacturers and are voluntarily followed by many motor manufacturers. To quote from NEMA MG1-1993, paragraph 12.58.2, Efficiency of Polyphase Squirrel-Cage Medium Motors with Continuous Rating [4]:

> Variations in materials, manufacturing processes, and tests result in motor-to-motor efficiency variations for a given motor design:

[1] Numbers in square brackets refer to articles listed in the References.

the full-load efficiency for a large population of motor of a single design is not a unique efficiency but rather a band of efficiency. Therefore, Table 12-8 [of NEMA MG1-1993] has been established to indicate a logical series of nominal motor efficiencies and the minimum associated with each nominal. The nominal efficiency represents a value which should be used to compute the energy consumption of a motor or a group of motors.

Although the MG 1 guidelines were developed primarily to provide uniformity in motor efficiency labeling, they are used for purposes of quality control by many manufacturers and may, therefore, provide a reasonable basis to estimate efficiency performance.

The analysis contained in this report is of value primarily as a qualitative comparison of the operating characteristics of the NOPR and NEMA proposals, and, secondarily, as a quantitative estimate of the risk, or statistical confidence, associated with motor testing under such proposals. The quantitative estimation of risk can be tenuous, since the results of these calculations depend on the model assumptions. Consequently, high significance should not be placed on these estimates of risk.

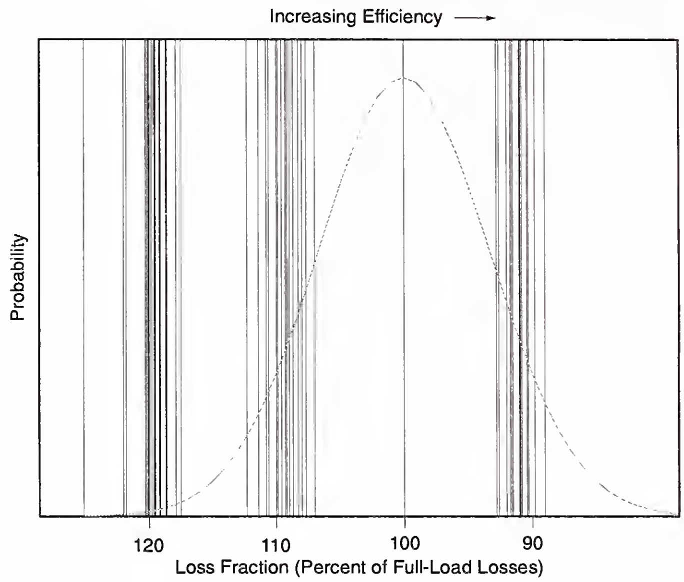


Figure 1: Graphical representation of MG 1 efficiencies. EPCA nominal efficiencies correspond to the vertical line at 100 percent of full-load losses. The vertical lines grouped around 90 percent and 110 percent correspond respectively to the next higher and lower MG 1 Nominal Efficiencies. The MG 1 Minimum Efficiencies correspond to the vertical lines grouped around 120 percent. A normal distribution with mean of 100 percent and 3σ equal to 20 percent is also shown in the figure.

Industry practice

Guidelines for motor efficiency labeling are provided in paragraph 12.58.2 of NEMA Standard MG 1-1993. Table 12-8 of that section establishes a series of Nominal Efficiencies that are used for purposes of labeling and a Minimum Efficiency associated with each Nominal value. Under the MG 1 guidelines, two conditions must be satisfied for a motor to be labeled at a given Nominal Efficiency:

1. "...the Nominal Efficiency...shall be not greater than the average efficiency of a large population of motors of the same design."
2. "The full-load efficiency...shall be not less than the minimum value...associated with the nominal value..."

The MG 1 guidelines are shown graphically in Fig. 1. In the figure, the Nominal Efficiencies are indicated by their full-load losses, where 100 percent of the full-load losses is equal to the difference, 100 − Nominal Efficiency. For this discussion, we define the loss fraction by the ratio,

$$\text{Loss Fraction} = \frac{100 - \text{True Full-load Efficiency}}{100 - \text{Nominal Efficiency}} \times 100,$$

which is given in percent. Values of loss fraction corresponding to the EPCA nominal efficiencies are plotted in Fig. 1, i.e.,

$$\text{Loss Fraction}_i = \frac{100 - \text{Nominal Efficiency}_j}{100 - \text{Nominal Efficiency}_i} \times 100,$$

for $j = i+1, i, i-1$, and $i-2$. The index i is assigned to the Nominal Efficiencies presented in Table 12-8 of the MG 1 standard: It is a positive integer that increases with the efficiency. We have chosen this graphical representation to illustrate the operating characteristics of the NOPR and NEMA proposals over the full range of the EPCA nominal efficiencies, and to give an indication of the precision that underlies the MG 1 standard. The MG 1 guidelines establish efficiency levels that differ by increments corresponding to 110 percent of the full-load losses. The vertical lines grouped around 90 percent and 110 percent in the figure correspond respectively to the next higher and lower Nominal Efficiencies; and the MG 1 Minimum Efficiencies correspond to the vertical lines grouped around 120 percent. The values of loss fraction fall over a range of values due to rounding in the least significant digit in the efficiencies given in Table 12-8.

Model Assumptions

Following methods used by the NEMA, Motor and Generator Section, we assume that motor efficiencies are normally distributed [5]. The efficiency distributions are thus characterized by two parameters: the true mean efficiency and the standard deviation, σ. Expectation values for the minimum average efficiencies may be clearly established from the MG 1 guidelines; however, the standard deviation is not as clearly defined: Since, for normally distributed efficiencies, there is a finite probability that a motor may test at any arbitrarily low value, there is no minimum efficiency, *per se*.

We make the following assumptions for these calculations:

1. The efficiencies of units of a basic model are normally distributed about the true mean efficiency,

2. The true mean efficiency is equal to the Nominal Efficiency,

3. The standard deviation of motor efficiencies is given by the following formula:

$$\sigma = \frac{\text{Nominal Eff.} - \text{Minimum Eff.}}{3}, \text{ and} \quad (1)$$

4. The motors tested are selected at random from a population of motors that is representative of the motors sold and in use.

We infer by these assumptions that a manufacturer may reject some motors due to low efficiency performance, and that the probability of rejecting a motor on this basis is on the order of one per thousand. We believe that these conditions approximate a worst-case scenario for a manufacturer following the MG 1 guidelines. The true distribution of efficiencies would depend on engineering and business factors and would likely differ between manufacturers and basic models.

There is an additional complication associated with these calculations due to the nature of testing under the NOPR: Under the NOPR, the number of motors to be tested is not fixed from the outset. In the case of compliance testing, a manufacturer could test as few as two motors, but may test any arbitrarily large number of motors. The NOPR Sampling Plan for Enforcement Testing specifies an initial sample of five but allows testing of as many as twenty motors. The scenario in which the sample size is not fixed from the outset is difficult to characterize statistically, and we have chosen to treat compliance and enforcement testing under the NOPR under the approximation that the sample size is fixed from the outset. The consequence of this approximation is that these calculations provide a lower bound on the probability of being found in compliance. For example, a fixed sample size of five includes some cases for which a manufacturer would have been shown to be in compliance after testing two motors and could have stopped testing at that point, but fails after testing five motors due to the final three test results. The computed probability may thus underestimate the probability of being found in compliance.

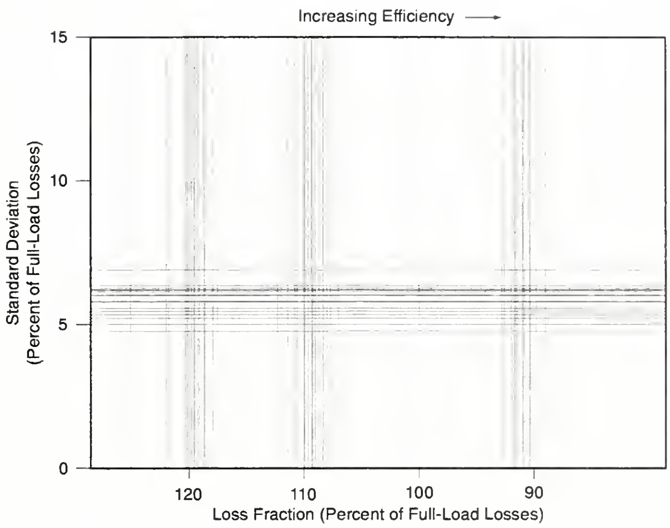


Figure 2: Model parameter space. The mean and standard deviation are given as a percentage of the full-load losses. The horizontal lines correspond to the standard deviations such that 3σ is equal to the difference (Nominal Efficiency – Minimum Efficiency).

These model assumptions are presented graphically in Fig. 2. In the figure, standard deviations corresponding to the EPCA nominal efficiencies and calculated by Eq. 1 are indicated by horizontal lines. The target performance established by the MG 1 guidelines corresponds to the vertical line at 100 percent. We assume that product quality control is maintained such that the standard deviations are at or below the band of horizontal lines.

Compliance testing

Operating characteristics of the NOPR compliance criteria

The criteria for establishing compliance with the efficiency levels mandated by EPCA are prescribed in §431.24(b)(1)(iii) of the NOPR [2], which may be found in Appendix A of this report.

§431.24(b)(1)(iii) makes reference to K coefficients that are tabulated in Appendix B of Subpart B of the NOPR. The K coefficients are based on NEMA Standard MG 1-1993 [4] and are calculated by the following formula:

$$K = \frac{\text{Minimum Efficiency}}{\text{Nominal Efficiency}}.$$

The NOPR assigns K coefficients to all MG 1 Nominal Efficiencies between 75.5 and 99.0 percent.

To emphasize the salient features of the proposal, we paraphrase the NOPR criteria for compliance testing as follows:

Compliance with EPCA efficiencies is demonstrated provided:

(A) The average full-load efficiency of the sample is not less than the EPCA nominal efficiency, and

(B) The lower 90 percent confidence limit of the average full-load efficiency of the entire population divided by the applicable K coefficient is not less than the EPCA nominal efficiency.

The operating characteristics of the NOPR criteria for compliance testing are shown in Figs. 3a and 3b, which present data for sample sizes of two and five, respectively. The contours plotted are for the specific case where the EPCA nominal efficiency is 80 percent, i.e., K has been set equal to 0.963.

Operating characteristics of the NEMA compliance criteria

The full text of the NEMA proposal may be found in Appendix D of this report. To emphasize the salient features of the proposal, we paraphrase the NEMA criteria for compliance testing as follows:

Compliance with EPCA efficiencies is demonstrated provided:

(A) The average full-load efficiency of a sample of motors is not less than the value given by the following expression,

$$\frac{100}{1 + 1.05\left(\frac{100}{NE} - 1\right)},$$

and

(B) No individual motor in the sample shall have a full-load efficiency of less than the value given by the following expression,

$$\frac{100}{1 + 1.15\left(\frac{100}{NE} - 1\right)},$$

where NE is the Nominal Efficiency.

Operating characteristics of the NEMA criteria for compliance testing are shown in Fig. 4. The model calculations shown there are for samples of two and five.

Enforcement testing

Operating characteristics of the NOPR sampling plan

The full text of the NOPR proposal for enforcement testing may be found in Appendix C of this report. The operating characteristics of the NOPR Sampling Plan for Enforcement Testing for sample sizes of five and twenty are shown in Figs. 5a and 5b, respectively.

Operating characteristics of the NEMA enforcement criteria

The full text of the NEMA proposal for enforcement testing may be found in Appendix D of this report. To emphasize the salient features of this proposal, we paraphrase the NEMA criteria for enforcement testing as follows:

Compliance with EPCA efficiencies is demonstrated provided:

(A) The average full-load efficiency of a sample of motors is not less than the value given by the following expression,

$$\frac{100}{1 + 1.15\left(\frac{100}{NE} - 1\right)},$$

and

(B) No individual motor in the sample shall have a full-load efficiency of less than the value given by the following expression,

$$\frac{100}{1 + 1.20\left(\frac{100}{NE} - 1\right)},$$

where NE is the Nominal Efficiency.

The operating characteristic of the NEMA criteria for enforcement testing for a sample sizes of five and twenty are shown in Figs. 6a and 6b, respectively.

Concluding remarks

Burden of testing

The data shown here indicate that the NOPR criteria for compliance testing are indeed inconsistent with NEMA guidelines. Under the NOPR compliance criteria, manufacturers are, in effect, required to have true mean efficiencies that are significantly above the Nominal values. While the NOPR criteria may allow minimal testing in principle, the premium paid for such reduced testing, in terms of average efficiency performance above the Nominal value, is severe. Figure 3a suggests that the true mean efficiency must lie above the next higher Nominal value for a manufacturer to have a 90 percent probability of being found in compliance for a sample size of two.

We note also that the K coefficients given in Appendix B of Subpart B of the NOPR [2] include *all* MG 1 Nominal Efficiencies equal to or greater than the lowest value allowed by EPCA, and that the NOPR criteria thus establish a protocol for assigning Nominal Efficiencies that applies to all covered motors. It is particularly important in this case that the labeling protocol established by the final rule be consistent with the MG 1 guidelines.

Risk for over-representation of efficiency

The performance of the NEMA proposal in deterring over-represented values of efficiency should be considered. The model calculations presented in Fig. 4b suggest that the probability of being found in compliance by testing five motors under the NEMA protocol is on the order of 90 percent to 95 percent and that the probability of compliance decreases substantially for true mean efficiencies that are below EPCA nominal efficiencies. However, a full evaluation of the deterrence against over-represented efficiencies may require cost-benefit analyses, which is beyond the scope of this report.

Our conclusions regarding the performance of the NEMA compliance criteria in deterring systematic over-representation of efficiencies would be much different, had we assumed product quality control supporting a smaller standard deviation:

$$6\sigma \approx \text{Nominal Efficiency} - \text{Minimum Efficiency}$$

for example. The NEMA criteria could be fine-tuned to more strongly favor higher efficiencies: the 1.05 coefficient could be changed to 1.03, for example. However, to our knowledge, the DOE has no data to suggest that the NEMA proposal provides a realistic advantage for systematic over-representation of efficiencies.

Table 1: t coefficients for specified confidence. Adapted from ASTM Standard E 122-89

t value	Confidence	Probability of exceeding E
3	99.7	0.003
2.56	99.0	0.010
2	95.5	0.045
1.96	95.0	0.050
1.64	90.0	0.100

Sample size under the NEMA compliance criteria

We note, as may be readily verified by examination of the data shown in Fig. 4, that the performance of the NEMA proposal for compliance testing depends on the sample size. We believe that compliance testing for the purpose of substantiation of an AEDM provides the most compelling argument for establishing a minimum sample size. The criteria for substantiation of an AEDM are provided in §431.24(b)(3) of the NOPR, which is reproduced in Appendix B of this report. Substantiation of an AEDM is based on compliance testing; and the results of such testing may be highly leveraged, in that testing as few as five basic models may provide the basis for labeling a substantial portion of a manufacturer's line of covered motors. The DOE thus has an interest in establishing the validity of such test results. The following discussion estimates the number of tests needed to support the required 10 percent precision recommended by the NOPR.

The scenario in which testing is required to conform to a predetermined precision is addressed by ASTM Standard E122-89 [7]. This standard is based on use of the t statistic and establishes the sample size required to determine a two-sided confidence interval for an estimate of the mean. The sample size, n, is given by the following expression:

$$n = \left(\frac{t\sigma}{E}\right)^2, \tag{2}$$

where E is the required tolerance and t is the coefficient that corresponds to the desired statistical confidence (see Table 1). In this case, the desired tolerance, E, is 10% of the total loss, i.e.,

$$E = 0.10(100 - NE).$$

Assume that the difference between the NEMA Nominal and Minimum efficiencies corresponds to three standard deviations, and use the approximation,

$$\sigma \approx \frac{0.20(100 - NE)}{3},$$

for the standard deviation. Finally, since a high statistical confidence is desired, set the coefficient t equal to three. Substitution of these values into Eq. 2 gives the following expression for sample size:

$$n = \left[\frac{3 \times 0.20(100 - NE)}{3 \times 0.10(100 - NE)}\right]^2 .$$

From this we can conclude that no fewer than four motors should be tested.

Harmonization of compliance and enforcement testing

The NEMA proposal presents motor testing criteria for compliance and enforcement that are closely related. While it may be desirable to harmonize such compliance and enforcement testing, the NEMA criteria for enforcement testing may have unwanted characteristics.

1. The NEMA criteria for enforcement testing appear to make little distinction between performance at and significantly below the EPCA levels: the data presented in Fig. 6a suggest that the true mean efficiency could be near the next lower Nominal value without an appreciable change in the outcome of enforcement testing. Thus, it may be argued that the NEMA enforcement crtieria do not adequately support the EPCA goals.
2. Although interrelated, compliance and enforcement testing differ in significant ways. For example, the consequences that may follow failure to pass an enforcement test cannot be foreseen by the rule. Under the NEMA criteria, the efficiency performance of a single unit could cause a basic model to fail the entire test, without recourse. The NEMA criteria may thus not allow a manufacturer to test as needed to protect its interests.

Performance of the NOPR Sampling Plan for Enforcement Testing

One important characteristic for evaluating the performance of the Sampling Plan for Enforcement Testing is the likelihood that testing could support a false conclusion. As proposed, the Sampling Plan for Enforcement Testing establishes that testing be consistent with a statistical confidence of not less that 90 percent. This statistical confidence implies that the likelihood of falsely concluding that a product is not in compliance may be as high as 10 percent. This level of assurance may not adequately protect the manufacturer's interests. The NOPR Sampling Plan for Enforcement Testing could be readily modified to increase the assurance against a false conclusion.

This modification could be accomplished by a change in the wording of Step 5 of the NOPR Sampling Plan for Enforcement Testing. The text could be changed to read as follows:

> Compute the lower control limit (LCL_1) for the mean of the first sample using the applicable statutory full-load efficiency (SFE) as the desired mean as follows:
>
> $$LCL_1 = SFE - tSE(\bar{X}_1).$$
>
> Here t is the <u>1</u> percentile of a t-distribution for a sample size of n_1 and yields a <u>99</u> percent confidence level for a one-tailed t-test,

where the modified text has been underlined.

In principle, specifying a higher statistical confidence may require a higher level of testing. To estimate the level of testing required, we estimate the likelihood that a motor that is labeled in accordance with the MG 1 guidelines would fail during enforcement testing due to insufficient sample size. Step 7 of the NOPR Sampling Plan for Enforcement Testing sets a condition on the sample size. To demonstrate compliance, the initial sample size, n_1, must satisfy the following condition:

$$n_1 \geq \left[\frac{tS_1(120 - 0.2SFE)}{SFE(20 - 0.2SFE)}\right]^2, \tag{3}$$

where SFE is the applicable EPCA nominal efficiency and S_1 is the standard deviation of the sample. This equation may be rearranged to yield a condition on the value of t:

$$t \leq \left[\frac{\sqrt{n_1}SFE(20 - 0.2SFE)}{S_1(120 - 0.2SFE)}\right]. \tag{4}$$

Following the earlier discussion, one can assume that the difference between the NEMA Nominal and Minimum efficiencies corresponds to three standard deviations, and use the following approximation:

$$S_1 \approx \frac{\sigma}{\sqrt{n_1}} \approx \frac{0.20(100 - SFE)}{3\sqrt{n_1}}.$$

Upon substitution into Eq. 4, the following condition on t is obtained:

$$t < 3n_1 \frac{SFE(20 - 0.20SFE)}{0.20(100 - SFE)(120 - 0.2SFE)}.$$

For an initial sample of five, t must exceed ten for the sample to fail due to insufficient sample size for all EPCA nominal efficiencies. The probability that t

would exceed ten by chance is less than 1 in 1000, for a sample of five. We conclude that it is highly unlikely that a product that is labeled in accordance with the MG 1 guidelines would require testing beyond the initial sample of five, and argue that any risk of additional testing is more than offset by the increased value of the test in assuring that the manufacturer's interests are protected.

The operating characteristics of the *modified* Sampling Plan for Enforcement Testing are shown in Fig. 7. The figure presents data for initial samples of five and twenty.

Summary

In this section, we summarize the relative merits of each set of criteria.

Compliance testing

NOPR criteria

Advantages:

- high assurance that the average motor efficiency meets or exceeds EPCA levels with minimal testing
- the likelihood of a correct determination increases with sample size

Disadvantages:

- high burden on manufacturers, i.e., the risk of a false determination of noncompliance can be as high as 50 percent
- complexity
- statistical methods that describe these criteria are not readily available

NEMA criteria

Advantages:

- simplicity
- reduced burden on manufacturers

Disadvantages:

- higher risk, relative to the NOPR criteria, of overly optimistic estimates of efficiency
- statistical methods that describe these criteria are not readily available

Enforcement testing

NOPR

Advantages:

- robust, i.e., the t-test is not strongly influenced by the exact form of the underlying distribution and it is a widely accepted basis for a testing protocol
- the likelihood of a correct determination increases with sample size

Disadvantages:

- complexity

NEMA criteria

Advantages:

- simplicity

Disadvantages:

- these test criteria do not appear to differentiate between efficiencies at and significantly below the EPCA nominal values
- statistical methods are not readily available

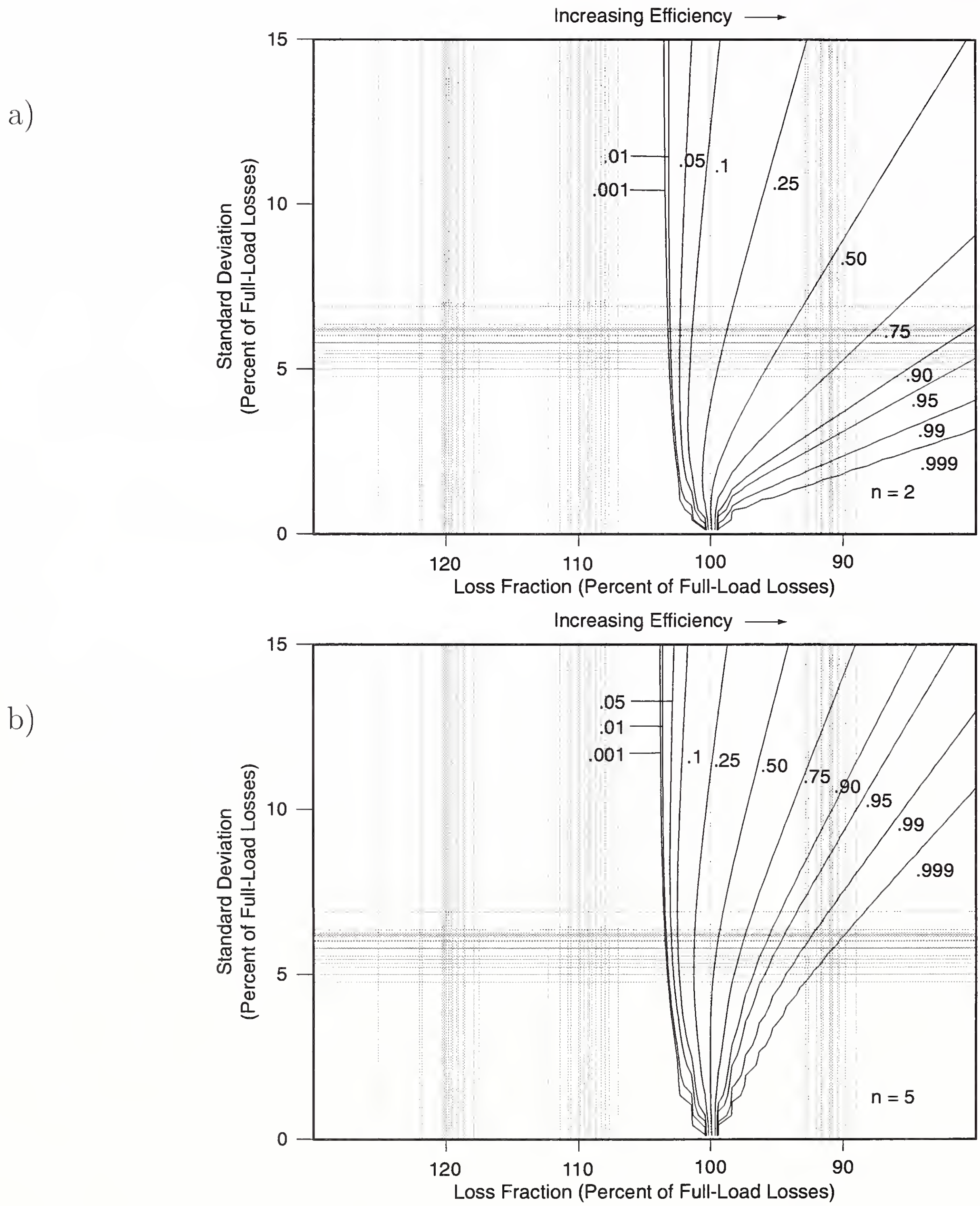
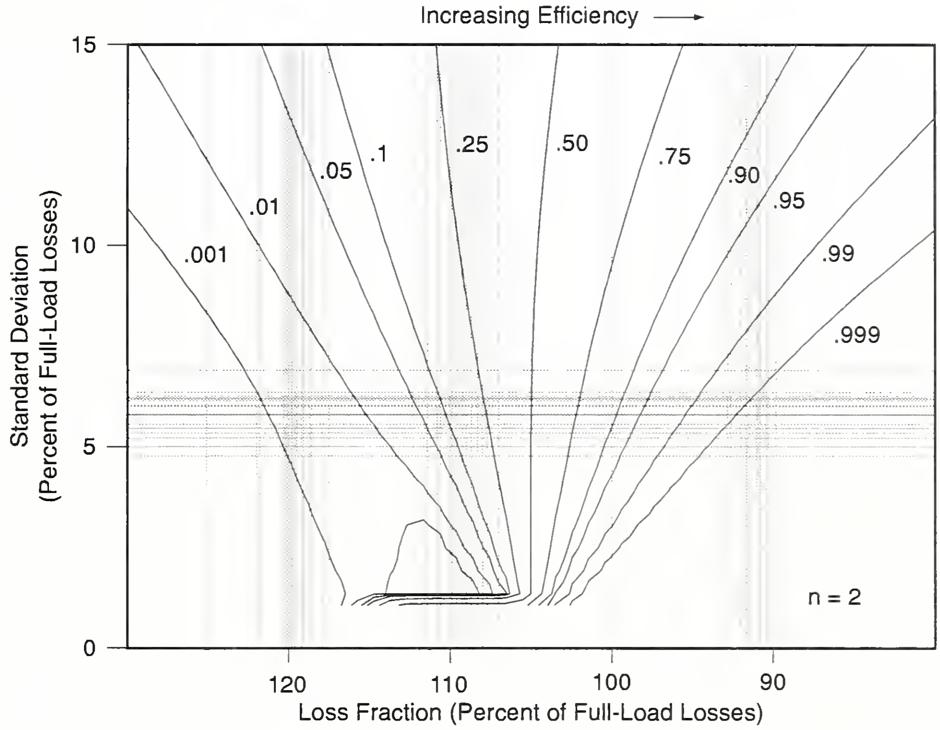


Figure 3: Operating characteristics of the NOPR compliance criteria. Model calculations for samples of two and five motors are shown in a) and b), respectively. The contours indicate the probability of demonstrating compliance, e.g., the .90 contour corresponds to a 90 percent likelihood of demonstrating compliance.

a)



b)

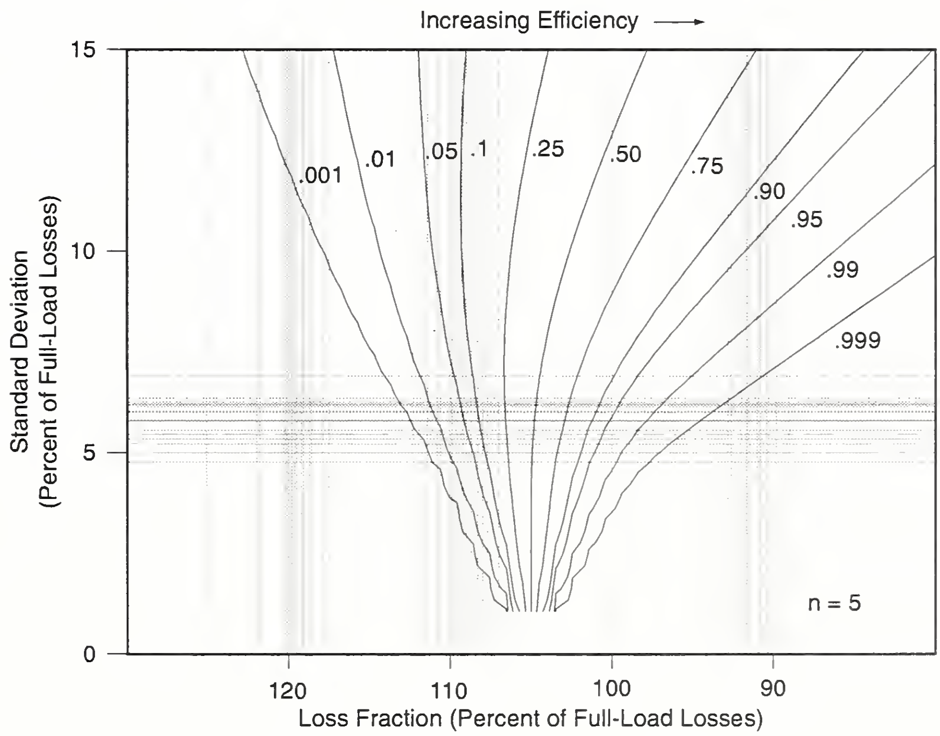


Figure 4: Operating characteristics of the NEMA criteria for compliance testing. Model calculations for samples of two and five are shown in a) and b), respectively. The contours indicate the probability of demonstrating compliance, e.g., the .90 contour corresponds to a 90 percent likelihood of demonstrating compliance.

a)

b)

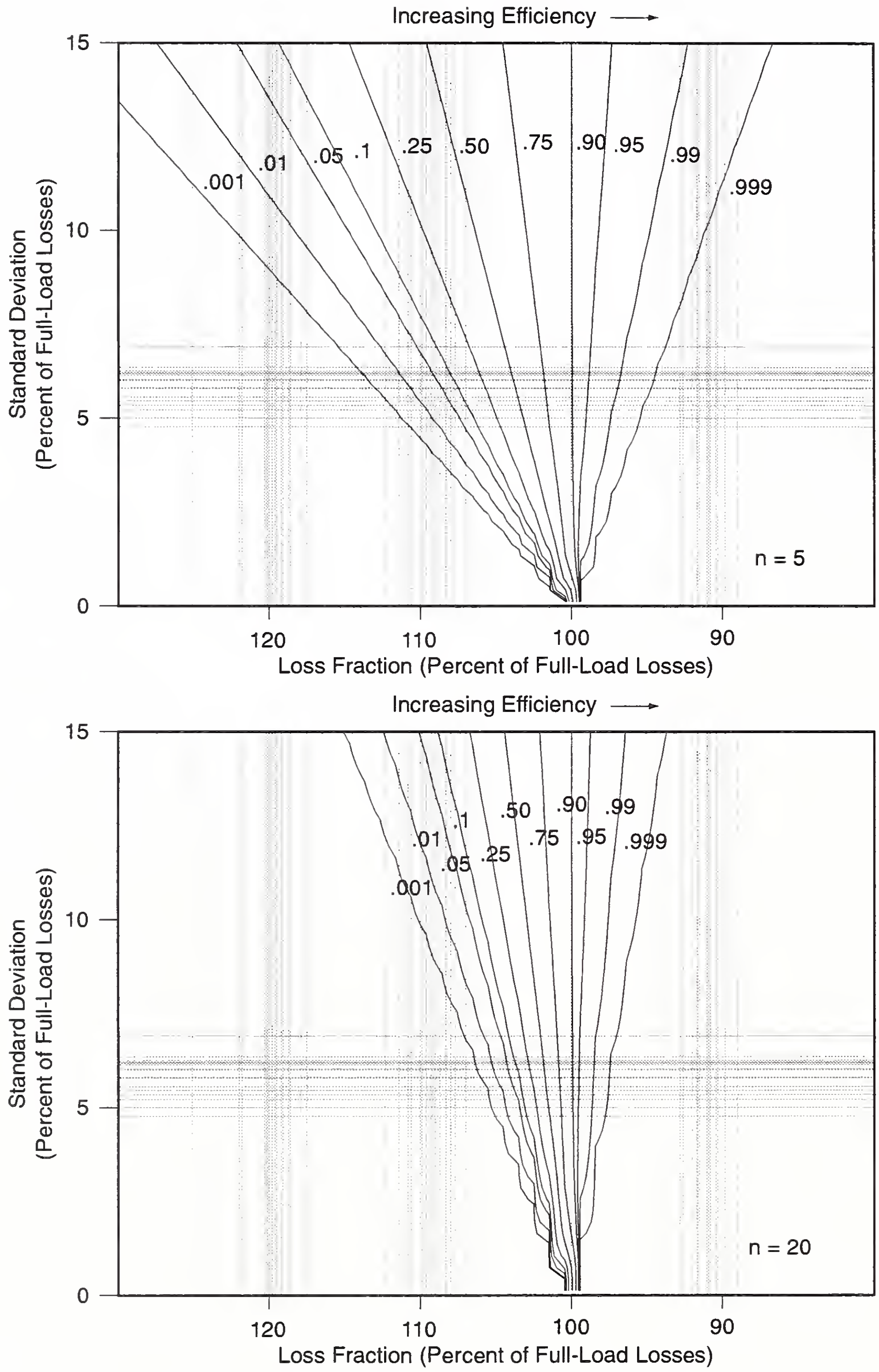


Figure 5: Operating characteristics of the NOPR proposal for enforcement testing. Model calculationds for samples of five and twenty are shown in a) and b), respectively.

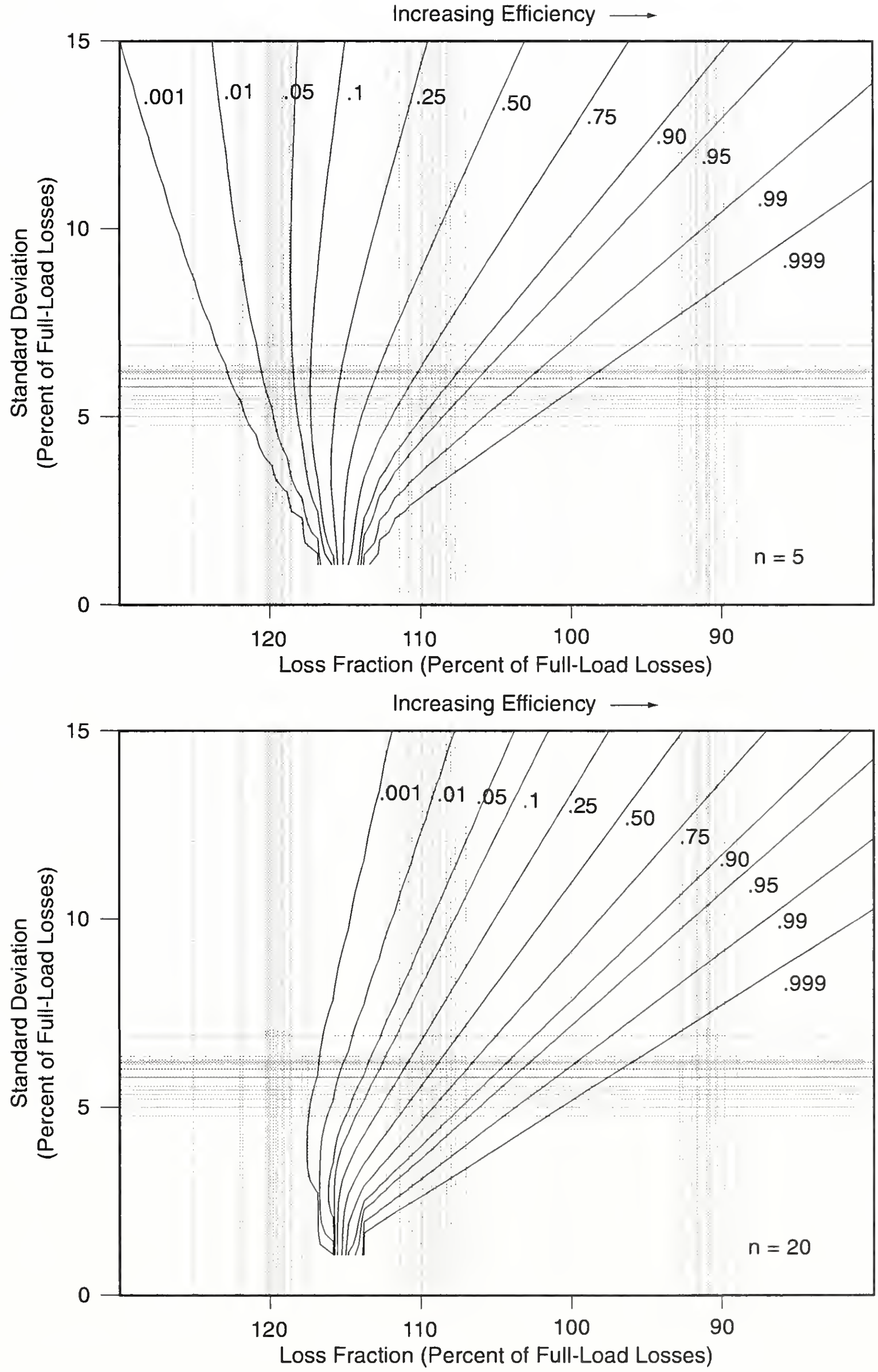
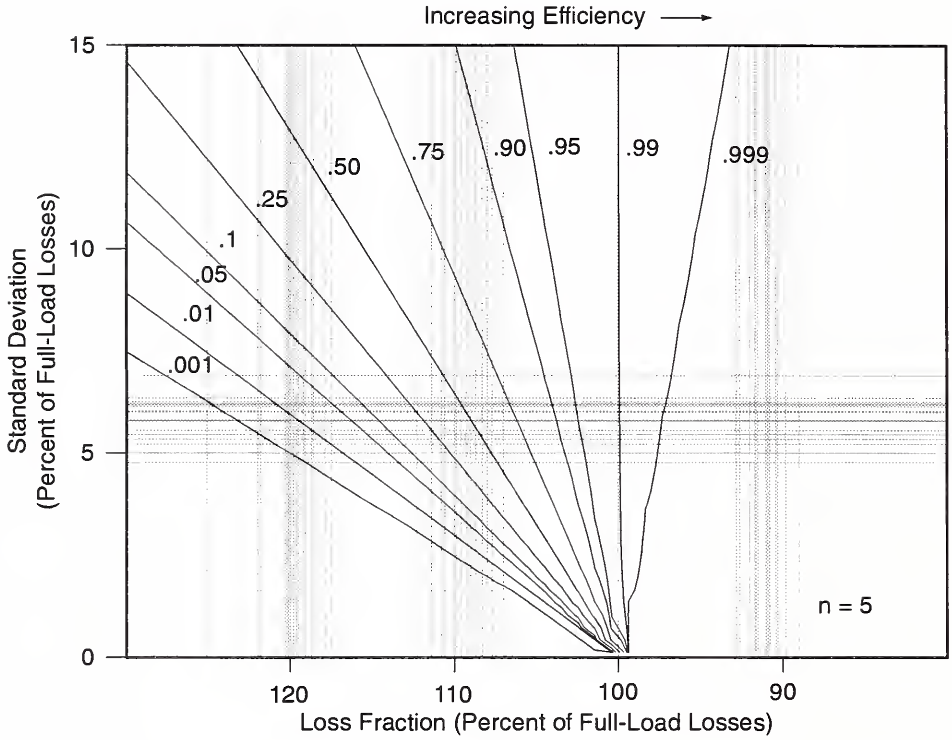


Figure 6: Operating characteristics of the NEMA criteria for enforcement testing. Model calculations for sample sizes of five and twenty are shown in a) and b), respectively. The probabilities of being found in compliance are indicated by the contours, e.g., the contour labeled .90 corresponds to a 90 percent probability of being shown in compliance.

a)



b)

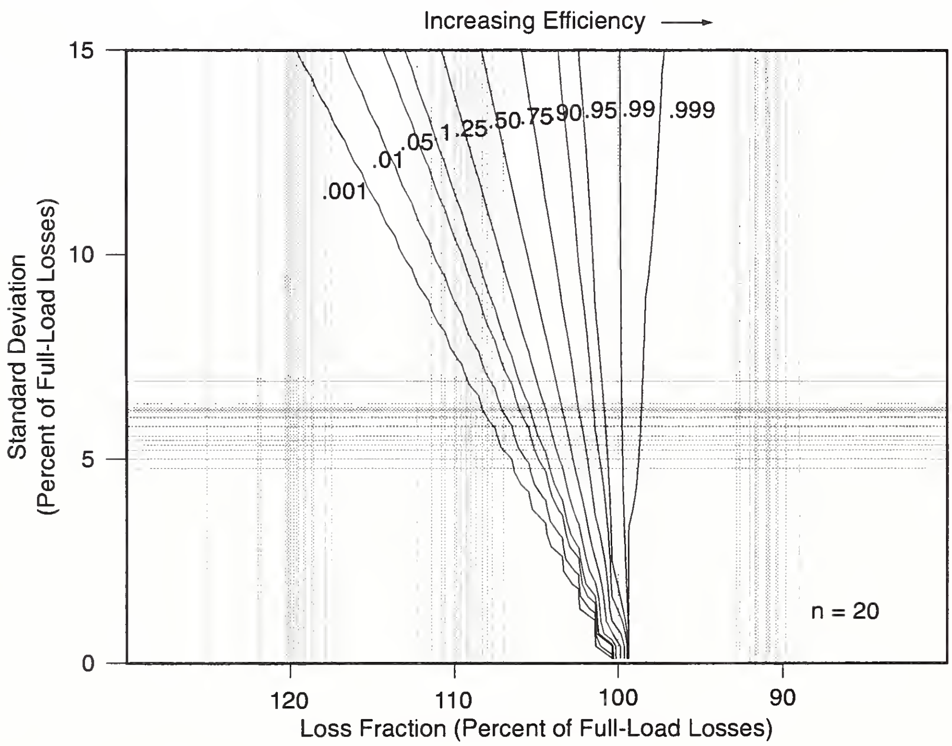


Figure 7: Operating characteristics of the NOPR proposal for enforcement testing at 99 percent confidence. Model calculations for sample sizes of five and twenty are shown in a) and b) respectively. The contours indicate the probability of being shown in compliance, i.e., the contour labeled .90 corresponds to a 90 percent probability of being found in compliance.

References

[1] Section 122(d), Energy Policy Act of 1992, Public Law 102-486, October 24, 1992.

[2] "10 CFR Part 431, Energy Conservation Program for Certain Commercial and Industrial Equipment: Test Procedures, Labeling, and Certification Requirements of Electric Motors; Proposed Rule," *Federal Register*, Vol. 61, No. 230, Wednesday, November 27, 1996, pp. 60439–60475.

[3] "Proposal for the Method of Determining Compliance and Enforcement for Electric Motors Under the Efficiency Labeling Program of DOE 10 CFR Part 431," NEMA Motor and Generator Section, Friday, April 18, 1997 (Docket No. EE-RM-96-400, NEMA, No. 23).

[4] "Motors and Generators," NEMA Standards Publication No. MG 1-1993, with Revisions, National Electrical Manufacturers Association, Rosslyn, VA 22209, 1996.

[5] "Statistical Methods for Motor Efficiency Data," Motor and Generator Section Publication, National Electrical Manufacturers Association, Washington, DC 20037, May 1978.

[6] K.L. Stricklett and M. Vangel, "Electric Motor Efficiency Testing Under the New Part 431 of Chapter II of Title 10, Code of Federal Regulations: Enforcement Testing," NIST Technical Note 1422, National Institute of Standards and Technology, Technology Administration, US Department of Commerce, December, 1996.

[7] "Standard Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process," ASTM Std E 122-89, American Society for Testing and Materials, Philadelphia, PA.

Appendix A

NOPR—Compliance Criteria

The criteria for establishing compliance with the efficiency levels mandated by EPCA are prescribed in §431.24(b)(1)(iii) of the NOPR [2].

§431.24(b)(1)(iii) makes reference to K coefficients that are tabulated in Appendix B of Subpart B of the NOPR. The K coefficients are based on NEMA Standard MG 1-1993 [4] and are calculated by the following formula:

$$K = \frac{\text{NEMA Minimum Efficiency}}{\text{NEMA Nominal Efficiency}}.$$

The table assigns K coefficients to all MG 1 Nominal Efficiencies between 75.5 percent and 99.0 percent.

§431.24(b)(1)(iii)

For each basic model selected for testing, a sample of units shall be selected at random and tested in accordance with §§431.23 and 431.25, and Appendix A. of this subpart. The sample shall be comprised of production units of the basic model, or units that are representative of such production units, and shall be of sufficient size to ensure that any represented value of the nominal or average full-load efficiency of the basic model is no greater than the lesser of

(A) The average full-load efficiency of the sample, or

(B) The lower 90 percent confidence limit of the average full-load efficiency of the entire population divided by the coefficient "K" applicable to the represented value. The coefficients are set forth in appendix B of this subpart.

Appendix B of Subpart B of Part 431—Nominal Full-load Efficiency and Corresponding Coefficient K

Nominal full-load efficiency	Coefficient K	Nominal full-load efficiency	Coefficient K
99.0	0.998	94.1	0.988
98.9	0.998	93.6	0.987
98.8	0.998	93.0	0.986
98.7	0.998	92.4	0.985
98.6	0.998	91.7	0.984
98.5	0.997	91.0	0.984
98.4	0.996	90.2	0.981
98.2	0.996	89.5	0.978
98.0	0.996	88.5	0.977
97.8	0.996	87.5	0.977
97.6	0.995	86.5	0.971
97.4	0.994	85.5	0.965
97.1	0.994	84.0	0.970
96.8	0.994	82.5	0.970
96.5	0.993	81.5	0.963
96.2	0.992	80.0	0.963
95.8	0.992	78.5	0.962
95.4	0.991	77.0	0.961
95.0	0.990	75.5	0.954
94.5	0.990		

Appendix B

NOPR—AEDM Substantiation

Criteria for substantiation of an AEDM are provided in §431.24(b)(3) of the NOPR [2].

§431.24(b)(3)

Substantiation of an alternative efficiency determination method. Before an AEDM is used, its accuracy and reliability must be substantiated as follows:

(i) The AEDM must be applied to at least five basic models that have been selected for testing and tested in accordance with paragraph (b)(1) of this section, and

(ii) The predicted total power loss for each basic model, calculated by applying the AEDM, must be within plus or minus ten percent of the mean total power loss determined from the actual testing of the basic model.

Appendix C

NOPR—Sampling Plan for Enforcement Testing

The Sampling Plan for Enforcement Testing proposed by the NOPR [2].

Appendix B to Subpart G of Part 431—Sampling Plan for Enforcement Testing

Step 1. The first sample size (n_1) must be five or more units.

Step 2. Compute the mean ($\bar{X}_1$) of the measured energy performance of the n_1 units in the first sample as follows:

$$\bar{X}_1 = \frac{1}{n_1} \sum_{i=1}^{n_1} X_i, \tag{C1}$$

where X_i is the measured full-load efficiency of unit i.

Step 3. Compute the sample standard deviation (S_1) of the measured full-load efficiency of the n_1 units in the first sample as follows:

$$S_1 = \sqrt{\frac{\sum_{i=1}^{n_1} (X_i - \bar{X}_1)^2}{n_1 - 1}}. \tag{C2}$$

Step 4. Compute the standard error ($SE(\bar{X}_1)$) of the mean full-load efficiency of the first sample as follows:

$$SE(\bar{X}_1) = \frac{S_1}{\sqrt{n_1}}. \tag{C3}$$

Step 5. Compute the lower control limit (LCL_1) for the mean of the first sample using the applicable statutory full-load efficiency (SFE) as the desired mean as follows:

$$LCL_1 = SFE - tSE(\bar{X}_1). \tag{C4}$$

Here t is the 10th percentile of a t-distribution for a sample size of n_1 and yields a 90 percent confidence level for a one-tailed t-test.

Step 6. Compare the mean of the first sample ($\bar{X}_1$) with the lower control limit (LCL_1) to determine one of the following:

(i) If the mean of the first sample is below the lower control limit, then the basic model is in noncompliance and testing is at an end.

(ii) If the mean is equal to or greater than the lower control limit, no final determination of compliance or noncompliance can be made; proceed to Step 7.

Step 7. Determine the recommended sample size (n) as follows:

$$n = \left[\frac{tS_1(120 - 0.2SFE)}{SFE(20 - 0.2SFE)} \right]^2 \tag{C5}$$

where S_1 and t have the values used in Steps 4 and 5, respectively. The factor

$$\frac{120 - 0.2SFE}{SFE(20 - 0.2SFE)}$$

is based on a 20 percent tolerance in the total power loss at full-load and fixed output power.

Given the value of n, determine one of the following:

(i) If the value of n is less than or equal to n_1 and if the mean energy efficiency of the first sample ($\bar{X}_1$) is equal to or greater than the lower control limit (LCL_1), the basic model is in compliance and testing is at an end.

(ii) If the value of n is greater than n_1, the basic model is in noncompliance. The size of a second sample n_2 is determined to be the smallest integer equal to or greater than the difference $n - n_1$. If the value of n_2 so calculated is greater than $20 - n_1$, set n_2 equal to $20 - n_1$.

Step 8. Compute the combined mean ($\bar{X}_2$) of the measured energy performance of the n_1 and n_2 units of the combined first and second samples as follows:

$$\bar{X}_2 = \frac{1}{n_1 + n_2} \sum_{i=1}^{n_1+n_2} X_i. \tag{C6}$$

Step 9. Compute the standard error ($SE(\bar{X}_2)$) of the mean full-load efficiency of the n_1 and n_2 units in the combined first and second samples as follows:

$$SE(\bar{X}_2) = \frac{S_1}{\sqrt{n_1 + n_2}}. \tag{C7}$$

(Note that S_1 is the value obtained above in Step 3.)

Step 10. Set the lower control limit (LCL_2) to,

$$LCL_2 = SFE - tSE(\bar{X}_2), \tag{C8}$$

where t has the value obtained in Step 5, and compare the combined sample mean ($\bar{X}_2$) to the lower control limit (LCL_2) to find one of the following:

(i) If the mean of the combined sample ($\bar{X}_2$) is less than the lower control limit (LCL_2), the basic model is in noncompliance and testing is at an end.

(ii) If the mean of the combined sample ($\bar{X}_2$) is equal to or greater than the lower control limit (LCL_2), the basic model is in compliance and testing is at an end.

MANUFACTURER-OPTION TESTING

If a determination of non-compliance is made in Steps 6, 7 or 11, above, the manufacturer may request that additional testing be conducted, in accordance with the following procedures.

Step A. The manufacturer requests that an additional number, n_3, of units be tested, with n_3 chosen such that $n_1 + n_2 + n_3$ does not exceed 20.

Step B. Compute the mean full-load efficiency, standard error, and lower control limit of the new combined sample in accordance with the procedures prescribed in Steps 8, 9, and 10, above.

Step C. Compare the mean performance of the new combined sample to the lower control limit (LCL_2) to determine one of the following:

(a) If the new combined sample mean is equal to or greater than the lower control limit, the basic model is in compliance and testing is at an end.

(b) If the new combined sample mean is less than the lower control limit and the value of $n_1+n_2+n_3$ is less than 20, the manufacturer may request that additional units be tested. The total of all units tested may not exceed 20. Steps A, B, and C are then repeated.

(c) Otherwise, the basic model is determined to be in noncompliance.

Appendix D

The NEMA Proposal

The following statement was prepared by the NEMA, Motor and Generator Section, and was submitted to the DOE on Friday, April 18, 1997, in response to the call public comment given in the NOPR [2]. The text of the original NEMA statement [3] has been modified to conform with the pagination and the figure labeling scheme used in this report.

PROPOSAL FOR THE METHOD OF DETERMINING COMPLIANCE AND ENFORCEMENT FOR ELECTRIC MOTORS UNDER THE EFFICIENCY LABELING PROGRAM OF DOE 10 CFR PART 431
Submitted by
NEMA Motor and Generator Section

Background - Analysis of Testing Samples from Total Population

The basis behind the NEMA proposal is best illustrated by way of examples. A normal distribution for a total population of motors having a nominal efficiency rating of 91.0% is shown in Figure D1 based on the assumption that three sigma (standard deviation) corresponds to the NEMA minimum efficiency of 89.5%. Also shown are the normal distributions for the means of samples of size 2 or five which are normally distributed about the true mean of the population and have a standard deviation proportional to that of the total population divided by the square root of the sample size n. The normal distribution of the total population also corresponds to the distribution of the means of samples of size 1.

Per Table 12-8 of NEMA MG 1 the values of efficiency in the vicinity of 91.0% which a manufacturer can mark on appropriately rated motors are 89.5%, 90.2%, 91.0%, 91.7%, and 92.4%. It remains to be determined which level of efficiency is supported by testing samples selected from the total population. For this example, a reasonable compliance criteria should show that the nominal efficiency is 91.0% within a desired degree of confidence.

Figure D2 illustrates the probability that the mean of a sample selected from the total population will be less than various levels of efficiency. The DOE proposed rule for compliance in 431.24.b.1.iii.A requires that the represented value of nominal efficiency for the basic model (total population) cannot be greater than the average (mean) full-load efficiency of the sample. From Figure D2 it can be seen that there is a probability of 50% that the mean efficiency of a sample of any size will be less than the nominal efficiency of the total population, 91.0% in this particular example. Combining this DOE proposed rule with the NEMA Standard for selection of efficiency levels for marking, there is then a probability of 50% that for any sample selected from the total population the declared value of nominal efficiency could not be greater than 90.2%. From Figure D2 the probability that the mean of the sample would actually be less than 90.2% and that the nominal efficiency must be selected to be the next lower value, 89.5%, is 5% for a sample of 1, 1.2% for a sample of 2, and a negligible value for a sample of 5. It should be apparent that the DOE proposed rule places an unreasonable burden (risk) on the manufacturer to show compliance to the actual true mean nominal efficiency. A rule based on the average efficiency of a sample not being less than some efficiency level lower than the nominal efficiency, 91.0% in this example, would appear to offer a reasonable risk for the manufacturer to show compliance to 91.0%.

Background - Analysis of Testing Samples from Limited Population

Because motors based on a basic model design are produced over a long period of time, the total population for which compliance is being determined will not be available at the time a sample must be selected for testing. As a result, the sample will be selected from production lot(s) which may incorporate a limited range of variation of all of the factors which can affect the efficiency of each individual motor; the variations in materials, variations in manufacturing processes, and variations in testing (see NEMA MG 1-12.58.2). It is not possible to include in a compliance rule, when testing is likely to take place in only one location, the allowance in the NEMA standard for the variation in testing results when a motor is tested at different locations. It is then reasonable to assume that if the distribution of efficiencies of the total population tested at any facility are as shown in Figure D1 then the distribution of the total population when tested at a single facility must have a lower value of standard deviation. Further, it should be evident that the standard deviation of any particular limited production lot should be even lower because it will not incorporate all of the possible variations in materials and manufacturing processes that can occur over the extended period of time the basic model is produced. For example, the electrical steel used to construct the stator and rotor laminated cores is purchased in large quantities at a time. The amount purchased may be sufficient to handle the production of motors for several months. The characteristics of the material in that stock will determine the efficiency in the motors selected for testing from those produced using that stock. A new stock of material having somewhat different performance characteristics will not be available for use until the present stock is depleted.

For the purpose of this illustration, it will be assumed that the processes under the manufacturer's control limit the minimum efficiency for any acceptable motor to 89.8%. The difference between 89.8% and the NEMA minimum efficiency of 89.5% allows for variations in the test value of efficiency when the tests are performed at facilities not under the direction of the manufacturer. It will be further assumed that the mean efficiency of the limited population is equal to 90.6% as a result of the effect of variations in materials, manufacturing processes, and testing performed at a single facility. The difference between efficiencies of 91.0% and 90.6% is equivalent to a reasonable variation of 5% in the total losses. A normal distribution on the basis of these assumptions is shown in Figure D3. Included are the normal distributions of the means of samples of size 2 and 5 as well as 1. From Figure D2 it can also be observed that the probability of a production lot of motors having a mean efficiency less than 90.6% is 21%.

The probability distribution function for the limited population in Figure D3 is shown in Figure D4. From Figure D4 the probability that a sample mean would exceed 91.0% is only 8% for a sample of 1, 2% for a sample of 2, and 0% for a sample of 5. In other words, a sample taken from such a limited population, even if the number of motors was in the hundreds or thousands, would be unlikely to support compliance to the correct true mean of the total population when following DOE's proposed rule.

This example does, however, provide additional guidance as to what the compliance rule could be. From Figure D4 there is a probability of 90% that the mean efficiency of a sample from this limited lot size will be greater than 90.25% for a sample of 1, 90.35% for a sample of 2, or 90.44% for a sample of 5. From Figure D2 for the total population there is a probability of 93% that any motor from the total population has an efficiency greater than 90.25%, a probability of 90% that any motor will have an efficiency greater than 90.35%, or a probability of 87% that any motor would have an efficiency of 90.44%.

Background - Overlapping Nominal Efficiency Distributions

The final criteria which must be examined for determining a practical compliance rule is the probability that the sample test may indicate an incorrect nominal efficiency for the basic model (total population). To aid in the discussion of this issue, Figure D5 is presented which illustrates the normal distribution of efficiencies for a population of motors which have a nominal efficiency of 91.0% and a population of motors which have a nominal efficiency of 90.2%. In this case 90.2% is the next lower level of nominal efficiency which the NEMA MG 1 Standard permits to be used for the marking of motors. Again, distributions based on test samples of sizes 1 (equivalent to the distribution for the total population), 2, and 5 are provided for each population. The corresponding probability distributions are shown in Figure D6.

From Figure D5 it can be observed that the various distributions of efficiency of the two populations tend to intersect each other in the region of an efficiency of 90.6%. This varies slightly based on the sample sizes because of the difference in the NEMA criteria permitted for the two nominal efficiency levels. For a nominal efficiency of 91.0% the NEMA minimum efficiency is 89.5% for a standard deviation of 0.5%. For a nominal efficiency of 90.2% the NEMA minimum efficiency is 88.5% for a standard deviation of 0.57%. This slight distortion in the relationships of the distribution functions is a result of basing the curves on efficiency when in fact the NEMA criteria for selecting discreet values of nominal efficiency for the use in marking motors was based on step changes in the total losses. The increase in losses in going from an efficiency of 91.0% to 89.5% is 19.6%. The increase in losses is 18.6% when going from an efficiency of 90.2% to 88.5%. This slight difference in the change in losses was introduced by rounding off the nominal efficiency values used for marking motors to 3 significant figures.

Per Figure D6 the probability that a motor from a population with a nominal efficiency of 91.0% would have an efficiency below 90.6% is 21%. The probability that a motor from a population with a nominal efficiency of 90.2% would have an efficiency above 90.6% is 24%. There is a probability of 13% that the mean of a sample of size 2 selected from the population with a nominal efficiency of 91.0% would be less than 90.6%. Similarly there is a probability of 16% that the mean of a sample of size 2 selected from the population with a nominal efficiency of 90.2% would be greater than 90.6%. There is a probability of 4% that the mean of a sample of size 5 selected from the population with a nominal efficiency of 91.0% would be less than 90.6%. Similarly there is a probability of 6% that the mean of a sample of size 5 selected from the population with a nominal efficiency of 90.2% would be greater than 90.6%.

This suggests that a reasonable criteria for the compliance rule that balances the manufacturer's and consumer's risks is that the minimum permissible value of average efficiency for the sample should be a value between the nominal efficiency to be declared and the next lower value of nominal efficiency in Table 12-8 of NEMA MG 1.

Proposed Test for Determining Compliance (Section 431.24.b.1.iii of Part 431)

Basing the test condition for compliance on the values of nominal efficiency in Table 12-8 would introduce a complexity of having to use a table of values in which the increment in efficiency between values is not fixed. It is simpler to use the basic principle under which the table was developed. This is the same principle that the DOE recognized in the proposed rule for enforcement testing in Appendix B to Subpart G of Part 431. The increment in efficiency between the nominal values in Table 12-8 were based on approximately a 10% change in total losses. The point at which the manufacturer's and consumer's risks are balanced between two NEMA nominal values of efficiency suggested above corresponds to a 5% change in losses.

It is therefore proposed that one of the conditions required to determine conformance is that the "average full-load efficiency of the sample is not less than the value of efficiency equal to the nominal efficiency reduced by an amount equivalent to a 5% increase in losses at full-load, i.e. the value given by

$$\frac{100}{1 + 1.05\left(\frac{100}{NE} - 1\right)}\text{"}$$

This proposal could also be written in a manner consistent with the DOE proposed rule 431.24.b.1.iii.A "as the represented value of the nominal full-load efficiency of the basic model is not greater than the value calculated from

$$\frac{105\bar{X}}{100 + 0.05\bar{X}}$$

where $\bar{X}$ is the average full-load efficiency of the sample."

The second condition that must be satisfied by the sample is related to the standard deviation of the efficiencies of the motors in the sample. In Appendix B to Subpart G of Part 431 the DOE proposed a test on the sample size based on a 20 percent tolerance in the total power loss at full-load. This recognizes the complete variation in efficiency testing at different facilities as identified in the NEMA MG 1 standard. It is recommended that this value of 20% can be reduced to 15% for the purpose of compliance testing at a single facility. The principle behind the incorporation of this recognized variation in Appendix B to Subpart G of Part 431 can be applied here by incorporating it in a simpler method as a requirement that "the full-load efficiency of each motor in the sample must be greater than the value of efficiency equal to the nominal efficiency NE reduced by an amount equivalent to a 15% increase in total losses at full-load, i.e. the value given by

$$\frac{100}{1 + 1.15\left(\frac{100}{NE} - 1\right)}\text{"}$$

Proposed Test for Enforcement (Appendix B to Subpart G of Part 431)

It is proposed that the rules for enforcement testing be similar to those for compliance. The primary difference being that the rules for enforcement testing be based on the total permissible variation in measured efficiency permitted by the NEMA MG 1 Standard. The recommended rules for enforcement testing would then be that the "average full-load efficiency of the sample is not less than the value of efficiency equal to the nominal efficiency NE reduced by an amount equivalent to a 15% increase in losses at full-load, i.e. the value given by

$$\frac{100}{1 + 1.15\left(\frac{100}{NE} - 1\right)}"$$

The second condition that must be satisfied by the sample is the again similar to that for determining compliance that "the full-load efficiency of each motor in the sample must be greater than the value of efficiency equal to the nominal efficiency NE reduced by an amount equivalent to a 20% increase in total losses at full-load, i.e. the value given by

$$\frac{100}{1 + 1.2\left(\frac{100}{NE} - 1\right)}"$$

Example of Normal Distribution of Total Population and Distribution of Means of Samples

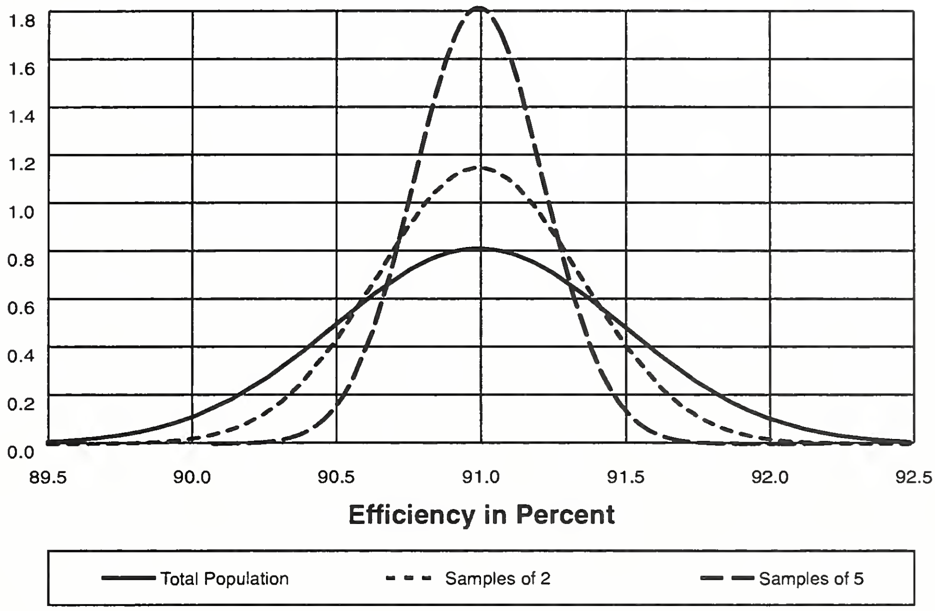


Figure D1:

Probability That Mean of Sample is Below Efficiency Value

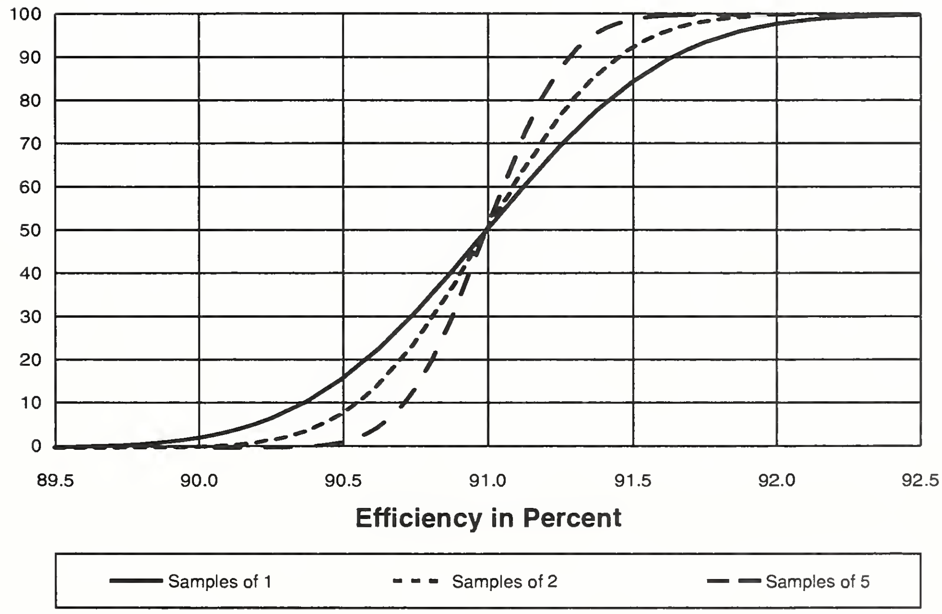


Figure D2:

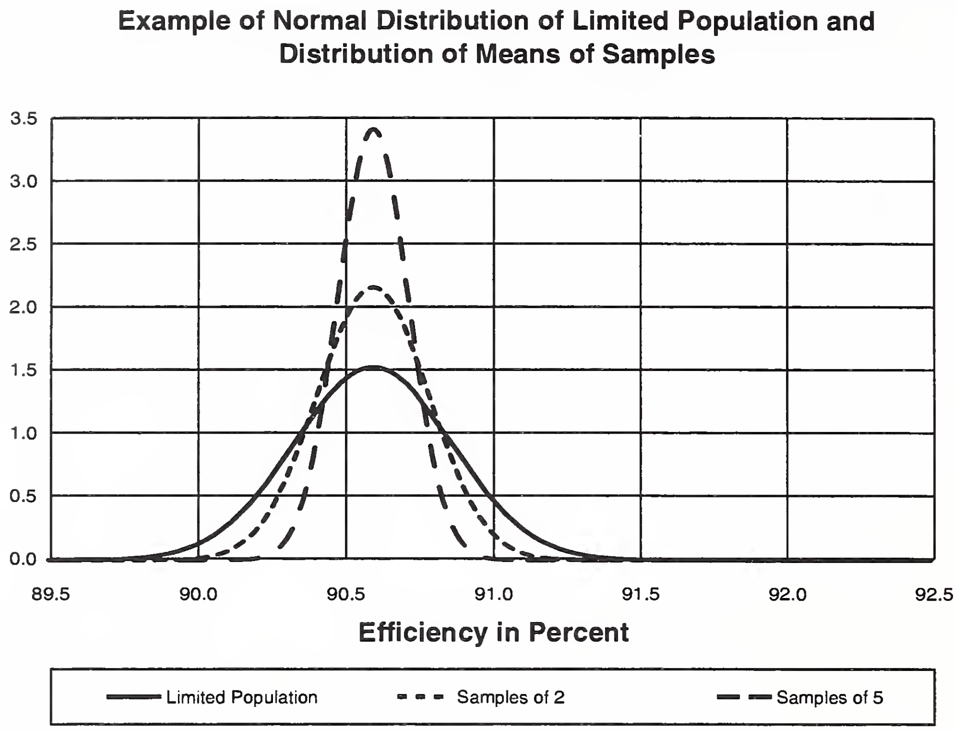


Figure D3:

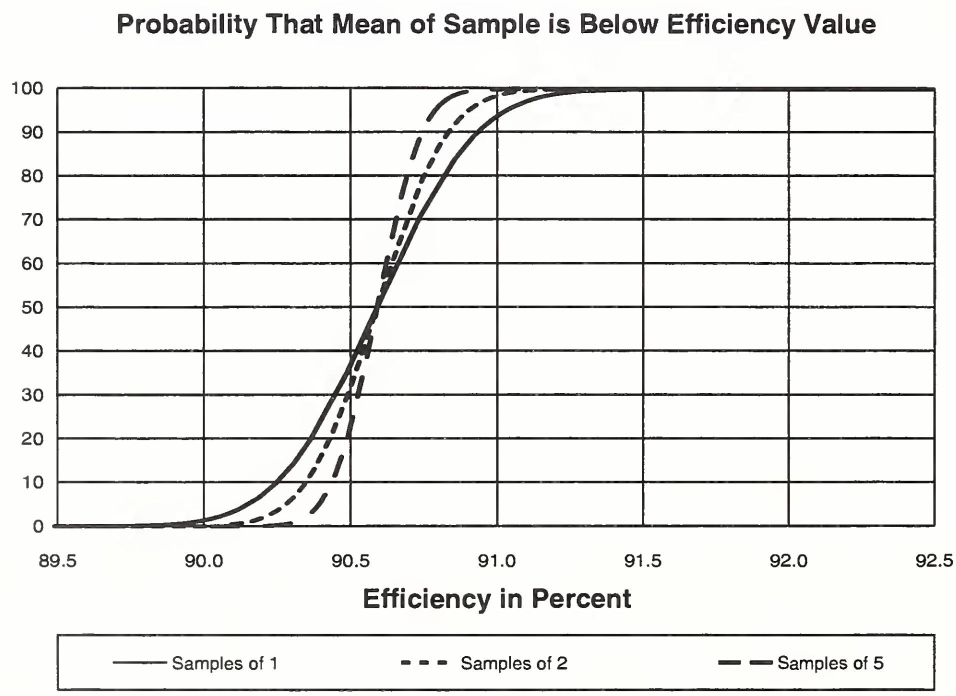


Figure D4:

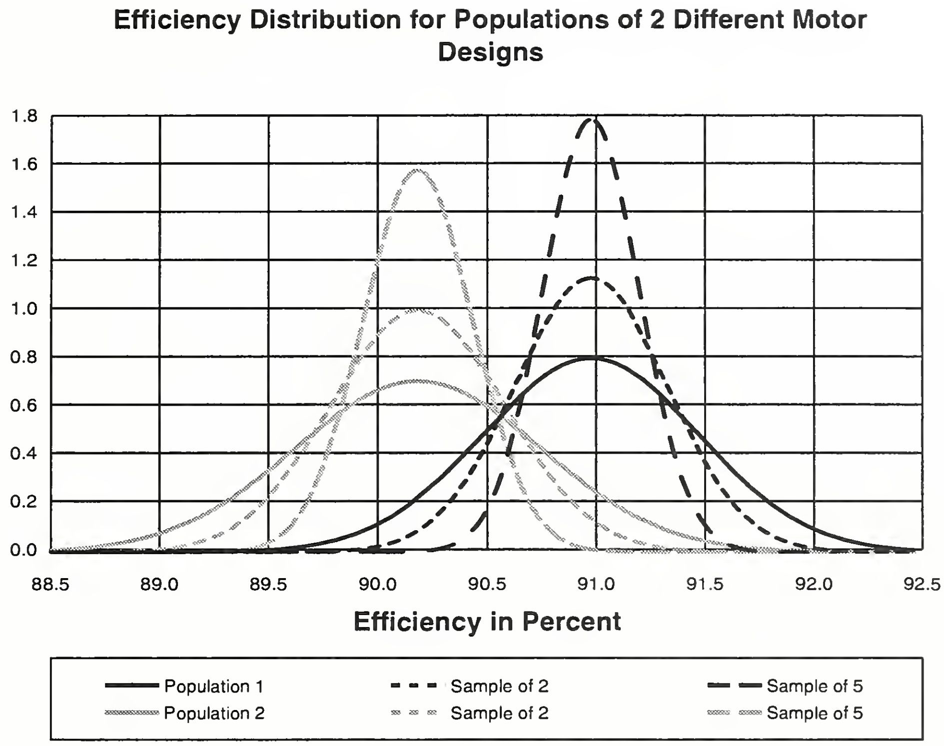


Figure D5:

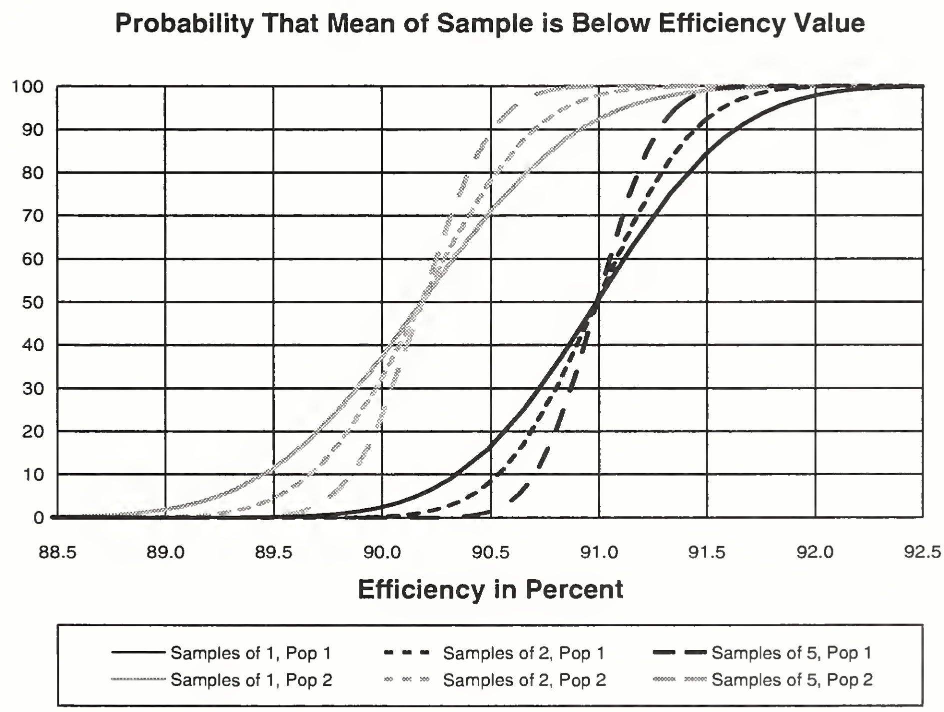


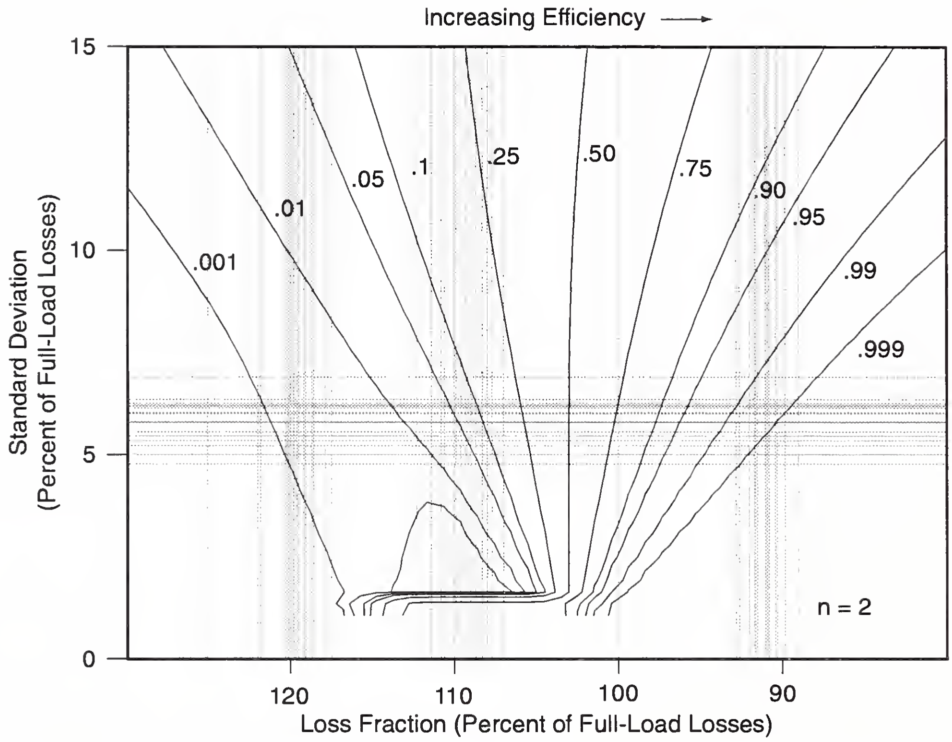
Figure D6:

Appendix E

Supplemental Analysis

As noted on page 5, the operating characteristics of the NEMA compliance criteria are influenced by the value of the coefficient used in criterion (A) (see page 4). The NEMA proposal recommends that compliance testing be based on the use of 1.05 for this coefficient. The operating characteristics of the NEMA compliance criteria for this value are shown on page 9. The analyses presented in this Appendix were performed at the request of the DOE in order to evaluate modification of the value of the (A) coefficient, and to compare the operating characteristics of the NOPR sampling plan for enforcement testing with the NEMA criteria for compliance testing. These supplemental analyses include: Model calculations of the operating characteristics of the NEMA compliance criteria with the (A) coefficient set to values of 1.03 and 1.01. These data are presented in Figs. E1 and E2, respectively. In the remaining figures, the operating characteristics of the NOPR protocol for enforcement testing and the NEMA compliance criteria are compared. For these comparisons, the operating characteristics of the NOPR enforcement protocol at 90 percent and 99 percent statistical confidence are plotted together with the .90 contours for the NEMA compliance criteria. Data for the NEMA compliance criteria with an (A) coefficient of 1.05, 1.03, and 1.01 are plotted in Figs. E3, E4, and E5, respectively.

a)



b)

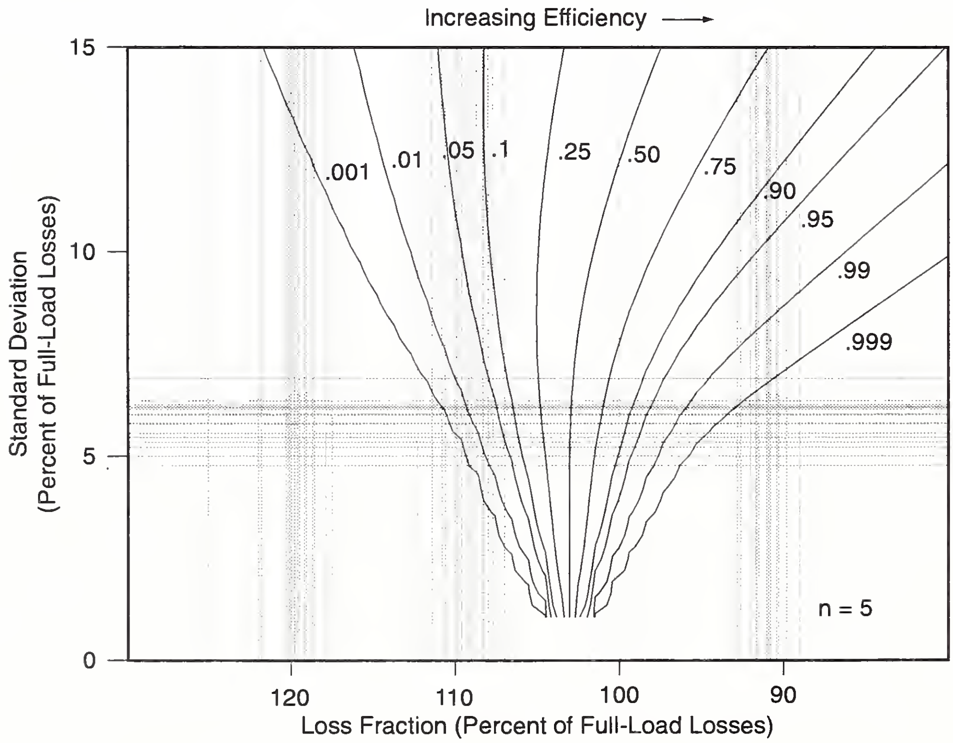


Figure E1: Operating characteristics of a modified NEMA compliance protocol. Here the coefficient in criterion (A) of the NEMA protocol for compliance testing is 1.03. Model calculations for samples of two and five are shown in a) and b), respectively. The contours indicate the probability of demonstrating compliance, e.g., the .90 contour corresponds to a 90 percent likelihood of demonstrating compliance.

a)

b)

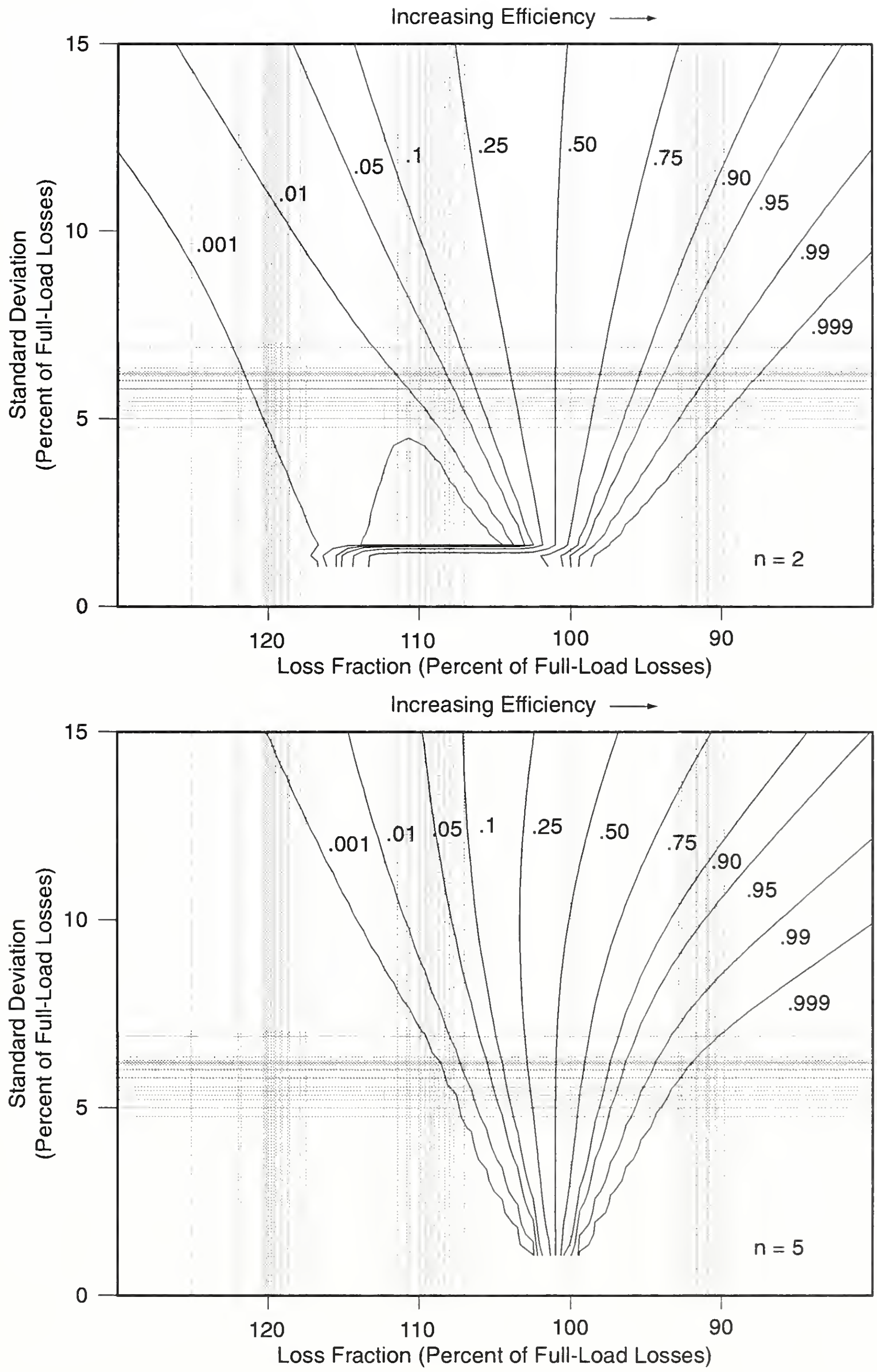


Figure E2: Operating characteristics of a modified NEMA compliance protocol. Here the coefficient in criterion (A) of the NEMA protocol for compliance testing is been 1.01. Model calculations for samples of two and five are shown in a) and b), respectively. The contours indicate the probability of demonstrating compliance, e.g., the .90 contour corresponds to a 90 percent likelihood of demonstrating compliance.

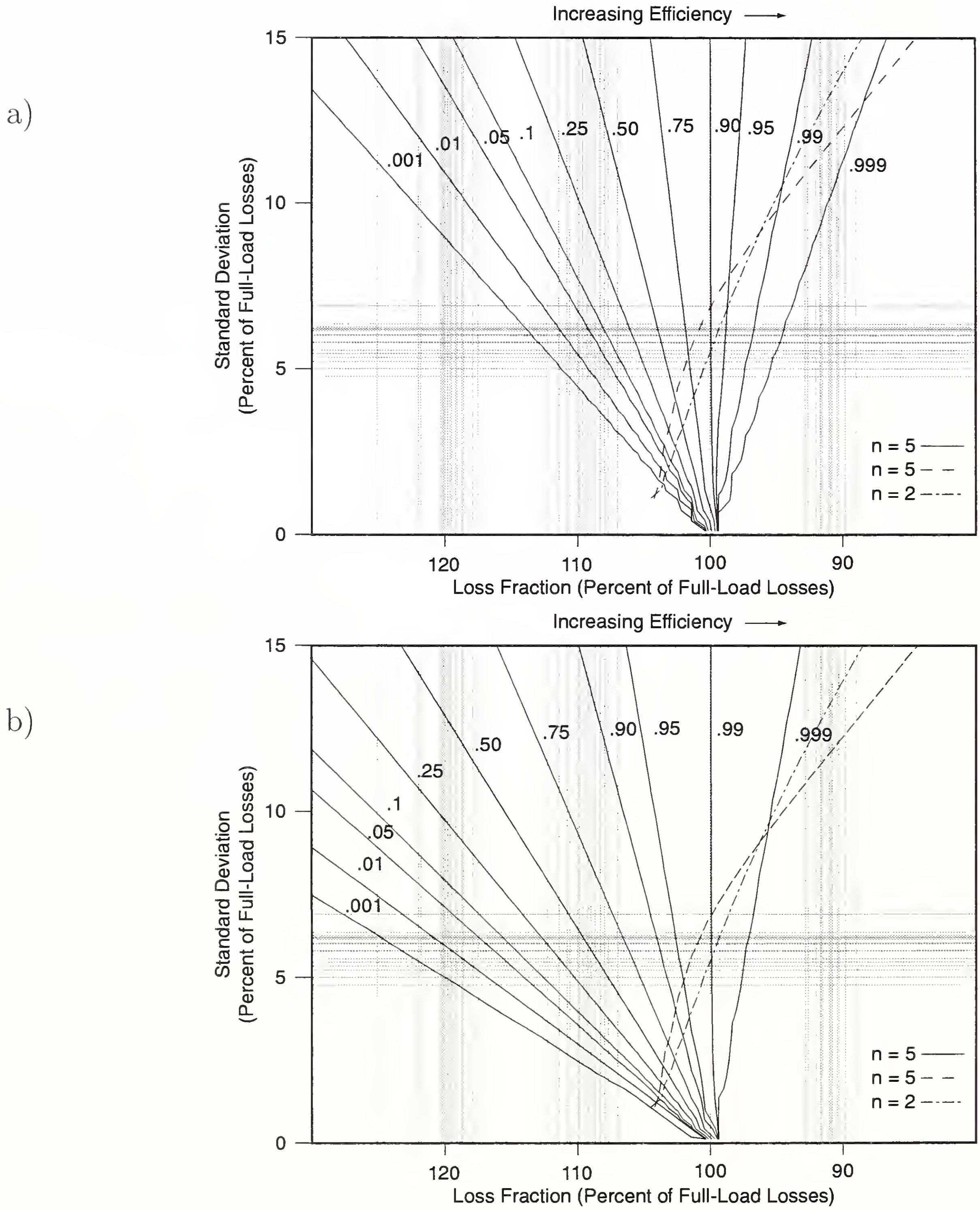
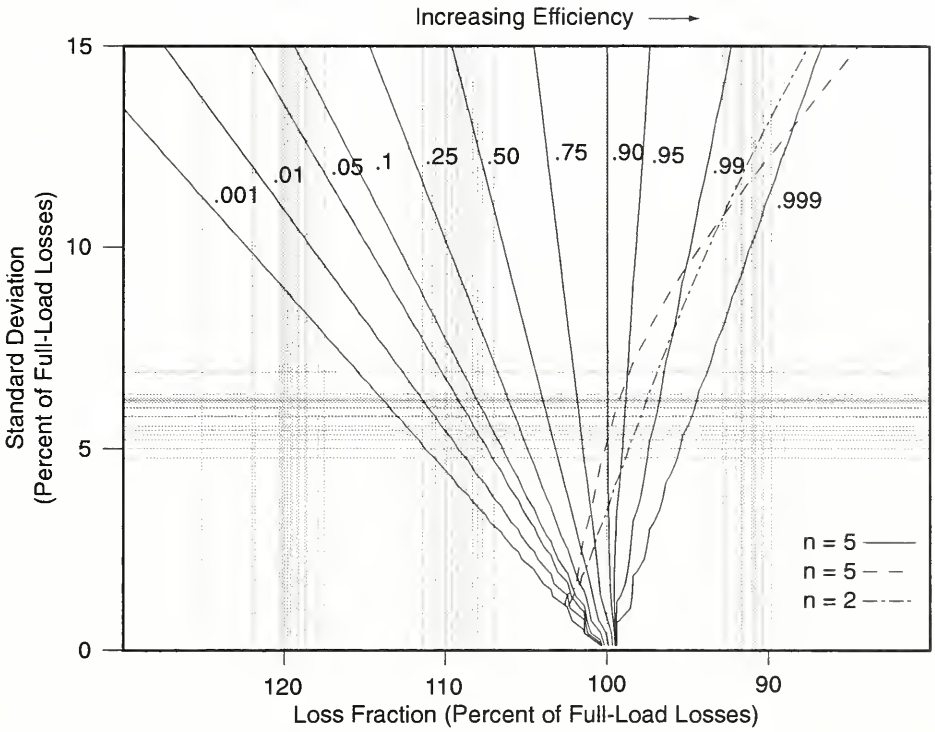


Figure E3: A comparison of the operating characteristics of the NOPR protocol for enforcement testing and the NEMA compliance protocol. The operating characteristics of the NOPR protocol at 90 percent and 99 percent statistical confidence are indicated respectively by the solid lines in a) and b). The .90 contours of the NEMA compliance protocol are shown for samples of two (–·–·–·-) and five (– – –). Here the coefficient in criterion (A) of the NEMA protocol for compliance testing is 1.05.

a)



b)

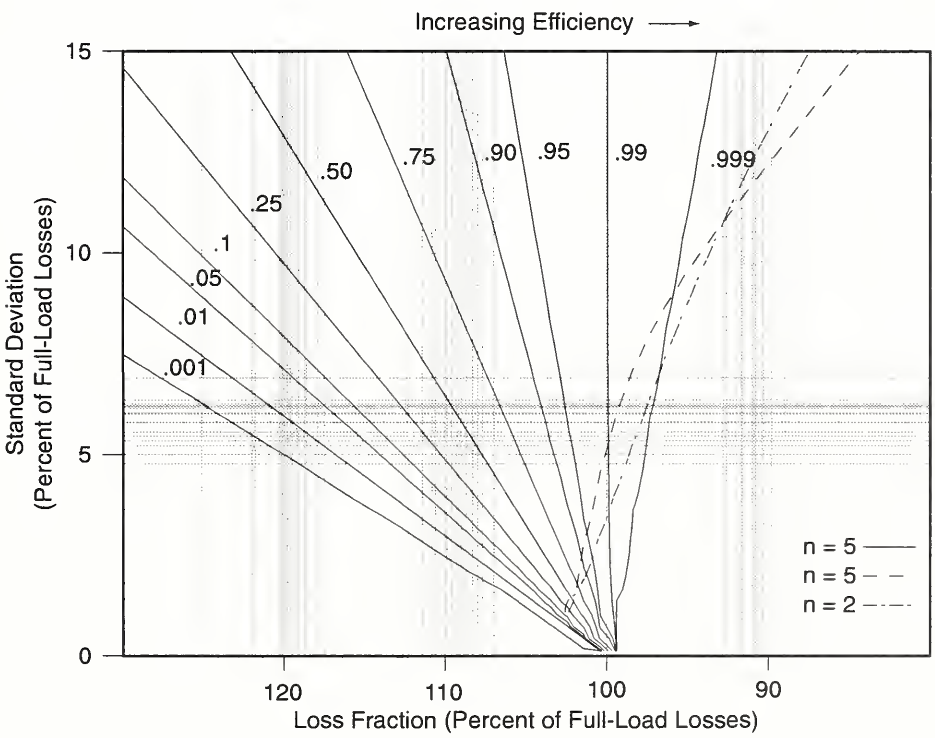
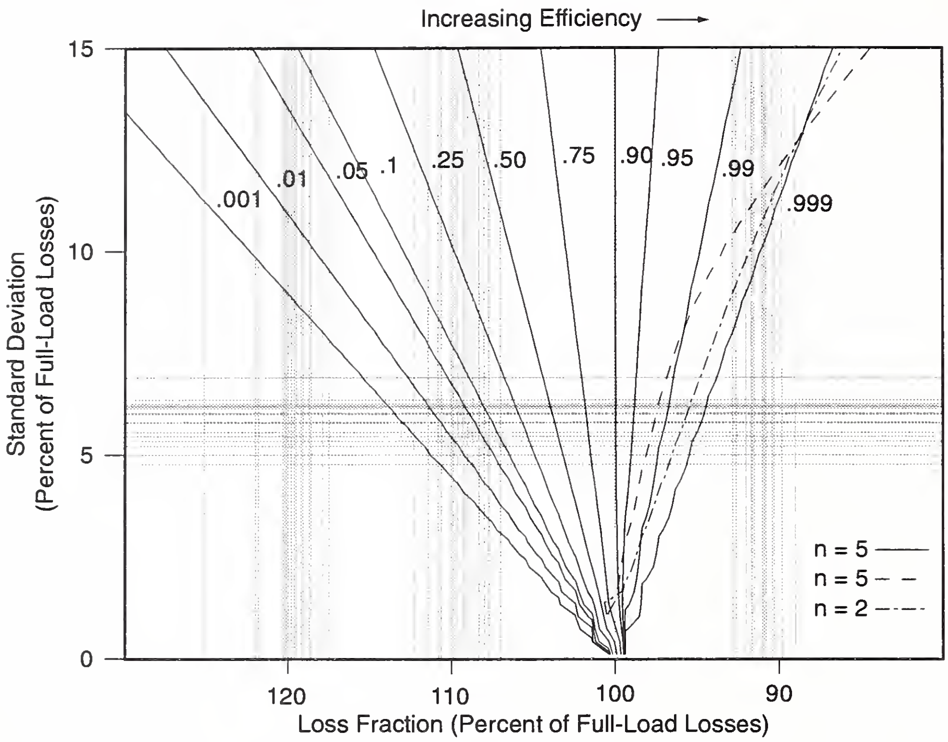


Figure E4: A comparison of the operating characteristics of the NOPR protocol for enforcement testing and the NEMA compliance protocol. The operating characteristics of the NOPR protocol at 90 percent and 99 percent statistical confidence are indicated respectively by the solid lines in a) and b). The .90 contours of the NEMA compliance protocol are shown for samples of two (—-—-—-) and five (— — —). Here the coefficient in criterion (A) of the NEMA protocol for compliance testing is 1.03.

a)



b)

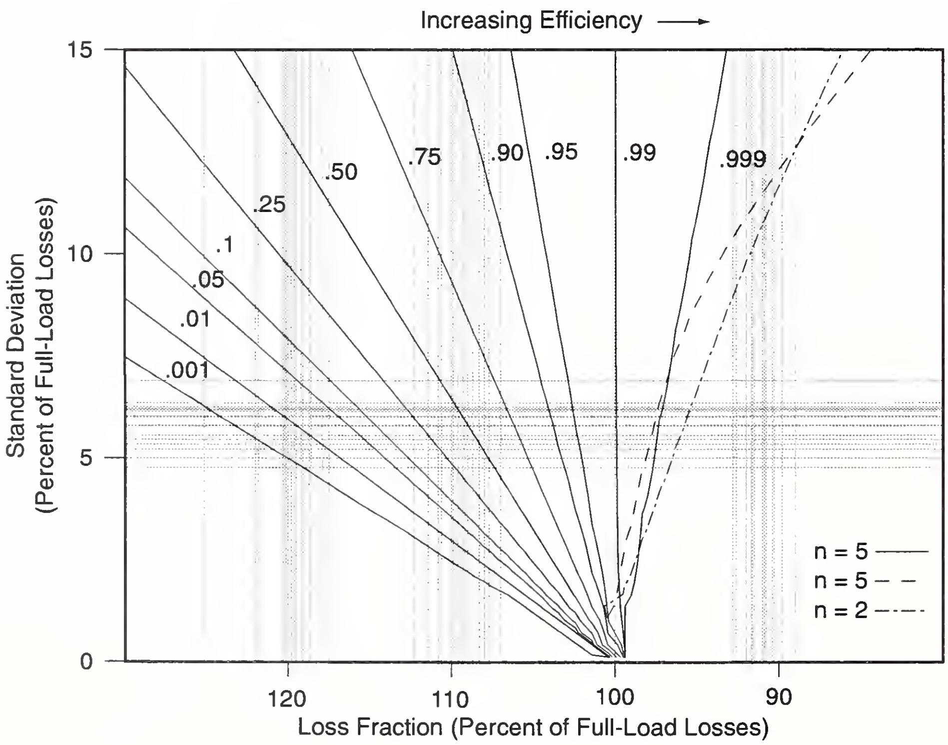


Figure E5: A comparison of the operating characteristics of the NOPR protocol for enforcement testing and the NEMA compliance protocol. The operating characteristics of the NOPR protocol at 90 percent and 99 percent statistical confidence are indicated respectively by the solid lines in a) and b). The .90 contours of the NEMA compliance protocol are shown for samples of two (—-—-—-) and five (— — —). Here the coefficient in criterion (A) of the NEMA protocol for compliance testing is 1.01.