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ITEM 222 AND RULE 41 EDGE CRUSH TEST COMPLIANCE

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EXECUTIVE SUMMARY

Recently approved changes in Item 222 and Rule 41 allow boxmakers to produce and certify corrugated paperboard packaging against Edge Crust Test specifications. These changes will require boxmakers and box users to understand the issues involved in achieving Item/Rule compliance in a cost-efficient manner.

Statistical equations are presented which allow the ECT compliance probability to be calculated for a specific box lot from the average ECT and the ECT standard deviation. The relationships show that the average ECT can be reduced by reducing the standard deviation. At relatively low standard deviation levels, the ECT compliance will be controlled by the 5/6 test and 20/24 retest criterion. At relatively high standard deviation levels, ECT compliance will be controlled by the criterion that no single test specimen ECT shall be more than 10% below the specification requirement.

The statistical equations will allow boxmakers and box users to calculate the economic opportunity that may be available through efforts aimed at minimizing the effect of converting operations on ECT. The analysis shows that the effect of converting processes on both the average ECT and the ECT variability need to be addressed in order to achieve the maximum economic opportunity.

KEYWORDS

Item 222, Rule 41, Edge Crush Test, Statistical Calculations, Converting Quality.

ABSTRACT

Recent changes to Item 222 and Rule 41 allow a box user to purchase packaging certified to be in compliance with Edge Crush Test (ECT) specifications. Statistical relationships are presented that can be used by a boxmaker to determine the probability of achieving ECT compliance with a given lot of boxes. The probability of compliance is dependent on the average ECT of the lot of boxes and on the variability of individual ECT test values within the lot of boxes. At high variance levels, compliance will be controlled by the

specification that allows no ECT test value to be more than 10% below the minimum ECT for the grade. At lower variability levels, compliance will be controlled by the 5/6 test and 20/24 retest criterion for the specification. Box plant quality control programs aimed at optimizing the ECT compliance capability of the plant need to address the effect of converting operations on both the average ECT and the variability of ECT within a box lot.

INTRODUCTION

Significant changes in Item 222 and Rule 41 were recently approved after a 15-year effort. One major change that was made allows a corrugated box user an option as to the specification characteristic that must be met in order to conform with the Box-maker Certification stamp. A box may now be certified to be in compliance with the minimum combined weight of facings and minimum combined board Mullen, which is unchanged from the requirements adopted in the 1940s, or the box may now be certified to be in compliance with the minimum ECT. Both are equally acceptable by truck and rail common carriers.

This paper deals with mathematical calculations that can be used by a boxmaker to quantify the level of ECT performance that is required in order to achieve Item/Rule ECT compliance. It also addresses the expected quantitative effect of quality control procedures aimed at minimizing the variability of ECT in the box plant converting process. Such reductions in ECT variability and therefore the average strength levels needed may offer economic opportunities in packaging costs.

ITEM 222/RULE 41 ECT COMPLIANCE REQUIREMENTS

The test compliance protocol for Item/Rule ECT compliance has two major criteria that must be met. First, six test specimens are sampled from a given lot of boxes and tested for ECT. If no more than one of the test specimen ECT values is below the minimum specification value for the grade, the lot of boxes is in compliance with this Item/Rule ECT requirement. If two or more of the test values are below the minimum specification value required, a retest consisting of 24 new test specimens is allowed. No more than four of the retest specimen values can be below the minimum specification value in order for the lot of boxes to be in compliance. This test criterion is identical to that required to determine compliance with the Mullen specification of the Item/Rule.

The second criterion for ECT compliance requires that none of the specimen test levels be more than 10% below the minimum specification value. This requirement is specific to the ECT certification and does not apply to the Mullen specification.

A box lot must meet both criteria to be in ECT compliance with the Item/Rule. If any one of the 24 valid retest values is more than 10% below the table minimum ECT specification required by the Item/Rule, that box lot is not in compliance, and there is no further recourse allowed under the Item/Rule. These ECT specification requirements for the Item/Rule are summarized by grade in Table I.

STATISTICAL METHODS

Binomial probability statistics are an accepted method for analyzing the compliance probability of this type of specification protocol (1), (2). The general binomial probability relationships are shown in Figure 1.

Figure 2 shows the equations as they apply to the Item/Rule ECT compliance calculations. The total probability of passing the 5/6 test protocol is the sum of the probabilities of having all six test values at or above the minimum specification requirement plus the probability of having five of the six at or above the minimum specification. Similarly, the total compliance probability for the retest is the sum of the probabilities of having 24, 23, 22, 21, and 20 specimen test values at or above the minimum specification. It should be kept in mind that the population probability value, Po, must be the same in both the 5/6 and 20/24 equations for a given box lot since it represents the distribution probability of the ECT strength in that lot of boxes. The probability equations are shown in Figure 3 where the compliance probability is plotted against the population probability. The plot shows that the 5/6 and 20/24 compliance definitions yield different probability curves. The two curves cross at a compliance probability of 0.85. Below this compliance probability, the 5/6 definition requires a lower population probability, and above this compliance probability, the 20/24 protocol requires a lower population probability. The population probability for the combined test + retest criterion always requires a population probability that is equal to or less than that of either compliance definition by itself.

The second criterion of ECT compliance, which states that no test value shall be less than 10% below the specified table value, can also be handled using the binomial statistics equations. The appropriate equations for this second criterion are also shown in Figure 2. The calculations for both criteria one and two must be performed to determine which criterion is controlling in terms of compliance. In general, criterion one will be controlling at lower ECT variability levels, and criterion two will be controlling at higher ECT variability levels.

The corresponding population/compliance probability values for the various compliance criteria are given in Table II to serve as an ease of use reference for the reader.

As shown by these equations, the compliance probability is determined by the box lot average ECT and the ECT standard deviation once the compliance protocol (5/6 test, 20/24 retest, no value more than 10% below) has been set. Therefore, for a defined compliance probability, the box lot average ECT required decreases as the ECT standard deviation decreases and increases as the ECT standard deviation increases. This relationship between average and standard deviation is the mechanism that can provide a box plant operation with an economic opportunity through quality control techniques to minimize the ECT variability. This opportunity is in addition to the opportunity available by reducing the loss in average ECT in the box plant converting operation. The sensitivity of this relationship is discussed quantitatively in the following section.

APPLICATION EXAMPLE

The 32 lb/in. ECT singlewall grade from Table I is used as an example for applying the statistical analysis methods and for demonstrating the sensitivity of the average ECT to the ECT standard deviation. The compliance criterion one for this grade is 32.0 lb/in. ECT, and the compliance criterion two, 10% below, is 28.8 lb/in. ECT. Based on the probabilities given in Table II, a population probability of 0.950 is required to achieve a 1.000 compliance probability for the test + retest criterion. A normal distribution table from any statistical reference shows that a 0.950 probability is equal to the lot average ECT plus 1.645 times the ECT standard deviation. Similarly, a population probability of 0.997 is required to achieve a compliance probability of 0.999 based on the second compliance criterion (no more than 10% below the table ECT value). A 0.997 population probability is equal to the population ECT average plus 2.75 times the ECT standard deviation.

The box lot average ECT required to achieve the 1.000 and 0.999 probabilities defined above will depend on the ECT standard deviation. The relationship is shown in Figure 4. The lot average ECT required increases as the standard deviation increases, and the lowest ECT test value expected decreases as the standard deviation increases. The ECT specification values which appear in the Item/Rule were generated using test data from 1989 corrugated packaging. The reported average industry ECT standard deviation from this study was 2.63 and is shown in Figure 4. The minimum test value line crosses the Item/Rule absolute minimum ECT of 28.8 at slightly above the 2.63 standard deviation. This indicates that the Item/Rule specification for this grade was set with an equal balance between the two compliance criteria based on the average industry performance. For this grade, criterion two will become the controlling specification if a box plant has an ECT variation higher than the industry average, and criterion one will be the controlling specification for a box plant with an ECT standard deviation equal to or lower than the industry average.

The lot average ECT required is shown plotted against the ECT standard deviation in Figure 5. The break point in the line represents the point at which the average ECT required for the defined compliance probability changes from being governed by the 5/6 + 20/24 criterion to being governed by the no more than 10% below criterion. The lowest lot average ECT to achieve the 100% compliance probability is 36.6 lb/in. at a standard deviation of 2.63. A one-third reduction in the standard deviation reduces the lot average ECT required to 34.9 lb/in. A one-third increase in the standard deviation increases the lot average ECT required to 41.6 lb/in. Such differences in the average ECT level required may have important economic implications.

BOX PLANT QUALITY CONTROL IMPLICATIONS

A great deal of attention is being given to box plant quality issues that can impact on the ability of a converter to comply with the ECT specification of the Item/Rule in the most cost-efficient manner. Many of the efforts have concentrated on the effect of converting operations on the average ECT levels achieved. While the ECT average is an important factor, the statistical analysis reported here strongly suggests that these quality improvement efforts should also address the effect of converting operations on the variability of ECT. Quality issues such as crushing and poor bonding may occur in very localized areas of the package. Their affect on the average ECT may be relatively minor, but their affect on the ECT variability can be relatively major.

This concept of the importance of ECT variability on achieving the Item/Rule ECT compliance also applies to the sample preparation and testing procedures. As much care needs to be taken in preparing and testing individual specimens as is taken in controlling the overall calibration of the test instrument.

LITERATURE CITED

1. J. J. Batelka, Packaging Technology, "How Proposed Changes in Rule 41/222 Will Effect Mulllen Strength," 40 (1980).

2. J. J. Batelka, Paperboard Packaging, "A Critic's Birdseye View of the Classification Rules," 78 (1979).

TABLE I

Item 222 and Rule 41 ECT Specifications

Grade	Minimum ECT, lbs./inch Criterion One	Criterion Two
Singlewall	23	20.7
	26	23.4
	29	26.1
	32	28.8
	40	36.0
	44	39.6
	55	49.5
Doublewall	42	37.8
	48	43.2
	51	45.9
	61	54.9
	71	63.6
	82	73.8
Triplewall	67	60.3
	80	72.0
	90	81.0
	112	100.8

Table II

Compliance Probabilities for Item 222 and Rule 41 ECT Protocol

	CRITERION ONE			CRITERION TWO		
FOR POPULATION	FOR 5/6 TEST	FOR 20/24 RETEST	FOR TEST PLUS RETEST	FOR 5/6 TEST	FOR 20/24 RETEST	FOR TEST PLUS RETEST
1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.990	0.999	1.000	1.000	0.941	0.786	0.987
0.980	0.994	1.000	1.000	0.886	0.616	0.956
0.970	0.988	0.999	1.000	0.833	0.481	0.913
0.960	0.978	0.998	1.000	0.783	0.375	0.864
0.950	0.967	0.994	1.000	0.735	0.292	0.812
0.940	0.954	0.987	0.999	0.690	0.227	0.760
0.930	0.939	0.977	0.999	0.647	0.175	0.709
0.920	0.923	0.961	0.997	0.606	0.135	0.659
0.910	0.905	0.941	0.994	0.568	0.104	0.613
0.900	0.886	0.915	0.990	0.531	0.080	0.569
0.880	0.844	0.847	0.976	0.464	0.047	0.489
0.860	0.800	0.761	0.952	0.405	0.027	0.421
0.840	0.753	0.663	0.917	0.351	0.015	0.361
0.820	0.704	0.561	0.870	0.304	0.009	0.310
0.800	0.655	0.460	0.814	0.262	0.005	0.266
0.780	0.606	0.366	0.750	0.225	0.003	0.227
0.760	0.558	0.283	0.683	0.193	0.001	0.194
0.740	0.510	0.213	0.614	0.164	0.001	0.165
0.720	0.464	0.156	0.548	0.139	0.000	0.139
0.700	0.420	0.111	0.484	0.118	0.000	0.188
0.680	0.378	0.077	0.426	0.099	0.000	0.099
0.660	0.338	0.052	0.372	0.083	0.000	0.083
0.640	0.301	0.034	0.325	0.069	0.000	0.069
0.620	0.266	0.022	0.282	0.057	0.000	0.057
0.600	0.233	0.013	0.243	0.047	0.000	0.047
0.580	0.203	0.008	0.209	0.038	0.000	0.038
0.560	0.176	0.005	0.180	0.031	0.000	0.031
0.540	0.152	0.003	0.155	0.025	0.000	0.025
0.520	0.129	0.001	0.130	0.020	0.000	0.020
0.500	0.109	0.000	0.110	0.016	0.000	0.016
0.460	0.076	0.000	0.076	0.009	0.000	0.009
0.420	0.051	0.000	0.051	0.005	0.000	0.005
0.380	0.032	0.000	0.032	0.003	0.000	0.003
0.340	0.020	0.000	0.020	0.002	0.000	0.002
0.300	0.011	0.000	0.011	0.001	0.000	0.001
0.260	0.006	0.000	0.006	0.000	0.000	0.000
0.220	0.003	0.000	0.003	0.000	0.000	0.000
0.180	0.001	0.000	0.001	0.000	0.000	0.000
0.140	0.000	0.000	0.000	0.000	0.000	0.000

FIGURE 1
BINOMIAL PROBABILITY EQUATIONS

$$P_{(T)_{xi}} = \frac{n!}{xi!\,(n - xi)!}\,(P_o)^{n}\,(1 - P_o)^{(n - xi)}$$

$$P_{(T)_{x=1\ to\ i}} = P_{(T)_{x1}} + P_{(T)_{x2}} + \ldots + P_{(T)_{xi}}$$

$$ECT_{MIN} = ECT_{SPEC} + Z_{(T)_{x=1\ to\ xi}}\,(S.D.)$$

WHERE:

n = THE NUMBER OF INDIVIDUAL OBSERVATIONS IN A SINGLE TEST SET.

xi = THE NUMBER OF TIMES THAT THE DESIRED RESULT IS OBSERVED IN A SINGLE TEST SET.

P_o = THE PROBABILITY OF THE DESIRED RESULT IN THE ACTUAL POPULATION REPRESENTED BY THE TEST SET SAMPLE.

$P_{(T)_{xi}}$ = THE TOTAL PROBABILITY OF OBSERVING THE DESIRED RESULT xi TIMES IN A SINGLE TEST SET.

ECT_{MIN} = THE MINIMUM POPULATION AVERAGE ECT NEEDED TO ACHIEVE THE COMPLIANCE PROBABILITY $P_{(T)_{x1,i}}$.

ECT_{SPEC} = THE SPECIFICATION MINIMUM ECT.

$Z_{(T)_{x=1\ to\ i}}$ = THE NUMBER OF STANDARD DEVIATION UNITS CORRESPONDING TO $P_{(T)_{x=1\ to\ i}}$.

S.D = THE STANDARD DEVIATION OF ECT WITHIN THE ACTUAL POPULATION.

FIGURE 2

ITEM 222/RULE 41 ECT STATISTICAL EQUATIONS

FOR CRITERIA ONE, 5/6 TEST.

$$P_{5/6} = 6(P_o)^5 - 5(P_o)^6$$

FOR CRITERIA ONE, 20/24 RETEST.

$$P_{20/24} = 8855(P_o)^{24} - 36960(P_o)^{23} + 57960(P_o)^{22} - 40480(P_o)^{21} + 10626(P_o)^{20}$$

FOR CRITERIA TWO, 5/6 TEST

$$P_{5/6} = P_o^6$$

FOR CRITERIA TWO, 20/24 RETEST.

$$P_{20/24} = P_o^{24}$$

FOR COMBINED TEST + RETEST.

$$P_T = P_{5/6} + (1 - P_{5/6})(P_{20/24})$$

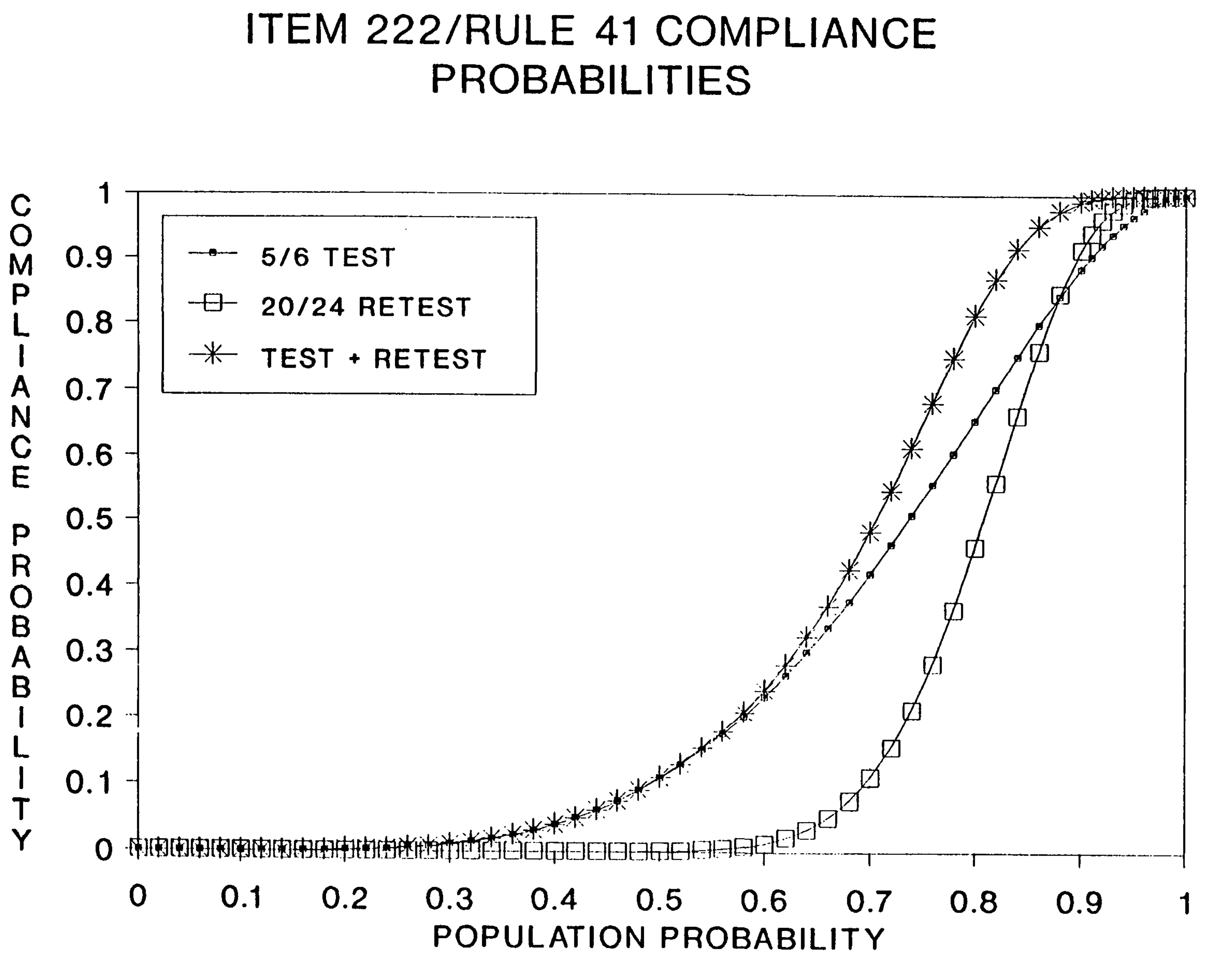
ITEM 222/RULE 41 COMPLIANCE
PROBABILITIES
5/6 TEST
20/24 RETEST
TEST + RETEST
COMPLIANCE PROBABILITY
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
POPULATION PROBABILITY

FIGURE 3

ITEM 222/RULE 41 ECT COMPLIANCE MINIMUM BOX LOT AVERAGE CALCULATIONS

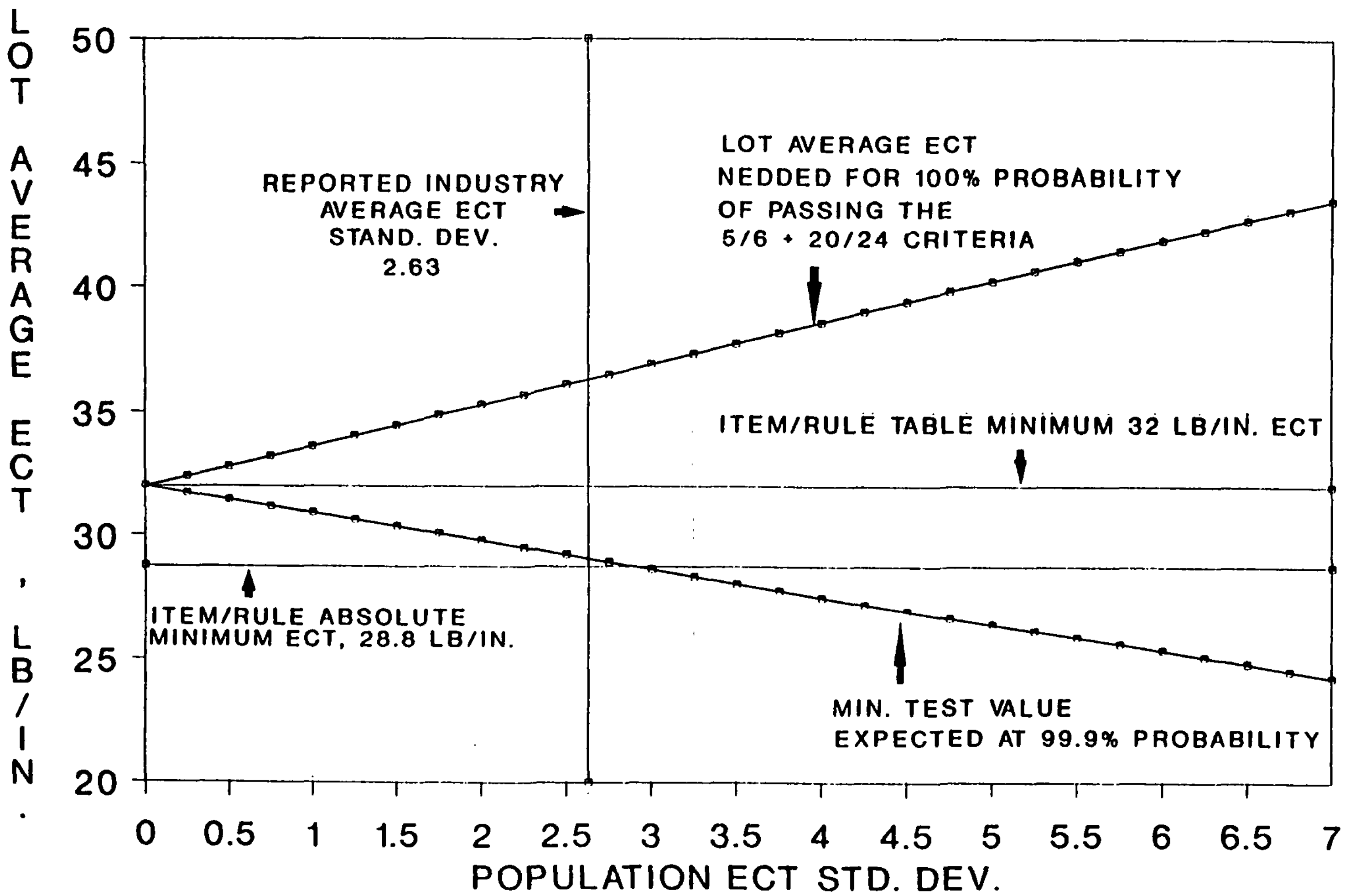

FIGURE 4

ITEM 222/RULE 41 ECT COMPLIANCE
MINIMUM BOX LOT AVERAGE CALCULATIONS

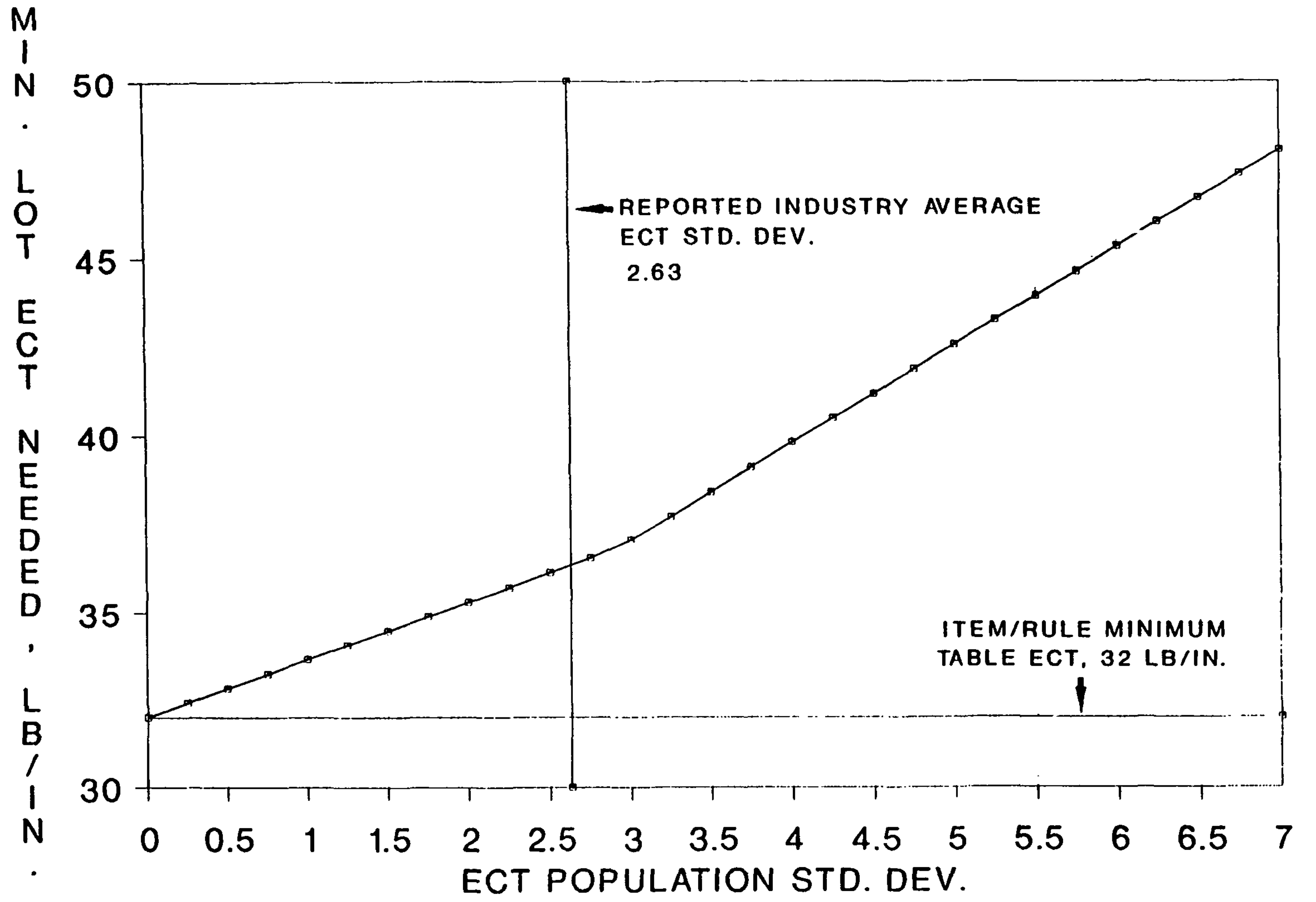

FIGURE 5