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ISOTESTER®: ADVANCED COLOR + TRASH MEASUREMENTS FOR GIN PROCESS CONTROL AND FOR CLASSING

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Abstract

IsoTester® provides modern, image-based, internet-ready technology for measurement of lint Color + Trash. Performance results for 2 standard IsoTesters, owned by USDA/AMS/Memphis, will be seen to be comparable in accuracy and superior in precision to HVI methods. These results are for conventional data products, lint Rd & +b and trash particle Count & %Area. IsoTester Leaf Grade measurements, a new data product based using charts of C & %A, will be seen to similarly track Human Classers in accuracy and precision. Other new data products will also be discussed.

Overview

In the 2004 Ginning Season, there were 34 IsoTesters (or their predecessor RapidTesters) in operation in the United States. 27 of these installations were in gins. In the 2003 season, there were 17 gin-based installations. (Figures 1,2 and 3) We in STI express our thanks to those leading Ginners who have made this significant growth in market share possible. There are sound economic and technical reasons for these Ginners' choices. We will present some of the technical reasons here.

We also thank the visionary folks at USDA/AMS and Cotton Incorporated, who have not only purchased IsoTesters but have encouraged some of our recent innovations. These extensions from our standard IsoTester Color + Trash methods can dramatically facilitate our industry's moving to instrument Leaf Grade for official classing purposes, now actively under consideration. (Other image-based Trash measurements are feasible: Bark/Grass, Preparation, etc.)

Broadly and boldly speaking, we claim that these are the primary reasons that Ginning and Classing Customers are increasingly finding favor with the IsoTester C + T method:

A. One IsoTester C + T can cost-effectively provide <u>conventional</u> data products currently produced by 3 older methods, with comparable accuracy and superior precision;

B. The modern, image-based, internet-ready, IsoTester C + T method enables significant improvements in conventional data products; and

C. New, <u>non-conventional</u> data products are enabled by the modern, internet-ready, image-based IsoTester measurement and communications technologies.

To substantiate Claim A, extensive results are presented in Section 2 on IsoTester accuracies and precisions, for conventional data products. IsoTester readings are compared to 3 older methods: HVI colorimeter (Rd & +b), HVI trashmeter (Count & %Area), and Human Classer (LG).

Substantiation of Claim B is beyond the scope of this paper. We do note that most (6 out of 9!) of IsoTester's distinct measurement advantages are disabled for the data reported in this paper. This is to force the responses to be like the older measurement technologies and thereby "track" them, i.e., to provide comparable conventional data products. Re-enabling these advantages will surely be justified in due course by market forces.

To substantiate Claim C, we focus in Section 3 on justifying use of charts of IsoTester trash particle Count, C, and Percentage Area, %A, to predict Human Classer Leaf Grades. This is a new data product. Use of C - %A charts was first published by Norma McDill, USDA/AMS Cotton Program Deputy Administrator, and her Colleagues at the 2004 Beltwide, is a "hot topic" these days, and will be appropriately emphasized here.

We briefly offer in the Concluding Section 4 two other non-conventional data products in the spirit of "food-for-thought:" lint-only color and NIST-traceable color. These data products were anticipated at the outset of the color image-based C + T conceptual designs in 1999. These new data products are easily enabled and the transitions from conventional to non-conventional can be commercial market driven and quickly and orderly implemented.

IsoTester® Accuracies and Precisions

All of the data reported in this paper are from tests performed with 2 standard IsoTesters C + T owned and operated by AMS and located in Memphis, Tennessee. The tests were executed over approximately the past year. We focus in this Section (and part of the next Section) on 3331 very special samples collected by AMS in the 2004 - 2005 ginning season. (Figure 4) These samples were obtained from all Classing Offices and represent a wide range of Leaf Grade, from LG = 1 to LG = 7.

Nominally 10 samples/week for each leaf grade were collected and sent to the Standards Section in Memphis. These samples are special because of the intentionally constant or flat histogram distributions with respect to LG, rather than the usual, "bell-shaped" distributions in LGs per Classing Office. This distribution enables a more thorough evaluation of instrumental leaf grade prediction methods because, as is well known, some regions rarely see LGs > 4 and others rarely see LGs < 2. Approximately 8000 such "Leaf Study" samples will be obtained by AMS Standards Section/Memphis by the end of the 2004 - 2005 season.

These 3331 samples were tested on the 2 standard IsoTesters, on HVI and by Human Classers, from early November to mid-December 2004. All 8000 samples will eventually be tested on 2 HVIs and by 2 Human Classers. A massive database is in the process of being compiled, a small part of which is presented here or in the companion paper by Gretchen Deatherage in the Fiber Quality Measurements Conference. These 2 papers, as well as the preceding paper by Steve Grantham, should be considered progress reports on major works in process.

The ten Figures 5 through 14 all have the same form and appear as five pairs of scatter plot graphs. The abscissa of the first scatter plot of each pair gives the AMS standards readings and the ordinate gives the corresponding IsoTester readings, for the 3331 samples. The second of the pair of graphs gives IsoTester 1 readings on the abscissa and IsoTester 2 on the ordinate. All data products are conventional. IsoTester Trash readings are for 28 in^2 per tested face, whereas HVI readings are for 9 in^2 per tested face. The data reported in all graphs here are for 4 faces, for both IT or HVI. Two of the faces are the tops of the usual, as-received Classer's samples; the other two are the bottoms.

Accordingly, Figures 5 and 6 show Rd responses: IsoTester vs HVI colorimeter and IsoTester vs IsoTester, respectively.

Figures 7 and 8 similarly show +b responses: IsoTester vs HVI colorimeter and IsoTester vs IsoTester, respectively.

Figures 9 and 10 show trash particle count C per 9 in^2: IsoTester vs HVI trashmeter and IsoTester vs IsoTester, respectively. Note: IsoTester C readings, which are for 4 x 28 in^2, are reduced by 9/28 for direct comparisons to 4 x 9 in^2, for HVI trashmeter readings.

Figures 11 and 12 show trash particle %A: IsoTester vs HVI trashmeter and IsoTester vs IsoTester, respectively.

Figures 13 and 14 show Leaf Grades: IsoTester vs Human Classer and IsoTester vs IsoTester. These IsoTester Leaf Grades by circular chart, LGcc, a new or non-conventional data product to be explained in the next section. LGcc results are presented in this Section because of the similarity of format and to support the strong conclusions about accuracies and precisions.

These scatter plots of the one IsoTester C + T method vs 3 older methods, HVI colorimeter, HVI trashmeter, and Human Classer, are self-explanatory, as are data comparing IsoTester #2 to IsoTester #1.

Some strong and important conclusions may be drawn from this large set of data on these very special samples:

The IsoTester method exhibits equivalent accuracy to the older methods

Since the linear regression analyses of 3331 bale by bale readings from two instruments have essentially 1:1 slopes and zero offsets, it may be concluded that the methods have essentially identical accuracies. That is, in the average over large sample set, the methods respond similarly to real cotton samples and are on the same levels. Evidently upon inspection, they do, in every case, rather well. They should, since the IsoTesters are forced by calibrations to respond like the older methods.

(Careful examination of these plots in fact reveals small differences in slopes, intercepts and "scatter," discussed next. Slope and intercept differences are worthy of scrutiny and some explanations already exist. But these small differences are subordinate to the main conclusion of similarly accurate responses.)

The IsoTester method exhibits superior precision to the older methods

Since the "scatter" around the 1:1 line is larger for the IsoTester vs standard readings (HVI or Human Classer) than for IsoTester vs IsoTester, it may be concluded that the IsoTester method is more precise. This conclusion relies upon the realistic assumption that the scatter is random. It is expected because of the larger sample area.

In these pairs of plots, scatter is quantitatively measured by the correlation coefficient R^2; the lower the R^2, the higher the scatter. Evidently upon inspection of the scatter plots, IsoTesters vs Standards methods have lower R^2, or lower precision, than IsoTester vs IsoTester except for Rd, where the R^2 are the same at ~ 0.92.

It is noted, for completeness, that sustainabilities and biases can, in principle, also be used for comparisons of performance. Such determinations unavoidably require the implicit assumption that one of the methods (usually the older one) is "right," i.e., absolutely accurate, with zero random error. The other method is then compared to it, in a wide variety of statistical ways, to assess accuracy and precision performance. The fact that both methods have their respective inaccuracy and imprecision is often ignored. Improperly applied and interpreted, such determinations can yield erroneous conclusions and can impede progress.

Never-the-less, we note that sustainability determinations for conventional data products are under investigation and refinement. We report here first results with a Histogram – Sustainability Presentation which compares Human Classer Leaf Grade with IsoTester Leaf Grade, LGcc. This analysis and presentation may be generally applied to any measurements but always with the above implicit assumption.

Leaf Grade Predictions via C & %A Chart Methods

Figures 17 – 21 are charts of IsoTester C & %A for the indicated Human Classer Leaf Grades = 1, 2, 3, 4 and 5, respectively. Evidently, there is a clear pattern of jointly and generally increasing C & %A with increasing LG. These data are for a set of 2074 samples which were tested on the same 2 AMS IsoTesters at the end of 2003 and beginning of 2004, from the 2003 crop. They are representative of the crop, with more samples having LG = 3, and almost no LG = 6 or 7, and are thus unlike the special 3331 set of the previous section and later of this section.

Rectangular, circular and hyperbolic boundaries in C & %A have been investigated to the ends of predicting Human Classer Leaf Grades. For examples, consider the circular boundaries in Figures 17 – 21. Evidently, most of the blue diamond data points lie between the respective boundaries. That is, for example, in Figure 19 for Human Classer LG = 3, most of the blue diamond points lie in the C & %A chart region marked 3. (Recall that the IsoTester reports decimal LG.)

We report here, for the first time, preliminary results for LGcc only, for the special 3331 samples described above, with these notes:

a. LGrect and LGhyp yield similar results;
b. These results for 3331 samples appear, in preliminary analyses, to be the same for nearly 5400 special samples tested by the beginning of 2005;
c. There has been no optimization of boundaries for a year;
d. The standard IsoTesters at AMS are the only instruments from which LGcc results have been determined; and
e. All data reported here are also for 4 x 28 in^2 faces, ie, two replications, tops and bottoms, of the usual 2 Classer's Samples.

With regard to note c, it was our objective to first establish prediction and performance analysis methods, particularly including procedures for analyzing sustainabilities, before optimizing boundaries.

With respect to notes d and e, all other IsoTesters currently predict Leaf Grade via a neural network algorithm, using typically 2 x 28 in^2 faces. The LGcc results reported here were calculated directly from C & %A for each bale sample. Development and installation of new software with LGcc and other features are under consideration.

Referring now to Figures 23 and 24, a "Histogram – Sustainability Presentation" is shown, in 2 parts. The first part, Figure 23, shows the LGcc (IsoTester) and LG (Human Classer) histograms, with side by side bars, by integral Leaf Grade 1, 2,..etc.

Note the nearly flat histogram for these special 3331 samples by both the IsoTester and the Human Classers. Also note the accidentally perfect agreement of average LG = 3.61 for the IsoTester and for the Human Classers.

Particulary noteworthy is the third bar (light tan) for each LG in this first part of the Histogram – Sustainability Presentation. This is the by-class sustainability, Sj, which is a very useful tool for evaluating and refining any Leaf Grade prediction method. This calculation provides the ratio of, for example, those LGs = 3 called by the Human Classer which were also called LG = 3 (after rounding) by the IsoTester, or S3 = 72.3%. Ideal results would be by-class sustainability Sj =100%. Good results are reasonably high and consistent Sjs, as seen in the bar graphs of part one, Figure 23.

The calculations of Sj, which the interested reader will find informative, and other information are seen in part two of the Histogram – Sustainability Presentation, Figure 24. The primary other information in part two are the "spot – on" sustainability, So, along with the +/-1 LG, etc results, in histogram form. The So ~ 63% seen here is typical of results so far, which, again, are not with optimized boundaries. This sustainability figure may sound lower than usually reported but it is correct, as may be intuitively confirmed by carefully reviewing Figures 17 – 21.

The Histogram – Sustainability Presentation may be applied to any measurements. The next pair, Figures 25 and 26, show comparisons of IsoTester 2 to IsoTester 1 for LGcc predictions. Obviously, and importantly, the Sjs and So are significantly higher than the previous case for IsoTester 1 vs Human Classer.

Accordingly, we can again conclude equivalent accuracy (or level) and superior precision (or reproducibility or sustainability) for the IsoTester LGcc method vs the Human Classer, in tracking C & %A. This new data product, which is still in active refinement, will be appreciated as a major step forward for moving to instrument Leaf Grade.

Conclusions

IsoTesters already produce conventional data products with comparable accuracies and superior precisions, when compared to older methods

The reader is kindly referred to Claim A of Section 1 and to its substantiation in Section 2. We may thus safely conclude that the IsoTester method, when limited to respond like the 3 older methods (colorimeter, trashmeter and Human Classer), produces conventional data of essentially identical accuracy (ie, level) and equal or superior precision to the older methods.

The conclusion headings correspond to the Claims A - C set forth in Section 1. There is no corresponding conclusion B, as that material is beyond the scope of this paper. We simply restate that re-enabling some of these currently disabled advantages will surely be justified in due course by market forces.

IsoTesters can produce meaningful, new, non-conventional data products.

New Data Product Example 1: Leaf Grade by Circular Chart Method, LGcc

The reader is kindly referred to Claim C of Section 1, and to its substantiation in Sections 2 and 3, for a first example of new and/or non-conventional data products enabled by the IsoTester method. We may also safely conclude that the new data product of LGcc is of equivalent accuracy and superior precision, when compared to Human Classer LG.

One of the primary objectives of this paper has been to defend and justify the validity of using chart methods to predict Human Classer Leaf Grade, a currently hot topic. One major justification for our industry's moving in this direction is the superior sustainability of IsoTester vs IsoTester, as seen above.

Another justification for LGcc is that the basic image processing results of C & %A are readily understood and rigorously calibratable. We note that some other figure of merit similar to Leaf Grade may be derived from C & %A and advantageously used for textile processing optimizations. We also note that other image parameters may be included.

As the final justification for chart methods presented here, we show images of 3 samples from the 3331 sample set, all 3 of which have LGcc ~ 3.5. That is, we searched the IsoTester database, which includes images as well as raw and final data, for extremes in C & %A for samples having the same LGcc ~ 3.5. The C & %A extremes are shown as A, B and C in the C & %A Chart of Figure 30. The images are seen in Figures 31, 32 and 33.

Thus we can take further justification in the validity of the chart method in the fact that these extremes are reasonably close. This is also seen in the original chart plots, Figures 17 – 21, wherein the LG clouds are seen to cluster around a diagonal line.

The following examples of non-conventional data products are not directly substantiated by the large set of results in Sections 2 and 3. Their proofs rely on the basic principles (and original design intent) of the IsoTester method, which has been extensively reported in the open and patent literature. These examples are given here to illustrate new data products which move our industry toward more rigorous color measurements.

New Data Product Example 2: Measure color of lint only, not lint + trash

The IsoTester's image-based Color method permits exclusions of the deleterious effects of trash particle on lint color. This feature is currently disabled in all IsoTesters, so that Rd & +b will track the HVI colorimetric method. Colorimetry provides a spatially integrated value and thus cannot possibly exclude the degrading effects of trash particles.

New Data Product Example 3:Measure lint color in NIST-tracable CIE coordinates

The internal calculations in IsoTesters are already in CIE units. It is a straightforward task to calibrate IsoTesters to read Lab color coordinates (or XYZ or L*a*b*, etc), which can be traced to National Institute for Standards and Testing. We note that the calibration is easy but that the tracing to NIST on real cottons is non-trivial.

Bottom line

IsoTester conventional data products (Rd, +b; C, %A) may be confidently and advantageously used for commerce, in place of the older methods, since they exhibit comparable accuracies and superior precisions.

IsoTester LGcc, a new data product, certainly appears to have the potential to be quickly, confidently and advantageously used for commerce, in place of Human Classer readings of Leaf Grade.

IsoTester®: Advanced Color + Trash Measurement for Gin Process Control and for Classing

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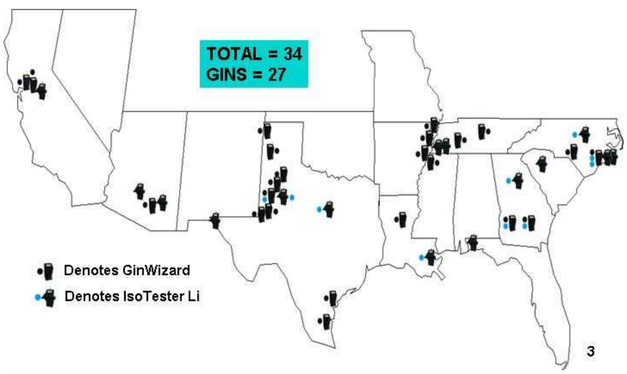

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AMS 3331 Samples Test Results

TESTS RUN AT AMS/MEMPHIS ON 2 STANDARD ISOTESTERS, AND ON HVI AND BY HUMAN CLASSERS
1 NOVEMBER – 15 DECEMBER 2004

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Fig. 5. Rd, AMS ISO1 vs HVI, 3331 SAMPLES, 4 FACES

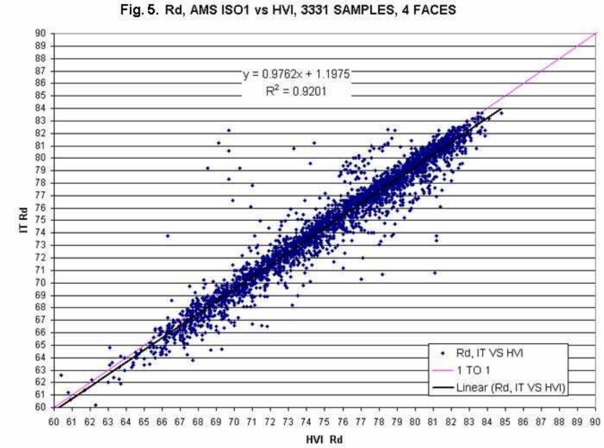

Fig. 6. Rd, AMS ISO1 vs ISO2, 3331 SAMPLES, 4 FACES

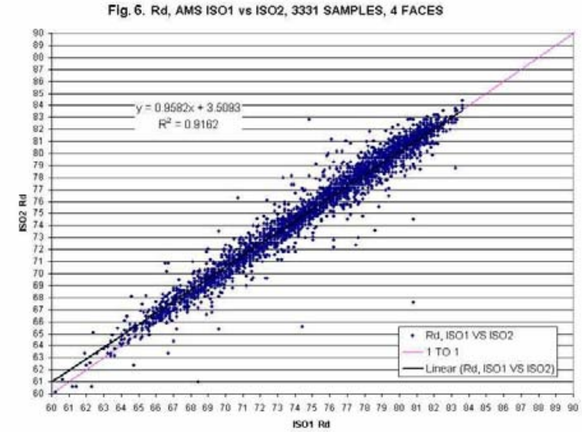

Fig. 7. +b, AMS ISO1 vs HVI, 3331 Samples, 4 Faces

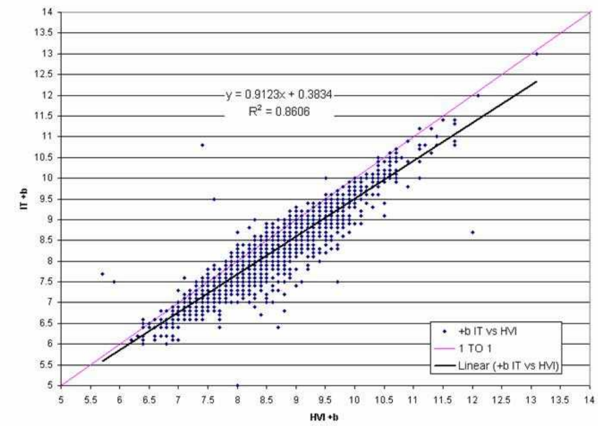

Fig. 8. +b, AMS ISO1 vs ISO2, 3331 Samples, 4 Faces

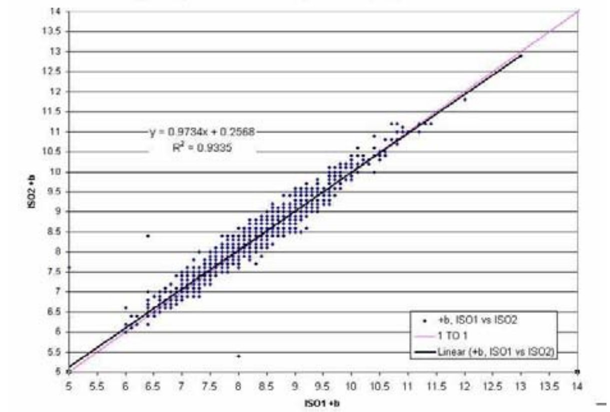

Fig. 9. Count Adjusted, ISO1 vs HVI, 3331 Samples, 4 Faces

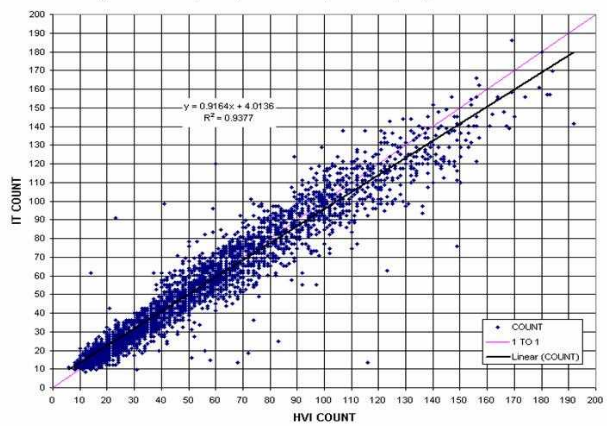

Fig. 10. Count Adjusted, ISO1 vs ISO2, 3331 Samples, 4 Faces

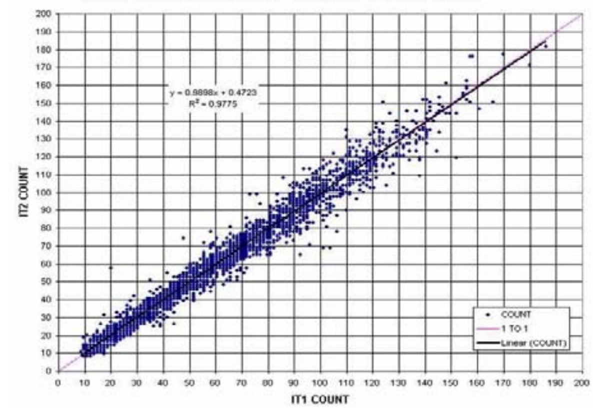

Fig. 11. %A, AMS ISO1 vs HVI, 3331 Samples, 4 FACES

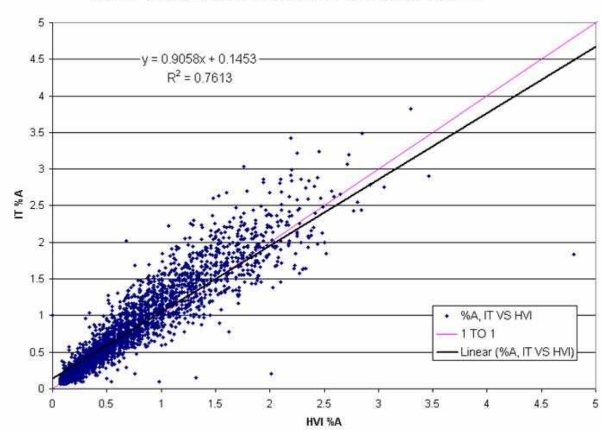

Fig. 12. %A, AMS ISO1 VS ISO2, 3331 SAMPLES, 4 FACES

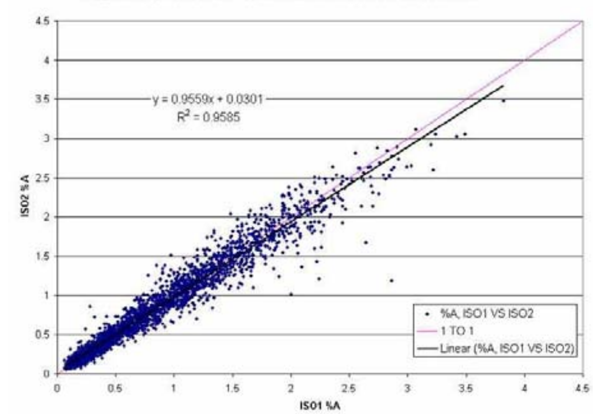

Fig. 13. **ISO1 LGcc DECIMAL VS HC LG**

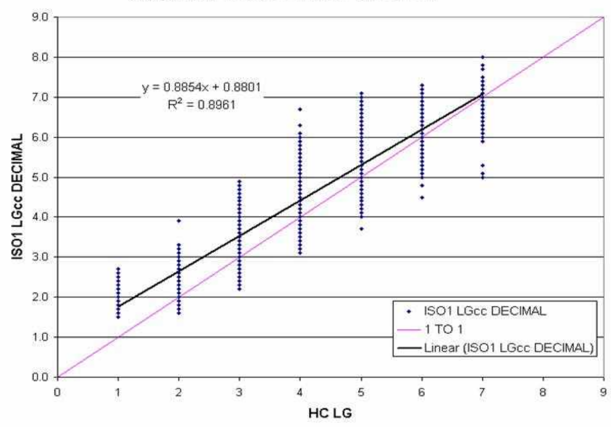

Fig. 14. **LGcc DECIMAL, ISO1 VS ISO2**

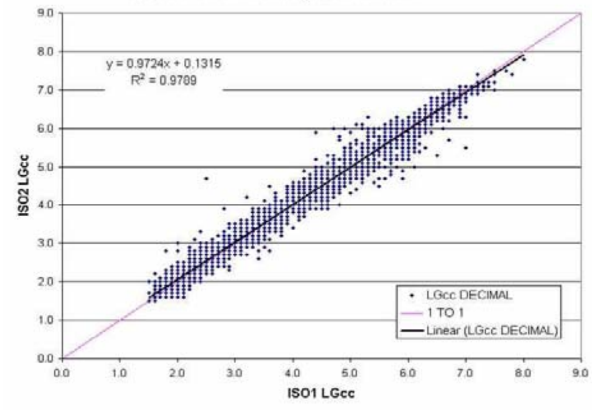

Chart Methods USING Counts & %Area to Predict Human Classer LGs

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AMS 1454 SAMPLES

- 1454 Samples are from 2003 Crop and were tested on AMS IsoTester #1 ~ Dec 03 to Jan 04.
- 4 x 28 in^2 faces; Software version as of end 2003, beginning 2004.
- Counts and %Area are adjusted to 9 in^2
- Counts and %Area Calibrated to HVI Levels

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Fig. 17. C & %A FOR HUMAN CLASSER LG=1

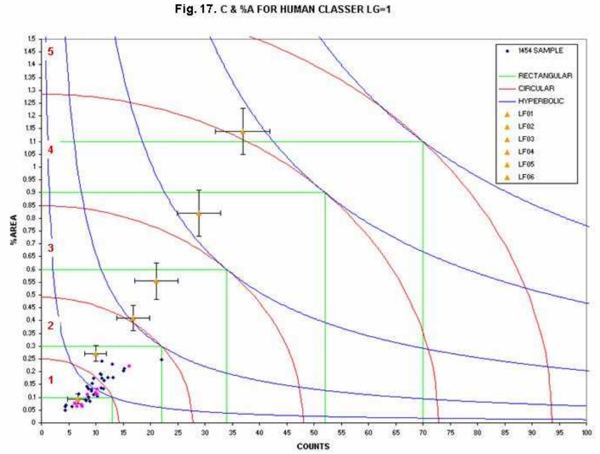


Fig. 18. C & %A FOR HUMAN CLASSER LG=2

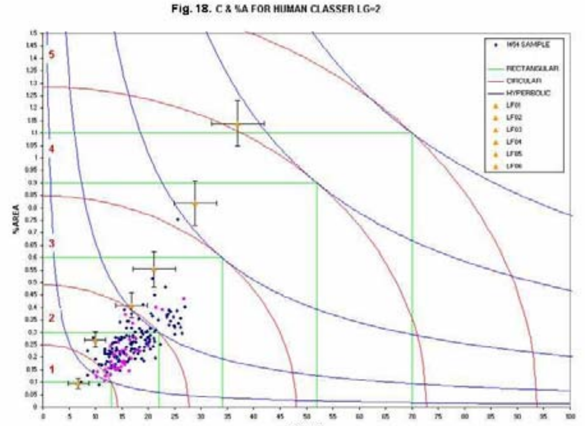


Fig. 19. C & %A FOR HUMAN CLASSER LG=3

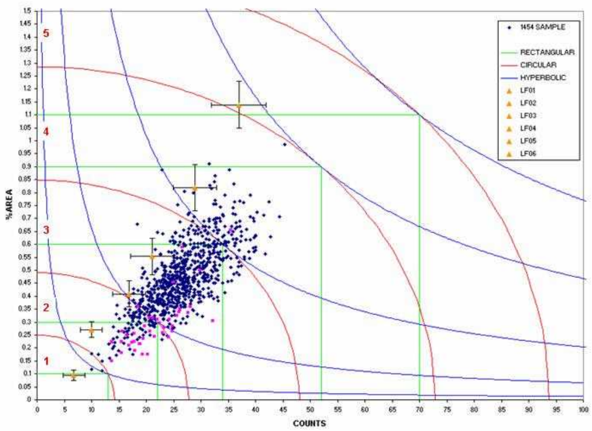


Fig. 20. C & %A FOR HUMAN CLASSER LG=4

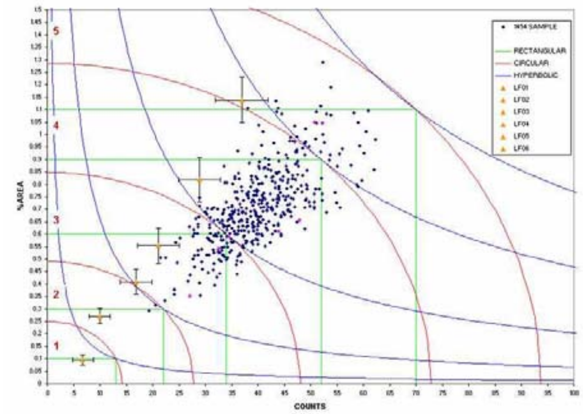
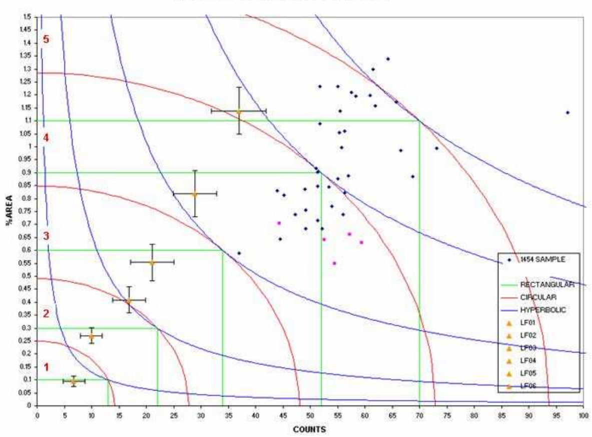


Fig. 21. C & %A FOR HUMAN CLASSER LG=5



AMS 3331 Samples Test Data

Continued

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Fig. 23. AMS ISOTESTER#1 LGcc VS HC LG, 4 X 28 in^2 FACES, N=3331

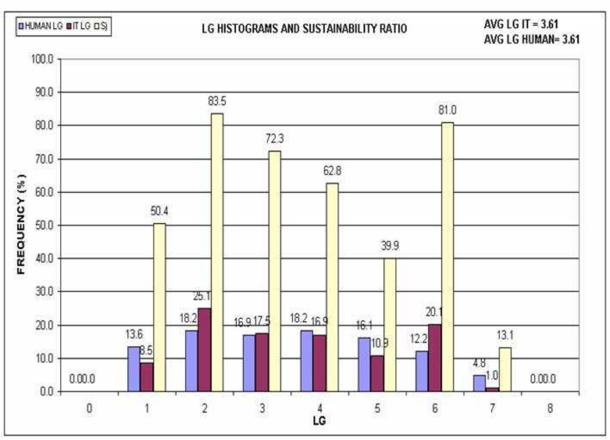
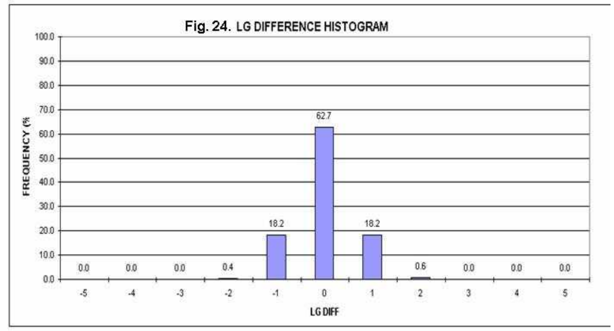


Fig. 24. LG DIFFERENCE HISTOGRAM



SUSTAINABILITY WITHIN LG CLASS j

LG	0	1	2	3	4	5	6	7	8	TOTAL
%Human LG	0.0	13.6	18.2	16.9	18.2	16.1	12.2	4.8	0.0	100.0
%IT LG	0.0	8.5	25.1	17.5	16.9	10.9	20.1	1.0	0.0	100.0
%IT LG Hits	0.0	6.8	15.2	12.2	11.4	6.4	9.8	0.6	0.0	62.7
Sj LG		50.4	83.5	72.3	62.8	39.9	81.0	13.1		57.6

Sj : Sustainability ratio, by LG class j

Fig. 25. AMS ISO2 LGcc VS ISO1 LGcc, 4 X 28 in^2 FACES, N=3331

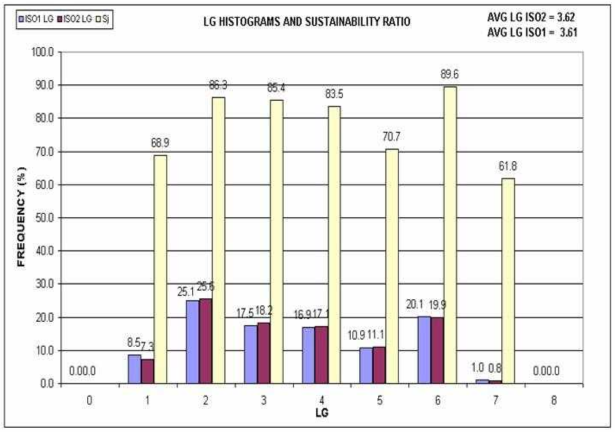
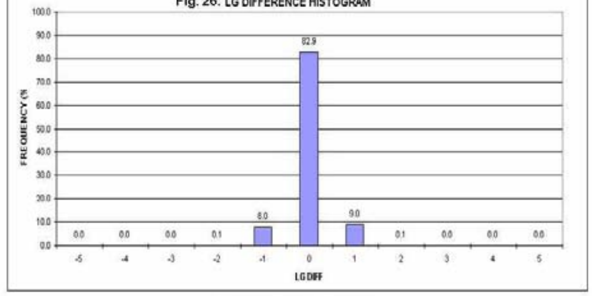


Fig. 26. LG DIFFERENCE HISTOGRAM



SUSTAINABILITY WITHIN LG CLASS j

LG	0	1	2	3	4	5	6	7	8	TOTAL
%Human LG	0.0	8.5	25.1	17.5	16.9	10.9	20.1	1.0	0.0	100.0
%IT LG	0.0	7.3	25.6	18.2	17.1	11.1	19.9	0.8	0.0	100.0
%IT LG Hits	0.0	5.9	21.6	14.9	14.1	7.7	18.0	0.6	0.0	82.9
Sj LG		68.9	86.3	85.4	83.5	70.7	89.6	61.8		78.0

Sj : Sustainability ratio, by LG class j

STI Claims

- **Claim A.** One IsoTester C + T can cost-effectively provide *conventional* data products currently produced by 3 older methods, with comparable accuracy and superior precision;

27

- **Claim B.** The modern, image-based, internet-ready, IsoTester C + T method enables significant improvements in conventional data products; and

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- **Claim C.** New, *non-conventional* data products were anticipated at the outset of the color image-based C + T conceptual designs.
- The transitions to broad commercial market usages can be easily, quickly and orderly implemented, provided the proper monetary incentives are in place.

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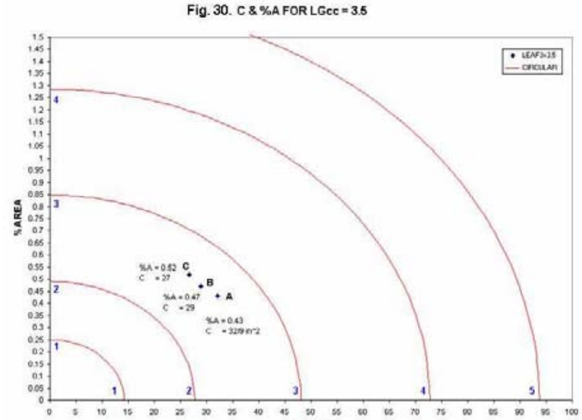
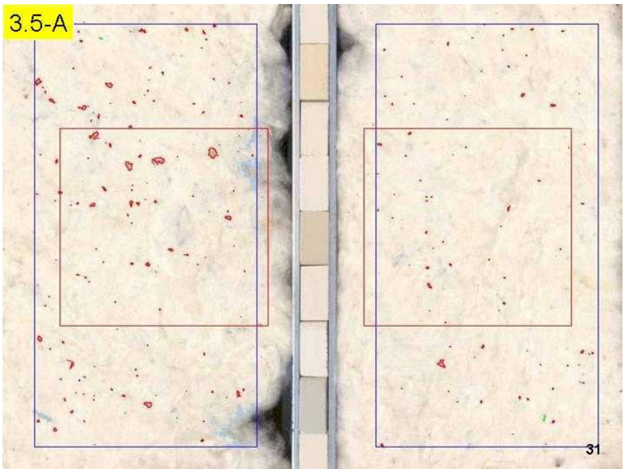
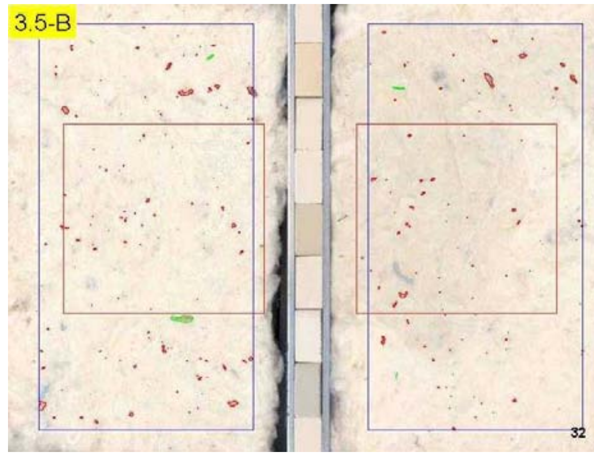
Fig. 30. C & %A FOR LGcc = 3.5




3.5-A
31


3.5-B
32


3.5-C
33