

To  
D. A. Turney - Columbiana

Date  
February 14, 1994

From  
S. Kopfelt - LRC

Copies To

G. L. Barna - Livermore  
P. R. Hilleman - Mexico  
G. E. Cooper - Mexico  
L. J. Bray-Scott - Mexico  
J. C. Brunner - Mexico  
F. S. Sutton - Columbiana  
J. D. Bailey - Tempe  
R. E. Farris - Merrillville  
G. A. McAuliffe - East Chicago  
T. D. Eales - Columbiana  
D. F. Wilson - Columbiana  
M. C. Hradil - Columbiana  
C. Hamilton - Columbiana  
J. S. Masaryk - Livermore  
R. B. Videtto - Livermore  
G. R. Angell - Livermore  
S. W. Sturgeon - Livermore  
D. J. Calkins - Livermore

Subject

Grindo Sonic -  
R&R<sup>1</sup> Krilex 621-2,  
9x4½x3  
(Columbiana, 11-19-93)

### SUMMARY

A Grindo Sonic<sup>2</sup> resonant frequency unit was subjected to a R&R Study. This gage capability test was conducted at the Columbiana Plant on Nov. 19, 1993 using Krilex 621-2 brick. The unit has excellent capability for measuring resonant frequency.

### CONCLUSIONS

1. The unit is compact and easy to operate.
2. The unit is suitable for a plant environment.
3. From the R&R test:
  - A. Operator average values are quite close (<0.0025 Khz; Fig. 1).
  - B. Operator deviation from the overall average is very small (<0.0015 Khz; Fig. 2)
4. Of the total test noise, the operator contributes only 15% (Page A-3)

<sup>1</sup> Repeatability and Reproducibility

<sup>2</sup> See Attached Brochure

5. For long term capability (<25% of spec), the tolerance range is 0.050 Khz (Fig. 3)

---

#### RECOMMENDATIONS

1. Prepare a project proposal to thoroughly evaluate the Grindo Sonic.
  - A. Correlation of resonant frequency with physical properties (variables).
  - B. Correlation of resonant frequency with brick defects (attributes).
  - C. Include more than one product and shape.
  - D. Include project flow time, manpower and funds required.
2. Review the potential of NDT via Grindo Sonic to replace or complement physical testing.
3. Learn through networking how other refractory producers and users are using the Grindo Sonic unit.

#### DISCUSSION

The R&R test was conducted using ten Krilex 621-2 straights (9x4½x3) and involved five operators. The operators were Mark Hradil, Svein Kopfelt, Andre van Leuven, Don Wilson and Chuck Hamilton. Andre ~~is the~~ Sales Engineer for J.W. Lemmens, Inc.. He brought the test unit to Columbiana for the trial.

Each brick in turn was set flat on a light to medium density foam support pad. A small screwdriver was used to tap the sample on the 9x4½ face. The Piezo Electric Probe was lightly held against the 9x3 face as the sample was tapped. (See Appendix pages A-1 to A-8).

The digital displayed reading in kilohertz<sup>1</sup> is the fundamental vibrational frequency of the sample. Repeated tappings of a sound brick yields the same frequency - plus or minus one to two units. The readings are displayed in less than two seconds after the impact. It's an easy and quick test to run.

<sup>1</sup>Hertz: A frequency of 1 cycle per second. A kilohertz is one thousand cycles per second.

D. A. Turney from S. Kopfelt  
February 14, 1994  
Page 3

The Lemmens Company does not claim that the unit is a flaw detector. It does claim non-stable kilohertz readings are likely if internal flaws are present in the sample. This claim was not verified during the R&R because it wasn't part of the test plan.

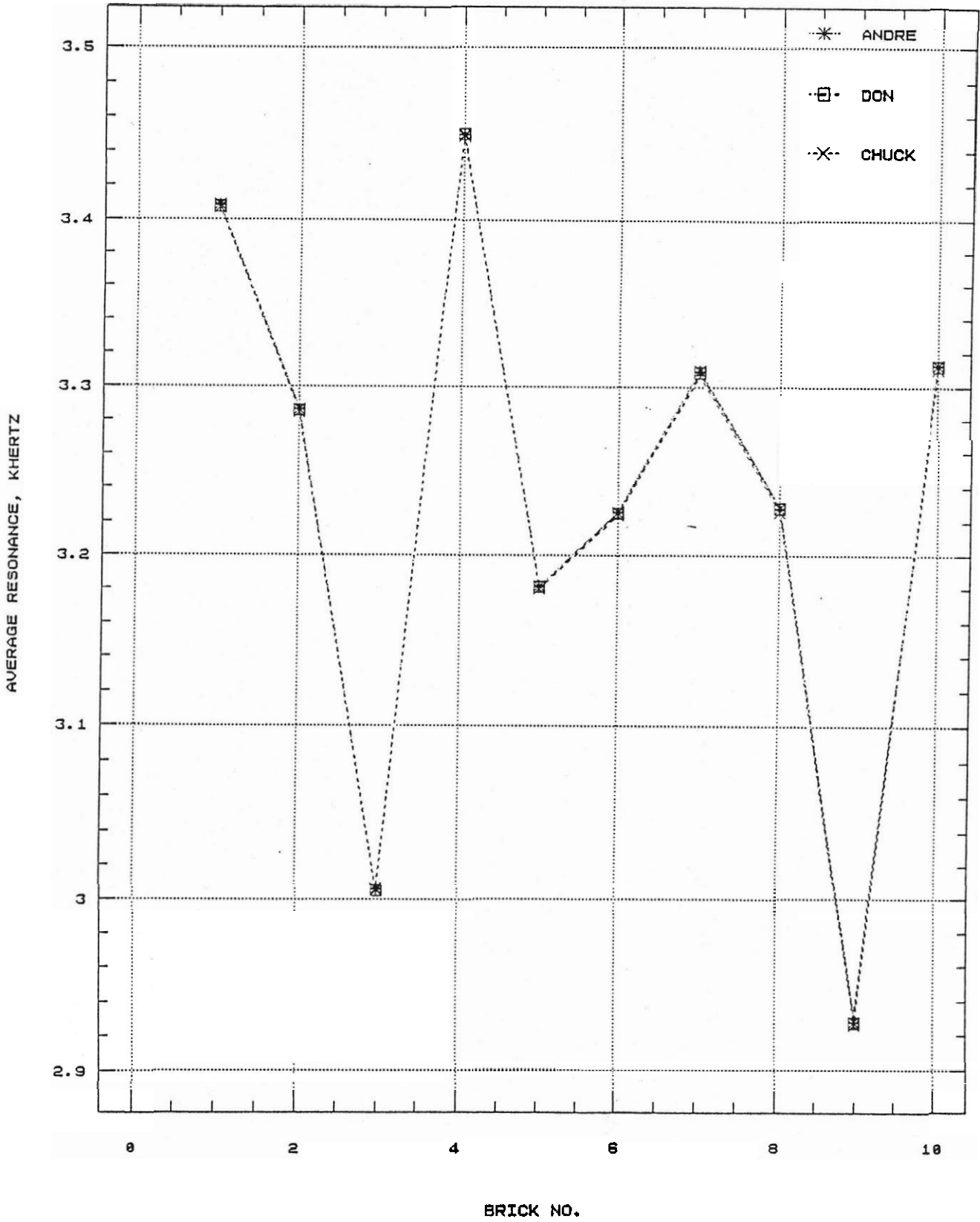
A potential use for the unit is to reduce destructive lot testing of product. And, non-steady readings may be useful when flaw sorting is required. The attached brochures from Lemmens (A-9 & A-10) illustrate the units potential in non destructive testing. They show good correlation coefficients for CMOR and CCCS and vibrational frequency.

The ASTM Subcommittee C28.01 (Properties and Performance) will publish a standard test method in 1995. The test is based on Lemmens unit. The test will yield dynamic Young's modulus, Shear modulus and Poisson's ratio for advanced ceramics. From an extensive round robin test array, coefficients of variation in frequency readings were <1.5%. The barest details of their work is in the Appendix (A-11). Additional information will be made available when ASTM formally releases the test method for general use.

Lemmens offers a two month rental plan for doing evaluation work. A portion of the rental is credited against the sale price if the unit is purchased. This presents an opportunity to obtain N.D.T. Data on some common shapes. Both basic and clay/alumina products could be included. However, a detailed testing plan is needed prior to renting a unit.

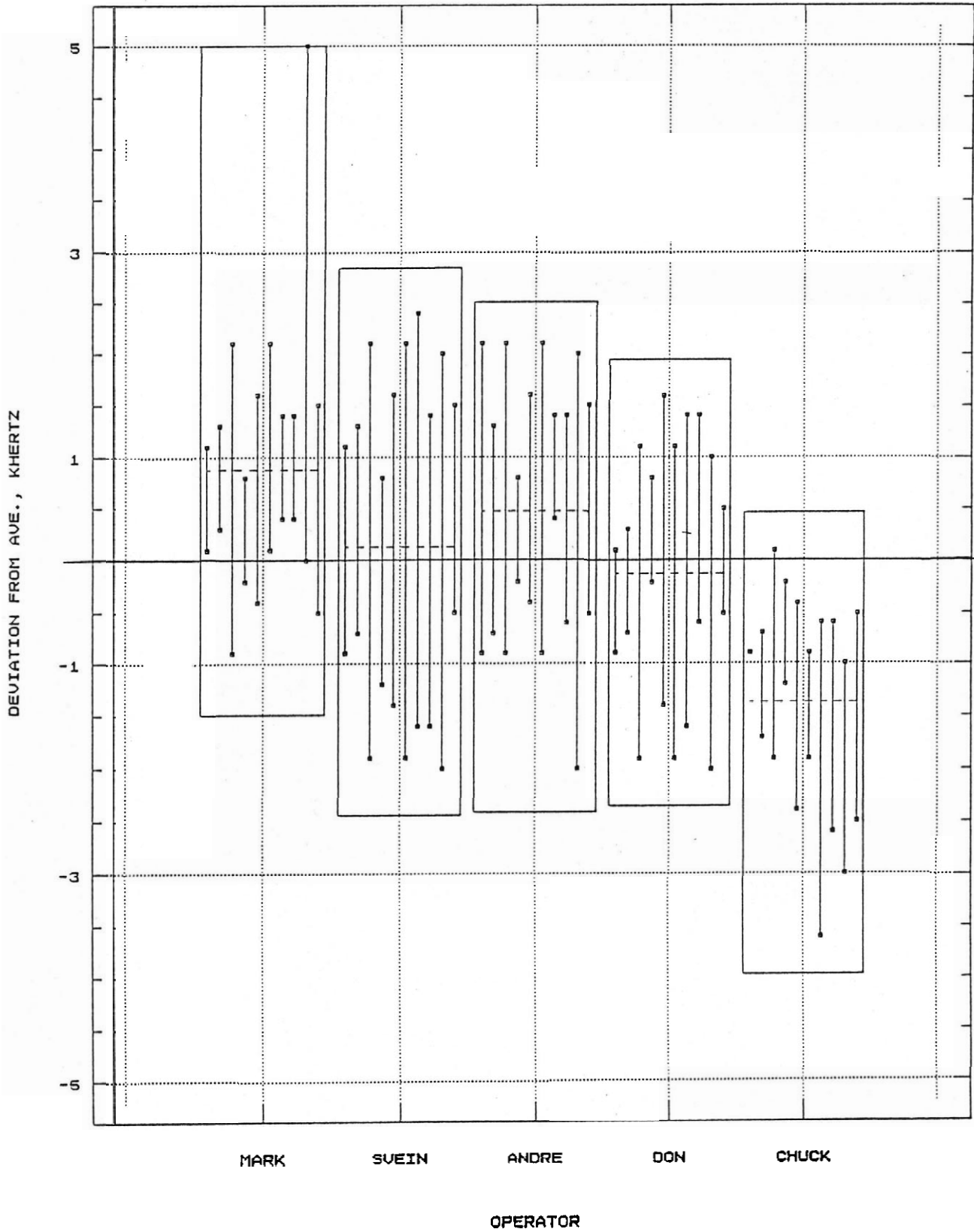
KRILEX 621-2 R&R GRINDO SONIC 11-19-93  
AVERAGE RESONANCE U.S. BRICK NO.

—•— MARK  
-+- SUEIN



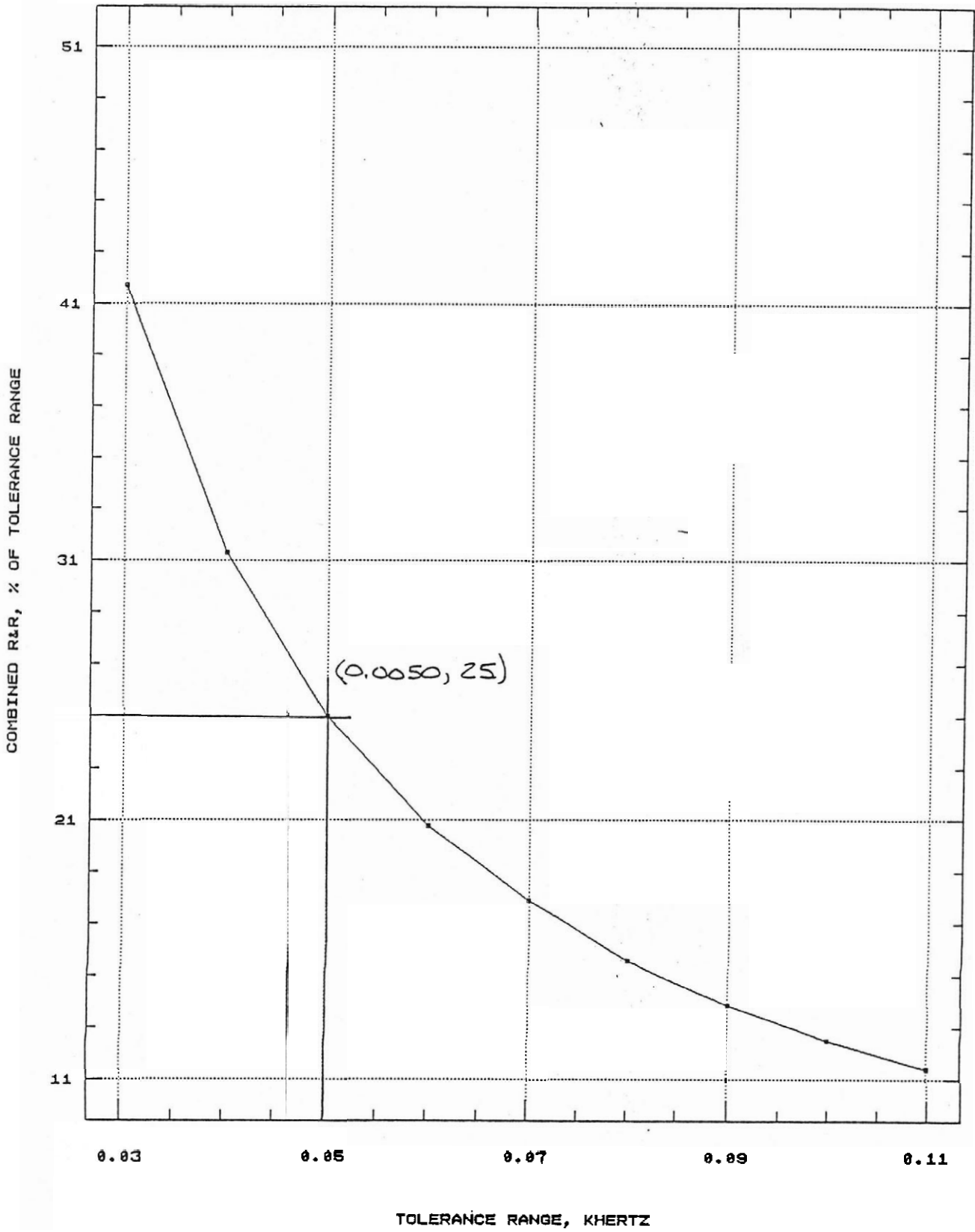
KRILEX 621-2 R&R GRINDO SONIC, 11-19-93  
DEVIATION FROM AVE. U.S. OPERATOR

(X 1E-3)



KRILEX 621-2 R&R GRINDO SONIC 11-19-93

COMBINED R&R v.s. TOLERANCE RANGE





## Variance Components

-----  
 Operators: 5    Parts: 10    Trials: 2    Rbar: 2.182E-3    R(xbar): 2.255E-3

|                 | Estimated<br>sigma | Estimated<br>variance | Percent<br>of total |
|-----------------|--------------------|-----------------------|---------------------|
| Repeatability   | 1.92346E-3         | 3.6997E-6             | 85.2                |
| Reproducibility | 8.02494E-4         | 6.43997E-7            | 14.8                |
| Combined R&R    | 2.08415E-3         | 4.3437E-6             | 100.0               |

## Percent Tolerance Analysis

-----  
 Tolerance: 0.050

Number of sigma intervals: 6.00

|                 | Measurement<br>units | Percent of<br>tolerance |
|-----------------|----------------------|-------------------------|
| Repeatability   | 0.0115408            | 23.1                    |
| Reproducibility | 4.81497E-3           | 9.6                     |
| Combined R&R    | 0.0125049            | <u>25.0</u>             |



Variance Components  
-----

Operators: 5    Parts: 10    Trials: 2    Rbar: 2.182E-3    R(xbar): 2.255E-3

|                 | Estimated<br>sigma | Estimated<br>variance | Percent<br>of total |
|-----------------|--------------------|-----------------------|---------------------|
| Repeatability   | 1.92346E-3         | 3.6997E-6             | 85.2                |
| Reproducibility | 8.02494E-4         | 6.43997E-7            | 14.8                |
| Combined R&R    | 2.08415E-3         | 4.3437E-6             | 100.0               |

Percent Tolerance Analysis  
-----

Tolerance: 0.110

Number of sigma intervals: 6.00

|                 | Measurement<br>units | Percent of<br>tolerance |
|-----------------|----------------------|-------------------------|
| Repeatability   | 0.0115408            | 10.5                    |
| Reproducibility | 4.81497E-3           | 4.4                     |
| Combined R&R    | 0.0125049            | <u>11.4</u>             |

| row | OPERATOR | BRICK | TRIALS | KHERTZ |
|-----|----------|-------|--------|--------|
| 1   | MARK     | 1     | 1      | 3.409  |
| 2   | MARK     | 2     | 1      | 3.287  |
| 3   | MARK     | 3     | 1      | 3.008  |
| 4   | MARK     | 4     | 1      | 3.450  |
| 5   | MARK     | 5     | 1      | 3.183  |
| 6   | MARK     | 6     | 1      | 3.227  |
| 7   | MARK     | 7     | 1      | 3.310  |
| 8   | MARK     | 8     | 1      | 3.229  |
| 9   | MARK     | 9     | 1      | 2.933  |
| 10  | MARK     | 10    | 1      | 3.314  |
| 11  | MARK     | 1     | 2      | 3.408  |
| 12  | MARK     | 2     | 2      | 3.286  |
| 13  | MARK     | 3     | 2      | 3.005  |
| 14  | MARK     | 4     | 2      | 3.449  |
| 15  | MARK     | 5     | 2      | 3.181  |
| 16  | MARK     | 6     | 2      | 3.225  |
| 17  | MARK     | 7     | 2      | 3.309  |
| 18  | MARK     | 8     | 2      | 3.228  |
| 19  | MARK     | 9     | 2      | 2.928  |
| 20  | MARK     | 10    | 2      | 3.312  |
| 21  | SVEIN    | 1     | 1      | 3.409  |
| 22  | SVEIN    | 2     | 1      | 3.287  |
| 23  | SVEIN    | 3     | 1      | 3.008  |
| 24  | SVEIN    | 4     | 1      | 3.450  |
| 25  | SVEIN    | 5     | 1      | 3.183  |
| 26  | SVEIN    | 6     | 1      | 3.227  |
| 27  | SVEIN    | 7     | 1      | 3.311  |
| 28  | SVEIN    | 8     | 1      | 3.229  |
| 29  | SVEIN    | 9     | 1      | 2.930  |
| 30  | SVEIN    | 10    | 1      | 3.314  |
| 31  | SVEIN    | 1     | 2      | 3.407  |
| 32  | SVEIN    | 2     | 2      | 3.285  |
| 33  | SVEIN    | 3     | 2      | 3.004  |
| 34  | SVEIN    | 4     | 2      | 3.448  |
| 35  | SVEIN    | 5     | 2      | 3.180  |
| 36  | SVEIN    | 6     | 2      | 3.223  |
| 37  | SVEIN    | 7     | 2      | 3.307  |
| 38  | SVEIN    | 8     | 2      | 3.226  |
| 39  | SVEIN    | 9     | 2      | 2.926  |
| 40  | SVEIN    | 10    | 2      | 3.312  |
| 41  | ANDRE    | 1     | 1      | 3.410  |
| 42  | ANDRE    | 2     | 1      | 3.287  |
| 43  | ANDRE    | 3     | 1      | 3.008  |
| 44  | ANDRE    | 4     | 1      | 3.450  |
| 45  | ANDRE    | 5     | 1      | 3.183  |
| 46  | ANDRE    | 6     | 1      | 3.227  |
| 47  | ANDRE    | 7     | 1      | 3.310  |
| 48  | ANDRE    | 8     | 1      | 3.229  |
| 49  | ANDRE    | 9     | 1      | 2.930  |
| 50  | ANDRE    | 10    | 1      | 3.314  |
| 51  | ANDRE    | 1     | 2      | 3.407  |
| 52  | ANDRE    | 2     | 2      | 3.285  |
| 53  | ANDRE    | 3     | 2      | 3.005  |
| 54  | ANDRE    | 4     | 2      | 3.449  |
| 55  | ANDRE    | 5     | 2      | 3.181  |
| 56  | ANDRE    | 6     | 2      | 3.224  |

- DATA FROM 11-19-93 GAGE  
CAPABILITY STUDY AT COLUMBIANA

- TEST UNIT: GRINDOSONIC

- SAMPLES: KRILEX 621-2  
9 x 4 1/2 x 3 STRT.

| row | OPERATOR | BRICK | TRIALS | KHERTZ |
|-----|----------|-------|--------|--------|
| 57  | ANDRE    | 7     | 2      | 3.309  |
| 58  | ANDRE    | 8     | 2      | 3.227  |
| 59  | ANDRE    | 9     | 2      | 2.926  |
| 60  | ANDRE    | 10    | 2      | 3.312  |
| 61  | DON      | 1     | 1      | 3.408  |
| 62  | DON      | 2     | 1      | 3.286  |
| 63  | DON      | 3     | 1      | 3.007  |
| 64  | DON      | 4     | 1      | 3.450  |
| 65  | DON      | 5     | 1      | 3.183  |
| 66  | DON      | 6     | 1      | 3.226  |
| 67  | DON      | 7     | 1      | 3.310  |
| 68  | DON      | 8     | 1      | 3.229  |
| 69  | DON      | 9     | 1      | 2.929  |
| 70  | DON      | 10    | 1      | 3.313  |
| 71  | DON      | 1     | 2      | 3.407  |
| 72  | DON      | 2     | 2      | 3.285  |
| 73  | DON      | 3     | 2      | 3.004  |
| 74  | DON      | 4     | 2      | 3.449  |
| 75  | DON      | 5     | 2      | 3.180  |
| 76  | DON      | 6     | 2      | 3.223  |
| 77  | DON      | 7     | 2      | 3.307  |
| 78  | DON      | 8     | 2      | 3.227  |
| 79  | DON      | 9     | 2      | 2.926  |
| 80  | DON      | 10    | 2      | 3.312  |
| 81  | CHUCK    | 1     | 1      | 3.407  |
| 82  | CHUCK    | 2     | 1      | 3.284  |
| 83  | CHUCK    | 3     | 1      | 3.004  |
| 84  | CHUCK    | 4     | 1      | 3.448  |
| 85  | CHUCK    | 5     | 1      | 3.179  |
| 86  | CHUCK    | 6     | 1      | 3.223  |
| 87  | CHUCK    | 7     | 1      | 3.305  |
| 88  | CHUCK    | 8     | 1      | 3.225  |
| 89  | CHUCK    | 9     | 1      | 2.925  |
| 90  | CHUCK    | 10    | 1      | 3.310  |
| 91  | CHUCK    | 1     | 2      | 3.407  |
| 92  | CHUCK    | 2     | 2      | 3.285  |
| 93  | CHUCK    | 3     | 2      | 3.006  |
| 94  | CHUCK    | 4     | 2      | 3.449  |
| 95  | CHUCK    | 5     | 2      | 3.181  |
| 96  | CHUCK    | 6     | 2      | 3.224  |
| 97  | CHUCK    | 7     | 2      | 3.308  |
| 98  | CHUCK    | 8     | 2      | 3.227  |
| 99  | CHUCK    | 9     | 2      | 2.927  |
| 100 | CHUCK    | 10    | 2      | 3.312  |