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An examination of some aspects of the use of ISO 140 Part 4 and 7 in field measurements.

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ABSTRACT

In recent years the Association of Noise Consultants, in collaboration with Robust details Ltd and the Building Research Establishment, has conducted a number of round robins to examine the repeatability of field measurements[2 and 7]. This paper examines some of the data from a new round robin conducted in 2008 which has provided the opportunity to examine the reproducibility of field test methods.

The reproducibility of the Manually Moving Microphone (MMM) technique is examined and compared to the Reproducibility Values from ISO 140 Part 2[6]. These results are also considered in the light of the repeatability of the MMM technique and the effect of the 'body in the room'.

In Section 5 of ISO 140 Part 4[1], there is some limited guidance on the use of diffusers for field measurements. The data set from this new round robin allows an examination to be made of the reproducibility of field measurements when diffusers are used in non-coupled room mode situations compared to not using diffusers at all.

ISO 140 is interpreted by many acousticians differently, allowing a wide range of testing methods and approaches. The Inspectors employed by Robust Details Ltd conduct their tests using a constrained interpretation of ISO 140[1]. The reproducibility of this constrained testing method is compared to the reproducibility achieved by ANC registered testers who are free to interpret ISO 140 as they choose.

The data set also provides a unique opportunity to examine the reproducibility of impact tests for the first time for field measurements. The effects of diffusers and a constrained testing regime are also examined for impact testing.

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1. INTRODUCTION

During the summer months of 2008, the BRE conducted a round robin in Building 68 at BRE, and both UKAS accredited and ANC Registered testers were invited to participate. The UKAS accreditation scheme and the ANC Registration scheme are recognised as being equivalent in Approved Document E[3] of the Building Regulations, England and Wales.

The intention of this research was to see what sorts of distribution of results were obtained from different testers with different equipment and different ways of conducting the measurements, i.e. to examine reproducibility rather than repeatability.

Some of the ANC testers and some of the UKAS testers were also Robust Details Inspectors. RDL inspectors test in accordance with ISO 140 but use a restricted set of measurement techniques. All of the testers rate their results using the relevant part of ISO 717[5].

RDL Inspectors were requested to submit their test results to both BRE using the BRE spreadsheet and to the author using the RDL standard spreadsheet. RDL Inspectors were instructed to use the standard RDL measurement protocols including using diffusers and then repeating the tests without diffusers. This data has been analysed separately to the BRE work and enables me to look specifically at the reproducibility of the manual moving microphone technique and the effect of diffusers in rooms that did not display any evidence of coupled room modes. In addition this is the first round robin to include impact tests and this presented us with the opportunity to examine the reproducibility of them.

2. THE ROUND ROBIN

A. Building 68

Photograph 1: Building 68, at BRE, Watford

Building 68 consists of two rooms at ground floor level separated by a 215 mm single leaf brick wall with two nominally identical rooms above them. The brick wall can be seen in the middle of the side wall, between the two windows, in Photograph 1. The total size of each room is of the order of 50m^3. On modern housing developments, room sizes are typically much smaller than this, especially in bedrooms and rooms of around 20m^3 volumes are commonplace.

The test arrangement is shown in Figure 1 below and represents some of the typical room conditions we come across when conducting field tests. Although Building 68 is a research facility the conditions in the rooms are fairly typical of site conditions, Room 4 even included a ventilation grille at high level, which can be seen in Photograph 1 above.

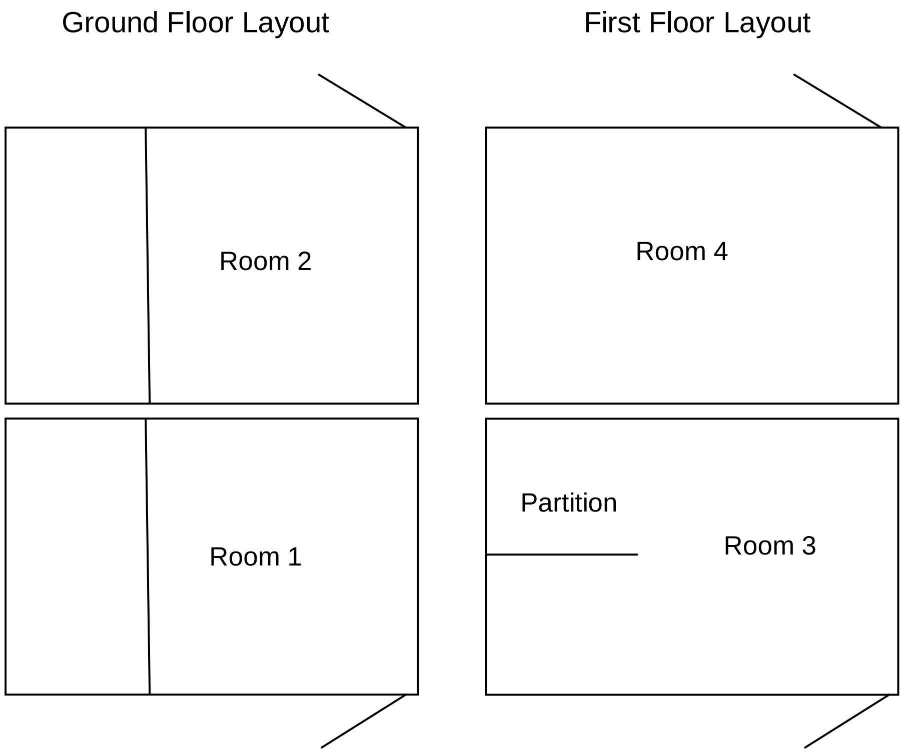

Figure 1: Building 68 Test arrangement.

The testers were instructed to conduct tests in accordance with ISO 140 parts 4 and 7 using their normal test procedure and their own equipment. The only exceptions were the Robust Details Inspectors who tested in accordance with the RDL Method Statement 2[4].

Each tester was required to measure the following:

- The airborne sound insulation of the wall between rooms 1 and 2
- The airborne sound insulation of the wall between rooms 3 and 4
- The airborne sound insulation of the floor between rooms 2 and 4
- The impact sound insulation of the floor between rooms 2 and 4

3. Reproducibility

The calculation of the Reproducibility Value 'R' is detailed in ISO 140 Part 2 and is defined at 3.16 of that standard as the value below which the absolute difference between two single test results, obtained under reproducibility conditions, may be expected to lie with a probability of 95%. Reproducibility conditions refer to tests using the same method, ISO 140 in this case, on an identical wall or floor by different testers using different equipment.

In Section 4.1 of ISO 140 Part 2 we see the following equation:

Reproducibility Value $R = 2.8\sqrt{S_R^2}$ where S_R^2 is the reproducibility variance.

Towards the end of Section 4.1 the standard says:

"Since……. the reproducibility values R are calculated from the estimator…….S_R^2, they will themselves be estimates, subject to errors. The probability levels associated with ……the reproducibility values R will therefore not be exactly 95% but only of the order of 95%."

Although less than precise, I have adopted this method of calculation because it is exactly as the ISO requires and hence traceable, even if slightly incorrect.

4. The Manually Moving Microphone Technique

The manually moving microphone (MMM) sweep method is described in the RDL Method Statement 2[4] and is NOT the 'survey method' as described in BS EN ISO 10052:2004[8]. The technique described involves holding the sound level meter (SLM), or the microphone on a pole, at arm's length and slowly and deliberately moving the SLM or microphone to describe a loop. The sweep trajectory should form a circle or ellipse according to the description in ISO 140 Part 4, 6.3.2 (b) and yet should try to sample as much of the permitted space as possible without passing too close to a room boundary or the sound source.

The Robust Detail Inspectors all used the MMM whilst the ANC testers used fixed microphone positions. As has already been mentioned the RD inspectors use a constrained sub-set of the possible ways of testing in accordance with ISO 140 Part 4 with the reverberation times being measured using interrupted pink noise and the T30 parameter. Further they are required to be present in the room whilst measuring the sound fields so that they can be sure that no changes, due to external noise sources or a change in the loudspeaker source levels, can adversely affect the results of their measurements. The effect of the 'body in the room' on the repeatability of measurements is discussed in the paper I jointly presented at the IOA Spring Conference 2008[7]. The conclusions of that research for rooms of $30m^3$ volume were:

"The variation caused by the presence or absence of a body in the source room is very small but appears to show a slight downward trend (towards an unfavourable test result) of up to 0.3 dB, compared to tests in unoccupied rooms. This effect is roughly the same as predicted by Sabine"

"This investigation suggests that the manual moving microphone technique (MMM), which also involves taking the tester out of the source room, produces the most

repeatable results in rooms of 30m³ or more when compared with any of the other test methods. Most notable is the improved accuracy and repeatability of this method at low frequency, where modal variations produce well-documented inaccuracies in the other, more traditional test methods."

In common with our earlier research I have calculated the $D_{nT,w} + C_{tr}$ values to two decimal places to ensure that small differences in results can be observed. The full data set is too large to present in this paper and I will only consider the calculated reproducibility values for each sub set of the data. The reproducibility of the airborne tests is shown in Figures 2 to 4 which compare the results of the MMM with those from the static microphone position technique.

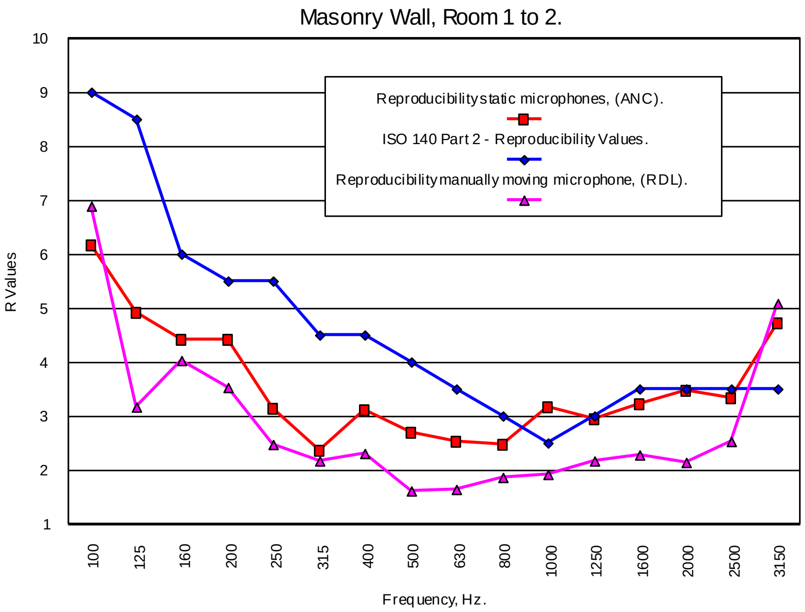

Figure 2: Ground Floor Wall

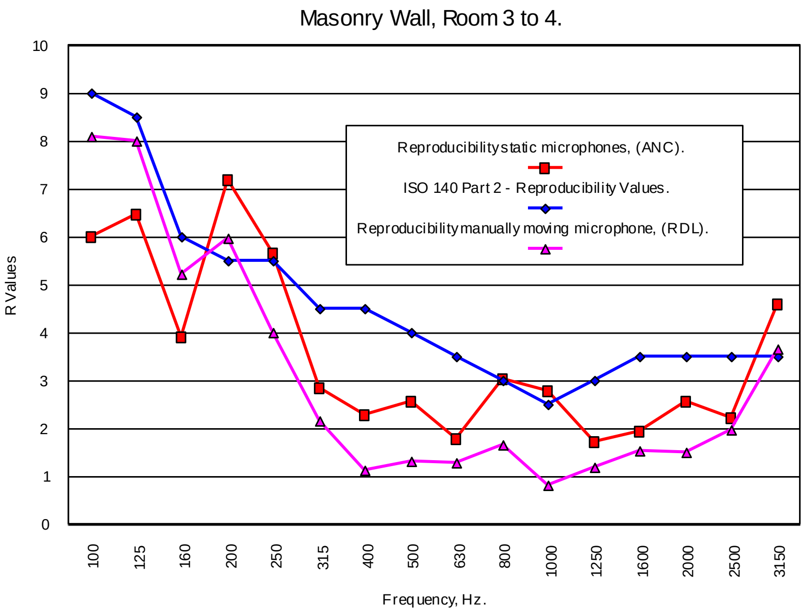

Figure 3: First Floor Wall

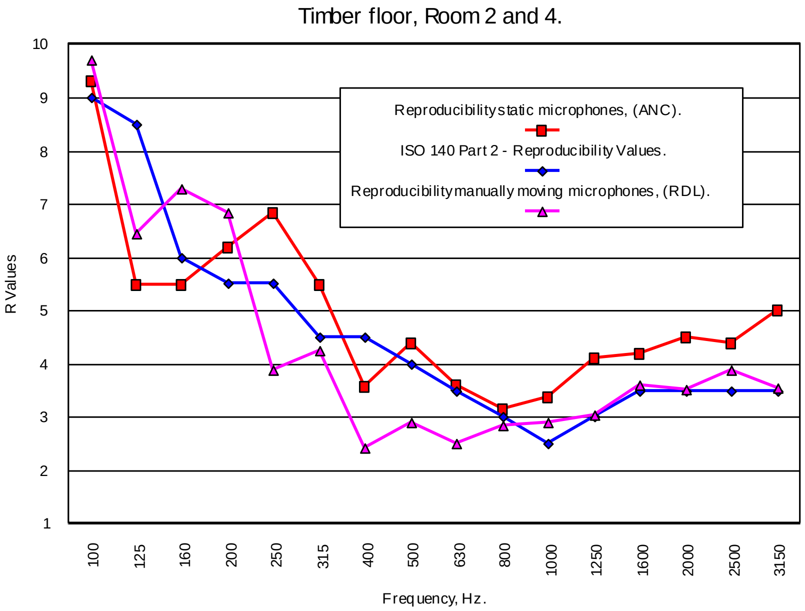

Figure 4: The separating floor.

The following table compares the values of the three sets of airborne sound insulation tests.

Test sample.	Condition	Mean	Standard Deviation	Reproducibility, R
Masonry Wall, rooms 1 to 2, $D_{nT,w} + C_{tr}$	Static	52.01	0.78	2.18
	MMM	52.24	0.58	1.62
Masonry Wall, rooms 3 to 4, $D_{nT,w} + C_{tr}$	Static	46.50	0.94	2.63
	MMM	46.84	0.92	2.58
Timber Floor, rooms 2 to 4, $D_{nT,w} + C_{tr}$	Static	36.36	1.53	4.28
	MMM	37.62	1.41	3.95

Several observations can be made about these results:

In general all the measured Reproducibility Values are of the same order of magnitude as those cited in ISO 140 Part 2, Table A.2.

The standard deviation and reproducibility values are lower for the MMM results except for the test between rooms 3 and 4 where they are nominally identical.

The standard deviation and reproducibility values are considerably more adverse when measuring a timber floor. Given that, the only difference for this test is a change from masonry to timber, it is probable that this is a function of the floor being timber rather than concrete.

Given that the MMM measurements were all made by Robust Details Inspectors three additional factors may be at work. Firstly the constrained RDL testing regime could well be influencing the better reproducibility. From earlier round robins[7] we know that the MMM technique shows lower standard deviations and hence better repeatability when compared to the results of the static measurements and this is probably the biggest factor. In addition the Robust Details Inspectors are by definition some of the most experienced acousticians in the UK and may simply be better at doing sound insulation tests than those with less experience. Clearly these effects cannot be quantified or disaggregated at this time.

5. Diffusers

In ISO 140 Part 4, Section 5, it says:

"Measurements between empty rooms with identical shape and equal dimensions should preferably be made with diffusers in each room (e.g. pieces of furniture, building boards). The area of the diffusers should be at least 1.0m^2, three or four objects will be normally sufficient."

In many modern residential developments the room dimensions are such that strong coupled room modes can exist in the 100Hz one third octave band. The 100Hz band has a strong influence on the C_{tr} term as shown in the round robin which was reported at the 2007 IOA Spring Conference[2].

The experience within the Robust Details Inspectorate is that the use of diffusers in the situation of coupled room modes breaks up the modal response and improves the measured value by anything up to +13dB. Logically then, if one always used diffusers when testing, there would be no need to establish if coupled room modes exist and the result of all tests would be as close as possible to the true value.

The RDL Inspectorate considered that this was an approach that was worth adopting. That particular experiment only lasted a few weeks as we quickly became aware of some results that seemed to indicate that the use of diffusers in non-coupled room mode situations actually adversely reduced the measured $D_{nT,w}$ + C_{tr} values. This particular round robin gave us an opportunity to explore the influence of diffusers. Each RD Inspector repeated their tests using diffusers and the results are shown in Figures 5 to 8 below:

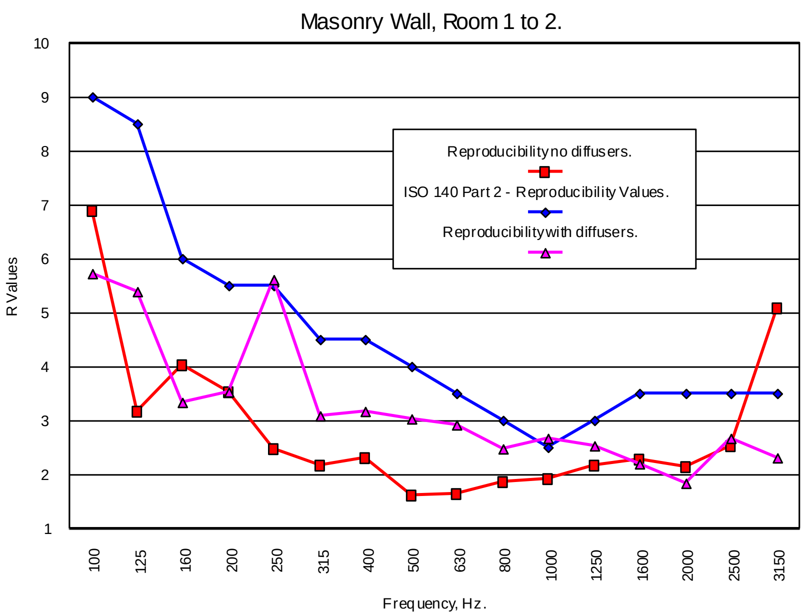

Figure 5: Ground Floor Wall.

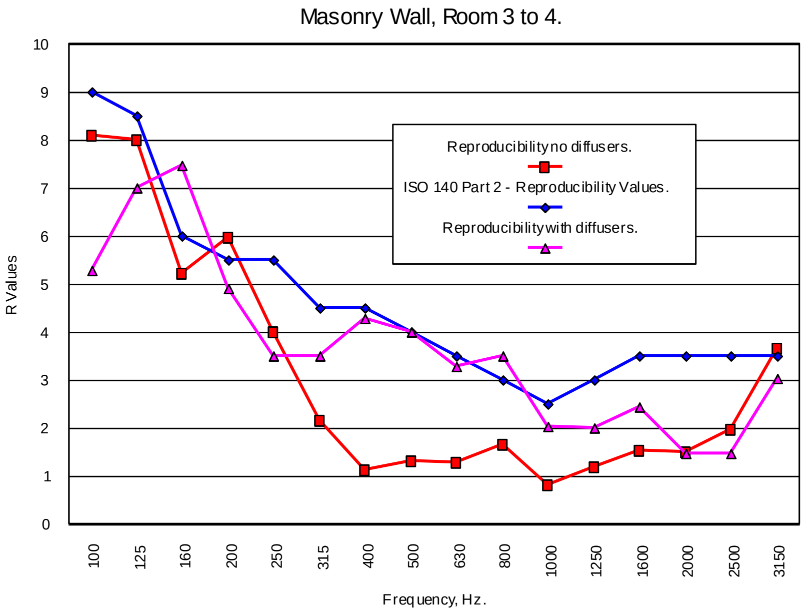

Figure 6: First Floor Wall.

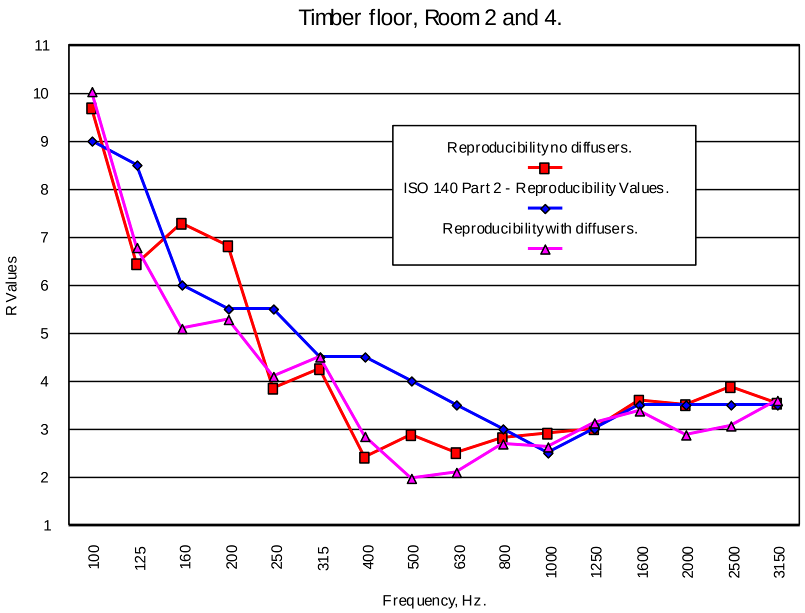

Figure 7: The Separating Floor, airborne.

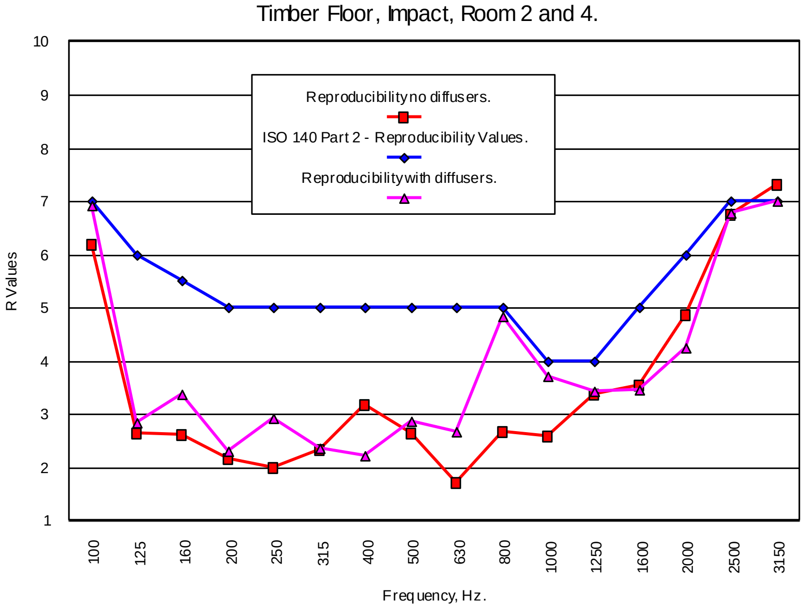

Figure 8: The Separating Floor, impact.

Test sample.	Diffusers	Mean	Standard Deviation	Reproducibility, R
Masonry Wall, rooms 1 to 2, $D_{nT,w} + C_{tr}$	No	52.24	0.58	1.62
	Yes	51.69	0.90	2.52
Masonry Wall, rooms 3 to 4, $D_{nT,w} + C_{tr}$	No	46.84	0.92	2.58
	Yes	47.14	1.06	2.97
Timber Floor, rooms 2 to 4, $D_{nT,w} + C_{tr}$	No	37.62	1.41	3.95
	Yes	37.78	1.96	5.49
Timber Floor, rooms 2 to 4, $L'_{nT,w}$.	No	66	0.57	1.60
	Yes	66	0.86	2.41

Several observations can be made about these results:

In general all the measured Reproducibility Values are of the same order of magnitude or lower than those cited in ISO 140 Part 2, Table A.2. This is the first time that we have conducted a round robin which includes impact test and it is interesting to note that the reproducibility values are considerably lower than those cited in ISO 140 Part 2, Table A.3.

In general the standard deviation and reproducibility values are greater when diffusers are used in a non-coupled room mode scenario. This is even true of the impact tests where the Inspectors used static microphone positions and not MMM which is in accordance with Method Statement 2[4].

Whilst apparently counter intuitive this confirms the Inspectors experiences. Precisely why this should be the case is not at all obvious and further research would be needed into this effect.

6. CONCLUSIONS

This investigation has produced some interesting conclusions.

1. The manually moving microphone technique has been demonstrated to offer enhanced reproducibility when compared to measurements made with static microphone positions.

2. The use of diffusers in rooms where coupled room modes are not present adversely increases the reproducibility value of the tests.

3. The reproducibility of field tests is shown to be at least as good as and generally better than the figures cited in ISO 140 Part 2.

ACKNOWLEDGMENTS

I gratefully acknowledge and thank all the ANC testers and all of the RDL Inspectors who took part in this round robin. I would also like to thank Dr Hall and BRE for their kind assistance.

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