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MEASUREMENT OF SOUND LEVELS PRODUCED BY BONE CUTTING MACHINERY IN THE ORTHOPAEDIC OPERATING THEATRE

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1. INTRODUCTION

Howmedica International, a part of the Pfizer Hospital Products Organisation, market a machine described as the Black & Decker of bone surgery.

The machine which is pneumatic resembles a small hand drill but is very versatile in that it can be used to drill or cut with a rotary or a oscillating motion.

Early in 1994 complaints were received from theatre staff about the noise created by the machine when in use, particularly when being used to cut in its oscillating mode.

The hospital occupational hygiene people took sound level readings of the machine in use. Howmedica also took sound level readings both here in the operating theatre and in Switzerland where it is manufactured.

Unfortunately no agreement was forthcoming as to the measured levels and it was agreed to have independent readings made to hopefully provide validated reading which could be repeated by all parties.

2. BACKGROUND

It was at this point that I was approached and asked to make some measurements in the with all parties represented.

At this time I had never been in a operating theatre whilst compos mentes, and a meeting of all parties was arranged and procedures explained to me. We visited the local orthopaedic hospital and witnessed a hip replacement being carried out.

It soon became obvious that during the course of a hip replacement operation the machine was used for a maximum of about four minutes, made up of a series of short duration on times.

The engineer delegated by the Swiss manufacturer to perform

their sound level measurements was insistent that corrections should be made for both temperature and atmospheric pressure.

It seemed to me by just watching that the two main causes of sound variation were, one operator pressure and, two the smoothness of the curve of the co-axial air line supplying **seven bar pressure** to power the machine.

It seemed sensible that rather than do the readings whilst cutting bits off a real live patient, some bones could be purloined from the local butcher and they could be cut and cut until we had managed to acquire all the data necessary.

It soon became apparent that bones vary in hardness bringing in another source of error and I was assured this variation was just as noticeable with humans as with the animal bones.

3. METHOD

The measurements were carried out in three different operating theatres, the change of venue although not ideal was forced upon us by the use needs of the hospital.

The three operating theatres used were all of identical shape and size and of the same layout.

The bone to be cut was positioned centrally on the operating table, the microphone diaphragm was positioned one metre from the cut position at 45° to the table length. The microphone was directly facing and 250mm above the cut.

The same operator was used each time to minimise operational error and the coaxial air pipe was carried around in as smooth a curve as possible.

Within a operating theatre the temperature is readily controllable but the pressure is and will remain atmospheric.

I felt that because of the close position of the microphone to the actual cut face questions of temperature and pressure could be ignored although as will be seen temperature played a part in one set of readings.

For each set of readings the anaesthetist position and instrument trolley was screened as for an operation and the operator faced the table with an assistant opposite ensuring the bone remained in position.

4. MEASUREMENT

Reverberation time measurements were made in each theatre used and it was found that provided the heating system was carefully controlled the reverberation times were to all intents identical.

The warm air from the heating system arrived in each theatre by way of a large rectangular duct through a louvred vent. close behind each vent was a damper which is controllable from within the theatre, when the vent was open allowing a large volume of warm air in the reverberation time became longer, therefore the dampers were shut for each set of readings to achieve a consistent result.

The first measurement at each session was made on the original machine.

1. Measurement made with machine free, that is with no tool and no contact with the bone.

2. Measurement made with tool installed but no contact with bone.

3. As 2, but actually cutting bone.

4. As 1, 2 & 3 but with second machine which was gradually developed with refined silencing.

The Measurements were made using a Bruel & Kjaer 2231 Precision modular sound level meter. The meter was loaded with module 2 (BZ 7101) and information was down loaded to a laptop computer using the Bruel & Kjaer link programme.

A frequency spectrum in third octaves was made of the original machine operating with a tool fitted and cutting bone. This was repeated with the final silenced version of the machine using both the Bruel & Kjaer 2231 and also with the new Bruel & Kjaer **** meter.

As the cutting of bone is a rapid operation I decided to take each measurement over a one minute period. In common with probably all modern instruments the 2231 produces an embarrassing number of statistical measurements.

For simplicity I decided to use the L_{Aeq} as the basis for comparison of my readings.

The meter was calibrated before and after each set of readings and was set up with the microphone incidence set to frontal, a preset time of one minute and the time weighting at fast. All readings were carried out with the meter set in the range of 40 to 113 dB(A).

Readings can be seen in appendix 1.

5. CONCLUSIONS

Firstly I must say that within the terms of the Noise at Work Regulations the noise of the bone cutter barely rates a thought but in the intense atmosphere of an operating theatre noise becomes important.The very short duration of the noise also means that risk to hearing is not a factor with this machinery.

However testing and the development of a silencer within the machine did bring about a significant reduction in both the level and the tonal characteristic of the noise.

I did try to compare the machine with one from a rival manufacturer but unfortunately the rival machine failed early in the test procedure.

Short of developing a rig similar to those used for the testing and classification of pneumatic road drills which guarantee a consistent repeatable pressure being applied we had to rely on the operator.

It was very important to ensure that the co-axial air line was in as consistent and smooth a curve as possible as any tight or sharp part of the curve produced significant increase in volume.

The point of this whole exercise was to provide measurements which could be repeated by different people in different places. This is particularly difficult with sound measurement because there are so many variables involved and in this current time people who in my opinion should know better want readings repeatable to not one but sometimes two decimal points.

What has been achieved is a simple and basic method for measuring the sound levels of a machine in common use in orthopaedic surgery. Within quite severe limitations the measurements are repeatable at one site an may be used as a comparison over a range of sites.

6. REFERENCES

1. Noise at Work Regulations 1989 made under the Health and Safety at Work Act 1974.

APPENDIX 1

NOISE MEASUREMENTS TAKEN AT THE EXETER ORTHOPAEDIC HOSPITAL

	MAXL	L(01)	L(10)	L(90)	MINL	LEQ
MEASUREMENT TAKEN ON 06/06/94						
BONE1	77.20	77.00	77.00	76.50	76.20	76.70
BONE2	90.70	80.50	80.50	79.50	79.00	80.00
BONE3	82.90	82.00	79.00	77.00	53.10	77.90
BONE4	91.50	84.00	83.50	81.50	81.00	82.60
BONE5	91.50	90.50	87.50	85.00	84.40	86.30
BONE6	89.40	87.00	85.50	57.50	52.90	83.70
BONE8	91.50	87.00	86.00	83.00	73.30	84.30
BONE9	91.30	80.50	79.50	78.00	76.70	78.90
BON12	91.40	87.00	86.00	84.50	82.00	85.20
BON13	90.50	90.00	88.50	84.00	79.50	86.50
BON14	89.80	89.00	88.00	86.50	85.50	87.30
BON15	91.40	76.50	76.00	75.00	74.50	75.80
BON16	91.20	86.00	85.00	80.00	79.30	82.80
BON17	91.40	80.00	79.00	77.00	76.60	78.10
BON18	89.40	88.00	86.50	82.50	80.70	84.80
BON21	86.90	80.50	80.00	78.50	77.80	79.20
BON22	87.10	78.50	77.50	76.50	76.30	77.20
MEASUREMENTS TAKEN ON 20/07/94						
HOW2	86.50	85.50	84.50	82.00	67.20	83.20
HOW3	93.50	92.00	91.00	90.00	89.30	90.50
HOW4	91.60	90.50	89.50	87.00	86.60	88.50
HOW5	91.40	82.00	81.00	80.50	80.20	80.90
HOW6	91.00	88.50	88.50	88.00	86.70	88.20
HOW7	89.00	88.50	88.00	87.00	85.00	87.30
MEASUREMENTS TAKEN 02/08/94						
B.TXT	89.70	83.00	82.50	80.00	78.80	81.20
B2.TXT	91.40	90.50	90.00	89.00	79.20	89.40
B3.TXT	91.30	90.50	89.50	87.50	74.00	88.40
B4.TXT	87.10	80.50	80.00	78.50	77.50	79.20
B5.TXT	82.20	82.00	81.50	81.00	80.20	81.20
B6.TXT	91.30	84.50	83.50	81.50	80.90	82.70
B7.TXT	91.10	86.50	84.00	82.50	81.80	83.40
B8.TXT	87.80	87.00	86.00	84.50	83.80	85.30
MEASUREMENTS TAKEN ON 18/08/94						
D.TXT	87.90	87.50	86.00	61.00	45.90	84.00
D1.TXT	93.50	93.00	93.00	90.50	82.80	91.80
D2.TXT	90.00	89.50	87.50	85.50	79.40	86.50
D3.TXT	81.50	81.00	80.50	79.00	73.60	79.90
D4.TXT	83.60	83.00	82.50	82.00	81.60	82.30
D5.TXT	87.60	87.00	84.00	81.00	74.80	82.60
D6.TXT	86.30	86.00	84.50	82.50	74.70	83.50
D7.TXT	86.60	86.00	84.50	83.50	76.90	84.10

BONE CUTTING MACHINERY IN THE ORTHOPAEDIC

MEASUREMENTS TAKEN ON 15/09/94						
E.TXT	88.00	88.50	86.00	63.00	46.20	84.10
E1.TXT	92.10	92.00	91.50	90.50	89.20	91.00
E2.TXT	93.60	93.00	91.50	90.00	89.00	90.90
E3.TXT	86.90	81.50	81.00	80.00	78.30	80.70
MEASUREMENTS TAKEN ON 15/09/94						
	MAXL	L(O1)	L(10)	L(90)	MINL	LEQ
E4.TXT	86.90	82.50	82.50	82.00	80.50	82.30
E5.TXT	90.60	85.50	85.00	83.50	77.60	84.20
E6.TXT	90.60	85.50	85.00	83.50	77.60	84.20
E7.TXT	90.10	89.00	87.50	85.00	83.90	85.90
MEASUREMENTS TAKEN ON 4/11/94						
F.TXT	100.10	85.00	84.50	82.00	80.50	83.60
F1.TXT	100.20	90.00	89.50	88.00	87.70	88.70
F2.TXT	100.20	90.00	89.50	88.00	87.70	88.70
F3.TXT	100.60	87.50	87.00	84.50	84.00	86.00
F4.TXT	81.10	79.00	78.00	77.50	71.40	77.60
F5.TXT	100.10	82.50	80.50	79.50	79.40	80.90
F6.TXT	100.10	85.00	83.00	81.00	80.40	82.50
F7.TXT	100.20	84.50	83.00	81.50	80.90	82.80
F8.TXT	84.80	84.50	83.00	81.50	78.00	82.20
F9.TXT	100.20	85.00	82.00	79.50	78.70	81.60
F10.TXT	100.10	82.00	67.00	65.50	64.60	74.60
F11.TXT	84.60	82.00	80.50	79.50	75.80	80.10
F12.TXT	86.40	84.50	82.00	79.00	76.80	80.60