Canadian Acoustics / Acoustique Canadienne 23(1) 3-9 (1995) **Research article / Article de recherche**

A NEW VACUUM ACTIVATED DAMPING DEVICE TO REDUCE NOISE AND VIBRATION DURING RIVETING

M. Amram*, P. Masson*,G. Brooks**,P.E. Boileau***,R. Lahlou*
* École Polytechnique de Montréal, C.P. 6079, Succursale "A"
** Canadair Limitée, C.P. 6087, Montréal Qc H3C 3G9
***IRSST, 505 de Maisonneuve O., Montréal Qc H3A 3C2

SUMMARY

An actual part of an airplane fuselage was mounted on a jig in an anechoic chamber in order to evaluate, among other things (see paper of P.E.boileau and Al. [1]), the performance of a vacuum-activated damping device called Vac Damps (damping material glued on aluminium back plate with a rubber seal all around that plate, in order to fix it on the fuselage by means of a partial vacuum underneath). Riveting with 4 mm diameter rivets requires two operators: a "riveter" , handling the rivet hammer and a "bucker",pushing on the reaction "bucking bar" to upset the rivet. The first goal of this study was to evaluate the noise attenuation provided by two Vac-Damp panels fixed one above and one below a row of rivets. The other goal was to assess the overall efficiency of such a device in lowering the exposure to hand-arm vibrations, mainly at the "bucker's" hand. Differences established on a LeqA basis between data with and without the two Vac-Damp have shown an attenuation of about 5 dBA on the global noise radiated at both "riveter's" and "bucker's" ears. Furthermore, the hand-arm vibrations on the handle of the rivets gun, and mainly on the "bucking bar" held by the " bucker" ,have also been reduced by approximately 2 to 3 dB through the use of the Vac-Damp panels. We should emphasize that for this particular study, only the radiated noise attenuation was considered. For more information on hand-arm vibration attenuation see ref. [1].

SOMMAIRE

Une partie de carlingue d'avion a été montée sur un banc d'essai dans une chambre anéchoique dans le but d'évaluer entre autre chose (voir publication de P.E.Boileau et Ass. [1]) la performance d'un système amortisseur appliqué par le vide appelé Vac Damp (matériau amortissant collé sur une plaque de fond d'aluminium avec un cordon d'étanchéité installé sur le contour de cette plaque, de façon à pouvoir le fixer sur la carlingue par un effet de vide partiel sous le tampon). Le rivetage de rivets de 4 mm de diamètre nécessite deux opérateurs: un riveteur qui manipule le marteau riveteur,et le porteur de bélier,qui appuie sur le bélier de réaction pour écraser le rivet. Le premier but de cette étude était d'évaluer l'atténuation produite par deux Vac Damp appliqués au dessus et au dessous de la rangée de rivets, affectant le bruit rayonné par le panneau d'avion riveté. L'autre but était d'estimer l'efficacité globale d'un tel sytème à diminuer l'exposition aux vibrations main-bras, particulièrement à la main du porteur de bélier. La différence évaluée sur une base de LeqA entre les données avec et sans les deux Vac Damp, a montré une atténuation d'environ 5 dBA sur le bruit global rayonné à la fois à l'oreille du riveteur et à celle du porteur de bélier. De plus, les vibrations main-bras sur le manche de la riveteuse, et principalement sur le bélier tenu par le porteur, ont aussi été diminuées de l'ordre de 2 à 3 dB en utilisant les Vac Damp. Il est à remarquer que dans cette étude nous n'avons consideré que les atténuations du bruit rayonné. Pour plus de renseignements sur l'atténuation des vibrations main-bras apportées par l'emploi des tampons Vac-Damp, consulter la référence [1].

INTRODUCTION

While riveting, two types of noise are generated by the blows of the riveting hammer on the impacted structure. One is the acceleration noise, directly related to the very fast change in momentum occurring during impacts, the other one is the ringing noise related to the two dimensional reverberation in the impacted structure and the possible structural resonances [2]. This second type of noise is generally predominant and generates intense vibration, which sometimes radiates as noise. A new type of vacuum activated device, called Vac Damp, has been developed, patented [3] and used primarily to attenuate the radiated noise by dampening the impacted panel by shear action. This investigation was combined with that of P.E. Boileau and al. who investigated hand-arm vibration exposure not only on the tool itself, but also on the wrist of the operator, using a special bracelet having three orthogonally oriented accelerometers. The intention was to evaluate the performance of the Vac Damp in lowering noise and hand arm vibration during the riveting process of an actual fuselage panel of a Boeing 767 installed on a jig in an anechoic chamber. With the Vac Damp installed it was noticed a correlation existed between an excess attenuation of the radiated noise of 4 dBA (ref. 2.10^{-5} Pascal) and the overall weighted hand-arm vibration level attenuation reaching 3 dB (ref. 1 μ m/s^2) with some riveting hammer/bucking bar combinations.

1. EXPERIMENTAL SETUP AND DESCRIPTION OF THE VAC DAMP

1.1 Experimental Set Up

The jig (scaffolding) was installed in an anechoic chamber and a fuselage panel was bolted on it as shown in figure 1. Stiffness of the curved panel was increased due to the presence of ribs and stringers. The bucking bar was hand-held along the channels formed by the U shaped longitudinal stringers (photo 1). The complete installation comprising the part of the fuselage panel is shown in photo 2. Photo 3 presents a view of the riveter holding the tool by the handle on which three accelerometers have been mounted at right angles to each other. The riveter was also wearing a special bracelet with three orthogonally oriented accelerometers to measure the vibration reaching his wrist. The same arrangement exists on the other side of the panel on the wrist of the bucking bar operator and on the bar. All twelve accelerometers are connected to charge amplifiers (shown on the anechoic chamber floor in photo 2), linked to a digital tape recorder. A vacuum pump was connected to two Vac Damp pads held against the fuselage panel by vacuum action, leaving a space for riveting along a row of rivets. Two microphones were installed on the stand shown in this same figure, one on each side at the top of the panel, to monitor the radiated noise on the riveter's and on the bucker's sides of this curved panel. These microphones were connected to a two channel FFT analyser (Bruel and Kjaer 2032) through two power amplifiers (Bruel and Kjaer 2610). The data was also recorded in parallel on a V.H.S tape recorder (Panasonic AG2400) through an analog/digital converter (Nakamichi DMP100) for further frequency analysis, and statistical study.

1.2 Description of the Vac Damp and of their Installation

Two Vac Damp pads are shown installed in photo 2. Their hidden face is made of polysulfide rubber molded on a rigid flat square aluminum (T6) plate .063" thick with its perimeter covered with a one inch wide gasket made of closed cell polyurethane. The polysulfide rubber contains some grooves to facilitate the creation of an almost complete vacuum (about 90%) with the vacuum pump shown in photo 2 along with its accumulator (which increases its capacity to about 8 c.f.m.). Each plate was tightly pushed against the curved panel surface.

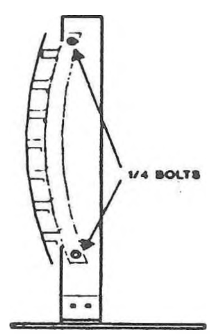


Figure 1. Scaffolding (or Bench) supporting an airplane panel

2. MEASUREMENTS AND DATA REDUCTION

2.1 Calibration

The Bruel and Kjaer model 4230 calibration source which gives 93.7 dB at 1000 Hz for the half inch microphone considered, was used to calibrate both the FFT analyzer and the video tape recorder. The calibration signal was amplified with a 10 dB gain and was recorded for a duration of 30 seconds on the videotape.

2.2 Description of the operations involved during measurement

Two half inch microphones were installed (photo 1) above the fuselage panel, one on each side of it, that is, one on the riveter's side and the other on the bucking bar operator's side. As shown in figure 2, the lines of rivets were numbered from one to nine. During riveting, the odd rows of rivets (1,3,5,7 and 9) were always used for the regular bucking bar (rectangular piece of steel having a mass of approximately 2 lbs). Rivets were driven in and taken out several times on each row. The even rows (2,4,6 and 8) were used to evaluate the performance of the Atlas Copco damped bucking bar (CL-4004). With the Vac Damp system applied, only the number 5 row was used for the regular bucking bar and the sixth row for the damped bucking bar. The excess attenuation was calculated using the data taken along, these two rows. For each riveting hammer/bucking bar combination, the data was recorded for at least twice for the same row of rivets (about 30 to 40 rivets). During riveting the setting of the measurement system was the following:

- signal attenuation -30 dB
- Hanning window for the FFT
- The data collection was triggered for 10% of the maximum level with a lag of 1 ms (figure 3).

The signal was recorded and stored on the VHS tape. The data analyzed in the frequency band 0-6400 Hz of the FFT lacks some precision at low frequency because of the weak resolution (8 Hz in the band 0-6400 Hz) of the spectrum analyser. This is the reason why the recordings were also analyzed in the frequency band 0-800 Hz where the resolution reaches 1 Hz, in order to obtain acceptable values below 500 Hz. Taking into account the difference in amplification between the calibration and the measurements themselves, the calibration value of the calibrator was taken as being 133.7 dB at 1000 Hz.

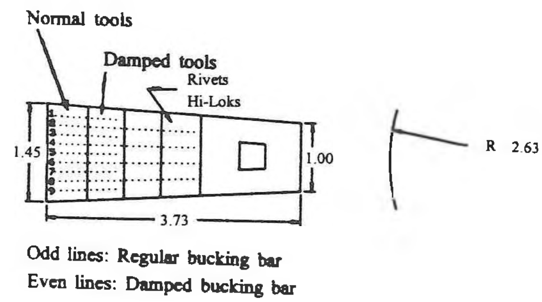


Figure 2. Fuselage panel where the experiment took place

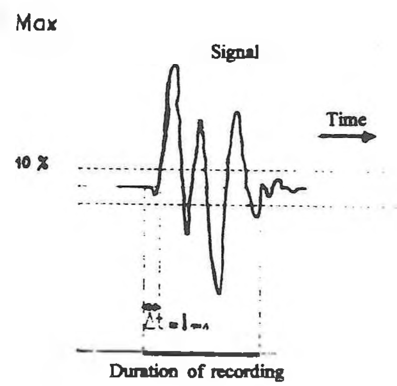


Figure 3. Time Duration of recording

2.3 Data Reduction and Validation using a Statistical Analysis

The error associated with the chain of instruments described in photo 4 has been evaluated in the following manner: first, by comparing the global sound pressure level obtained directly while riveting with that obtained from analysis of the recording;

consecutive analyses of the recording for the same rivet. In both cases, the discrepancy was within one dBA for sound pressure levels varying between 100 and 110 dBA. The analysis concentrated on a basis of rivet by rivet. For each rivet, the A weighted sound pressure level given by the analyzer adjusted as indicated previously, was noted in the frequency band 0-6400 Hz. These measurements were performed on the row of rivets 5 using the Chicago Pneumatic model 2X riveting hammer along with a regular bucking bar, successively with and without two vacuum pads being applied. The position of the rivets was identified on the videotape for comparison with and without pads, and for further statistical analysis. It was then possible to evaluate the total excess attenuation for each rivet and then with the FFT analyzer to calculate the mean and the standard deviation of the distribution obtained. For an ensemble of 36 rivets (twice the same row), the average noise attenuation (without pads minus with pads) was 4.1 dBA with a standard deviation of 2 dBA. This level of error is mainly due to the discrepancies associated with the handling of the tools by the operators. It is to be compared to the one (1 dBA) associated with the chain of instruments previously described. Furthermore, verification of negligeable influence of the distance of the rivets from the microphones was carried out at fixed position without consideration of directivity. Finally, with the use of a Hewlett Packard 9816 computer, it was possible to calculate the attenuation in each one third octave frequency band between 250 and 5000 Hz and between 0 and 800 Hz to obtain a better resolution of the FFT for the lower frequency bands. These results are presented in figures 4 to 7 for a small riveting hammer (model 2X) and in figure 8 to 11 for a larger tool (model 4X). A comparaison between the two tools is also presented in figure 12 to 15. The same operations were accomplished using a damped bucking bar and the results are presented in figure 16 to 19 for the two riveting hammers (2X and 4X).

3. ANALYSIS OF THE RESULTS AND DISCUSSION

When using the Vac Damp pads, and the conventional bucking bar it is clear by looking at figures 12 and 13 that the excess attenuation due to the pads is larger at low frequency for the larger, heavier riveting hammer (4X), than for the smaller, lighter one (2X). The comparison curves shown in these figures enhance this fact, and show also that a better control of the tool vibrations (mainly the bucking bar) should be accomplished with a heavier, larger riveting hammer while using the Vac Damp pads. Maybe this is because a larger, heavier tool reduces the acceleration noise which may become predominant, once the riveted panel is damped with an associated reduction of the ringing noise. Furthermore figures 14 and 15 show that the Vac Damp pads are more efficient at higher frequencies when we use the riveting hammer 2X instead of the 4X. Concerning the use of the damped bucking bar (Atlas Copco) the performance of the Vac Damp is very much dependent on the frequency mainly from 0 to 800 Hz where we can find attenuations and amplifications (figures 16 to 19). It seems to have a contradictory effect when the two damping devices (the Vac Damp panels and the damped bucking bar) are used simultaneously.

CONCLUSION

Attenuation due to the Vac Damp seems larger at low frequency for a larger heavier riveting hammer 4X than for a smaller lighter tool 2x. Then the tool vibration about 50 Hz should be best controlled with a large tool and with Vac Damp pads. This effect may be due to a better <u>acceleration noise</u> control which becomes predominant over the <u>ringing noise</u>, once this latter has been reduced with the Vac Damp, creating a damping effect.

REFERENCES

[1] P.E. Boileau, H. Scory, G. Brooks, M. Amram,"Hand arm vibration associated with the use of riveting hammers in the aerospace industry and efficiency of antivibration devices", Proceedings of the Canadian Acoustical Association Symposium, Vancouver B.C.,8-9 Oct. 92, p-15-16.

[2] J.Cushieri,F.J.Richards,"On the prediction of impact noise IV: estimation of noise energy radiated by impact excitation of a structure",Journal of Sound and Vibration,Vol.86,p319-342.

[3] G.Brooks,"Vac Damp for vibration and noise control".U.S.Patent No 446057, September 1990.

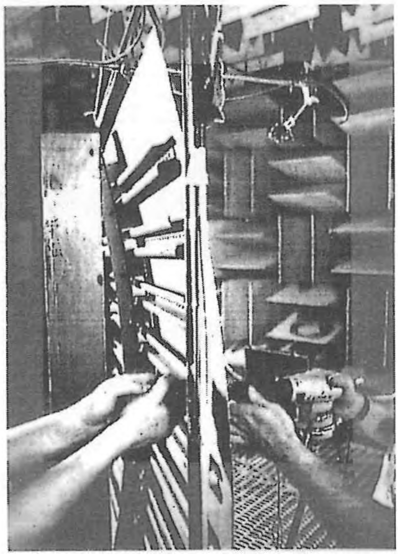


Photo 1. RIVETING OPERATION:
on one side the riveter, and
on the other side, the bucking
bar holder

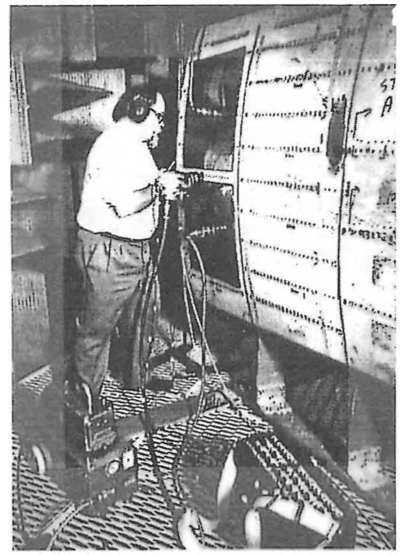


Photo 2. Riveting of an airplane panel
with two dampers (Vac Damps)
installed using a vacuum pump

Photo 3. View of the riveter and the accelerometers

Photo 4. Instrumentation for noise and vibration
measurements and recording

Radiated noise attenuation

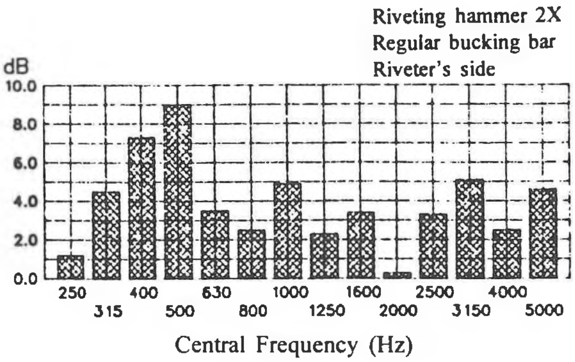


Figure 4.

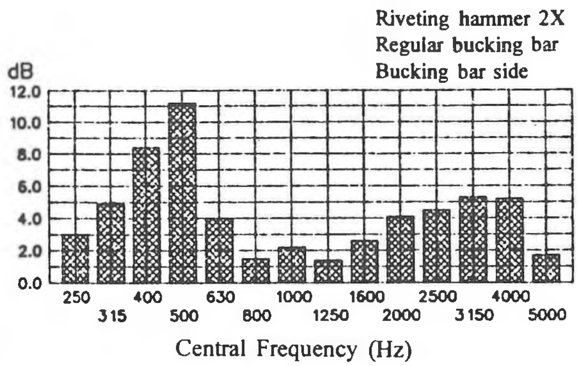


Figure 5.

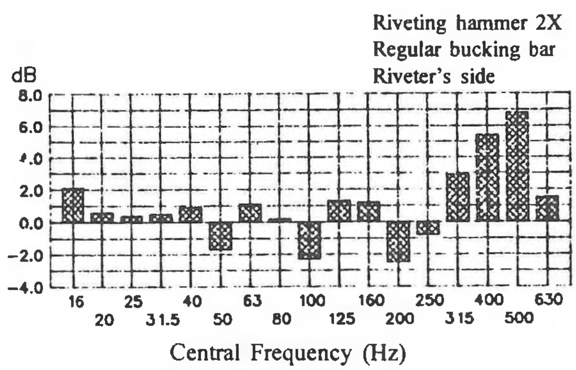


Figure 6.

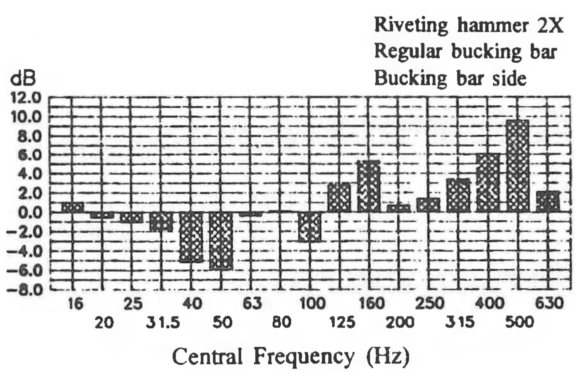


Figure 7.

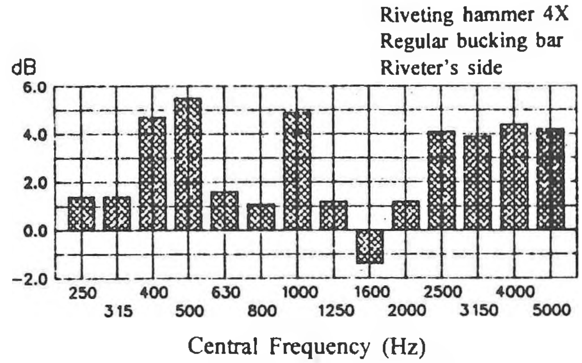


Figure 8.

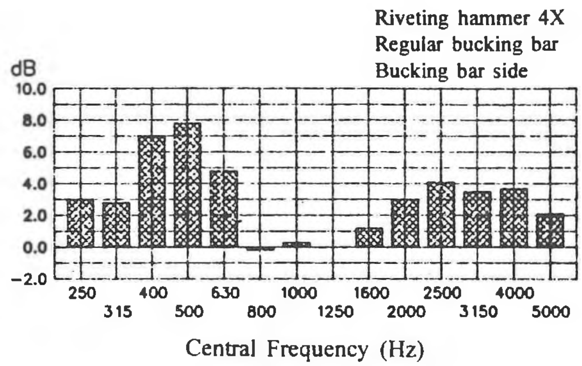


Figure 9.

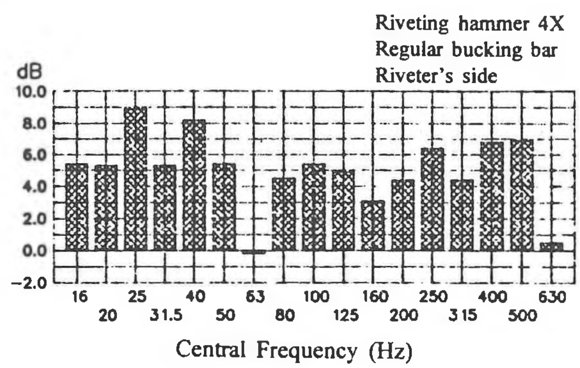


Figure 10.

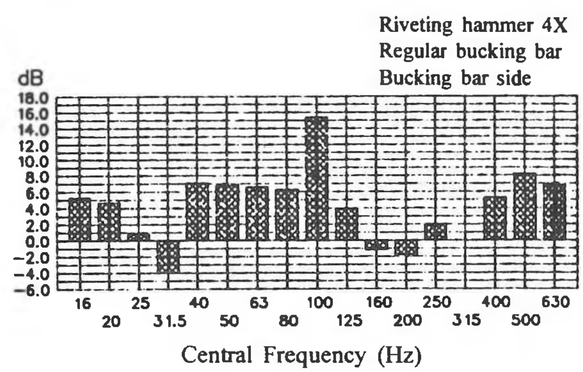
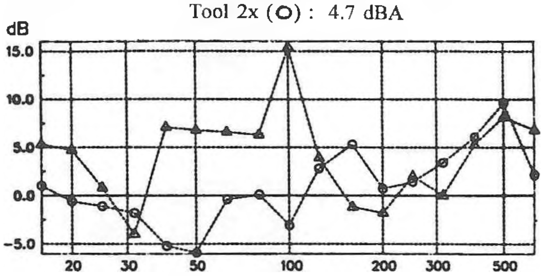


Figure 11.

Radiated noise attenuation of vac damp with riveting tools 2x and 4x with regular bucking bar

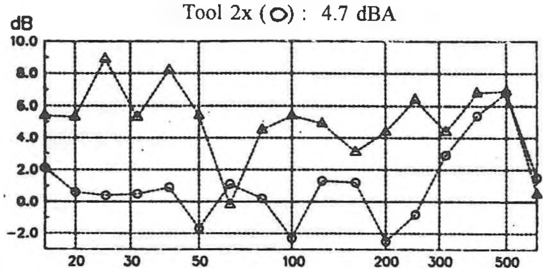
Overall attenuation on 3.2 KHz band (bucking bar side)
Tool 4x (△) : 4.7 dBA
Tool 2x (○) : 4.7 dBA



Central Frequency (Hz)

Figure 12.

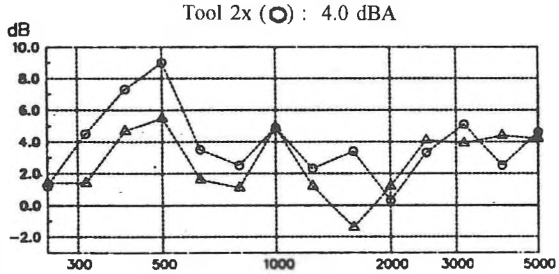
Overall attenuation on 3.2 KHz band (riveter's side)
Tool 4x (△) : 4.9 dBA
Tool 2x (○) : 4.7 dBA



Central Frequency (Hz)

Figure 13.

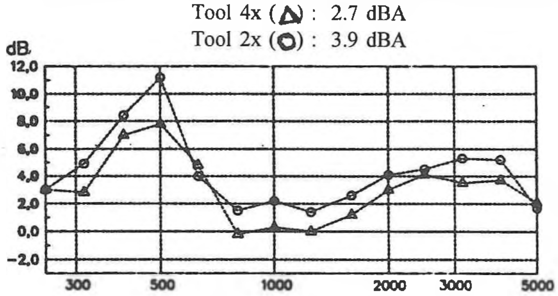
Overall attenuation on 3.2 KHz band (riveter's side)
Tool 4x (△) : 3.3 dBA
Tool 2x (○) : 4.0 dBA



Central Frequency (Hz)

Figure 14.

Overall attenuation on 3.2 KHz band (bucking bar side)
Tool 4x (△) : 2.7 dBA
Tool 2x (○) : 3.9 dBA

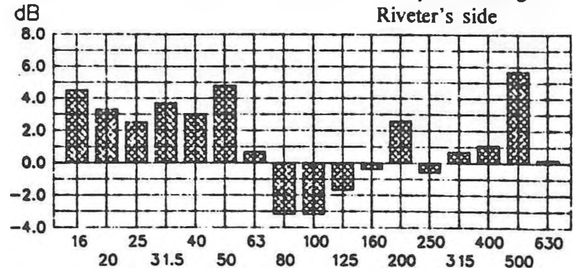


Central Frequency (Hz)

Figure 15.

Radiated noise attenuation of vac damp with riveting tools 2x and 4x with damped bucking bar

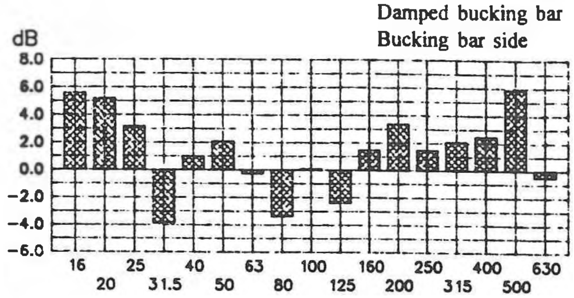
Riveting hammer 2X
Damped bucking bar
Riveter's side



Central Frequency (Hz)

Figure 16.

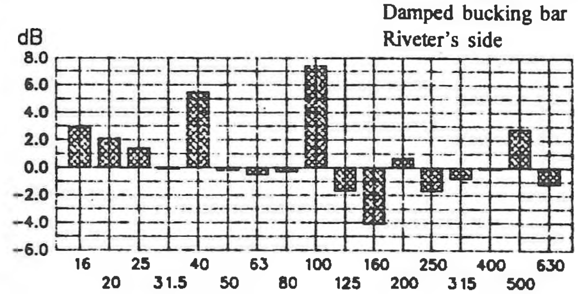
Riveting hammer 2X
Damped bucking bar
Bucking bar side



Central Frequency (Hz)

Figure 17.

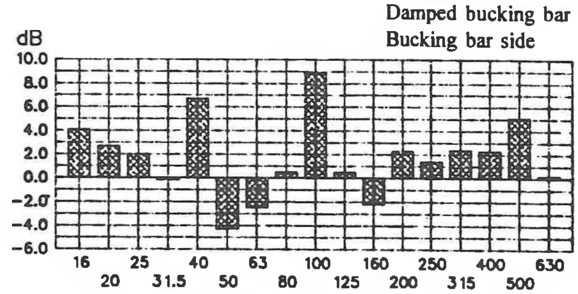
Riveting hammer 4X
Damped bucking bar
Riveter's side



Central Frequency (Hz)

Figure 18.

Riveting hammer 4X
Damped bucking bar
Bucking bar side



Central Frequency (Hz)

Figure 19.