# Describing Noise of Water Appliances by ISO 3822:what happens really?

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## Introduction

Noise caused by water supply installations mainly has its origin in water appliances. A measurement method to describe the noise generation of appliances is given by ISO 3822 [1]. According to this standard the tested appliance is connected to a test pipe which is fixed to the wall of the test room. The air-borne sound radiated by the test wall into the test room will be the considered quantity. To overcome the difficulty of insufficient comparability between various laboratories a standardized flow noise source, the so called INS (Installation Noise Normal), is used. An additional measurement with this INS in the same test configuration leads to a "correction" of the measured results of the tested appliance. The final result is the appliance sound pressure level $L_{ap}$, which is given in octave bands as

$$L_{apn} = L_n - L_{sn} + L_{srn} \qquad (1)$$

($L_n$: measured noise of the appliance in the test room, $L_{sn}$: measured noise of the INS in the test room, $L_{srn}$: reference spectrum of the INS).

## Principles of Reference Source Method

The main aspects of this measuring procedure simply can be discussed taking a single linear, time invariant transmission system. For this the connection between the input quantity $A_1(f)$ and the output quantity $A_2(f)$ of a source is given in the frequency domain by $A_2(f) = A_1(f) \cdot H(f)$. This connection also is valid for a reference source with $R_2(f) = R_1(f) \cdot H(f)$. Then the relation between both sources will be given by

$$\frac{A_2}{R_2} = \frac{A_1 \cdot H}{R_1 \cdot H} = \frac{A_1}{R_1} \qquad (2)$$

To all appearance the relation of the source quantities is a characteristic quantity being independent of the transmission system itself. This relation can be considered as the basis of the reference source method. Again in a second transmission system with H'(f) the relation of the sources is given by $A'_2/R'_2$ and obviously the following declaration applies:

$$\frac{A'_2}{R'_2} = \frac{A_2}{R_2} \text{ and so } A'_2 = \frac{A_2}{R_2} \cdot R'_2 \qquad (3)$$

This means: The unknown response $A'_2$ of a source in a transmitting system H'(f) (e.g. a building) can be predicted by means of the <u>relative</u> characteristic value $A_2/R_2$ of this sources gained in another transmitting system H (f) (e.g. laboratory) and the response of the reference source R' in the building situation. Transformation of eq.(3) as level equation directly leads to eq. (1), where $L_{apn}$ is the predicted level of the appliance, ($L_n - L_{sn}$) its relative characterisation in the laboratory and $L_{srn}$ the response of the INS in a specified situation. The hopes and intentions of ISO 3822 are that the formulated procedure eliminates individual characteristics of the transmission system. The measuring result $L_{ap}$ then should be independent from specific properties of the test facility. The results of different laboratories should be comparable.

## Handling of ISO 3822

In contradiction to the hypothesis of the method in certain cases unsatisfactory comparability between the results of different laboratories became evident over the years. As a consequence of round robin tests a much more restrictive assessment for the design of the test arrangement was laid down (e.g. binding guidelines for the pipe system at the appliance connection and for the mounting of the test pipe on the test wall; more detailed instructions for some other features) which can be found in the actual version of ISO 3822. But the need for very detailed design rules is quit in contradiction to the basic principles of the reference source method which should eliminate individual characteristics of the test arrangement.

## What happens really?

According to figure 1 structure-borne sound of water appliances on the pipe walls not only is caused by energy transition from the water column to the pipe walls ("secondary" structure-borne sound) but also by direct excitation ("primary" structure-borne sound). So water appliances not only can be regarded as fluid-borne but also as structure-borne sound sources. In deed the primary structure-borne sound in many cases cannot be neglected. According to figure 1 two different transfer functions for the two cases have to be regarded:

$$H_F = \frac{A_{F2}}{A_{F1}} \text{ and } H_S = \frac{A_{S2}}{A_{S1}} \qquad (4)$$

By superposition of the two contributions the total output of structure-borne sound on the pipe wall is given by

$$A_{2tot} = A_{F2} + A_{S2} = A_{F1}.H_F + A_{S1}.H_S \qquad (5)$$

Defining a "power coefficient" $\alpha_A$ for the appliance and $\alpha_I$ for the INS with

$$\alpha_A = \frac{A_{F1}}{A_{S1}} \text{ and } \alpha_I = \frac{I_{F1}}{I_{S1}} \qquad (6)$$

the relation of the sources following eq. (2) can be written as

$$\frac{A_{2tot}}{I_{2tot}} = \frac{A_{S1}}{I_{S1}} \cdot \frac{[\alpha_A \cdot H_F + H_S]}{[\alpha_I \cdot H_F + H_S]} \qquad (7)$$

In contrast to the initial relation the additional expression in brackets indicates an influence of the transmission path which only can be neglected if $\alpha_A = \alpha_I$. It can be shown that this not generally will be true. So we are in contradiction to the initial assumptions of the applied reference sound source method. In deed a lot of experimental results [2] demonstrate clearly the violation of the reference source method.

Experimental tests show that the source characteristics of many appliances are different from the INS. This holds true especially for operation noise (e.g. opening, closing or shifting of an appliance). As an example figure 2 shows the level difference between fluid-borne and structure-borne sound measured in special measuring pipe arrangement, which gives a simplified representation of the power coefficient α. Unfortunately even the source characteristics of the same appliance significantly can change when the hydraulic operation conditions (pressure, flow rate) are changed. Other results show that the relation of the appliance and the INS can have a strong dependence of the measuring position in the transmitting path. Under these conditions it is not very astonishing that also a prediction based on the $L_{ap}$-philosophy can lead to misleading results. Figure 3 shows that even the ranking of different appliances can change. Obviously the $L_{ap}$ is not really a characteristic product quantity but a system quantity for an appliance in a very special transmitting system.

## Some Conclusions

The reference source INS will not compensate the individual characteristics of the measuring arrangement on principle. Only in those cases where the source characteristics of the appliance and the INS are comparable (expressed e.g. by the here defined power coefficient) the reference source method of ISO 3822 will be correct. All other cases violate the basic assumptions of this method (test result independent of the transmission path) and comparability between different laboratories is challenged. Critical section of the transmission path is the pipe system.

Altogether the following shortcomings of ISO 3822 are evident:

1. Insufficient source characterisation: no real product quality but product behaviour in a specified (and very special) situation.
2. Ranking of products may change with the chosen measurement situation.
3. Primary structure-borne sound of the appliances is neglected or underestimated.
4. No verification for operation noise.
5. With respect to 3) and 4): the most important parts of appliance noise contributing to real annoyance in most building situations are neglected.
6. $L_{ap}$ is not an appropriate and reliable quantity to serve as input data for predictions.
7. The method requires considerable expense for the test facility (special rooms).

Only very detailed specifications of the test arrangement within ISO 3822 can guarantee a sufficient comparability between various test laboratories. But this would not solve the rest of the problems mentioned above. Obviously the procedure of ISO 3822 does not meet the related requirements. So a new approach seems to be necessary for a satisfactory solution of the shortcomings. A revision of ISO 3822 should lead to a measuring method based on real emission quantities, preferably on the basis of sound powers (fluid and structure-borne sound). Some remarks to these topics are given in [3].

## References

[1] EN ISO 3822, parts 1 –4; Acoustics – Laboratory tests on noise emission from appliances and equipment used in water supply installations

[2] Fischer, H.-M., Efinger, S.: Vereinfachtes Verfahren zur Erfassung des von Auslaufarmaturen verursachten Körperschalls, IBP-Bericht B-BA 1/1991

[3] Alber, T. et al: A new method to describe valve noise, CFA/DAGA 2004 Strasbourg

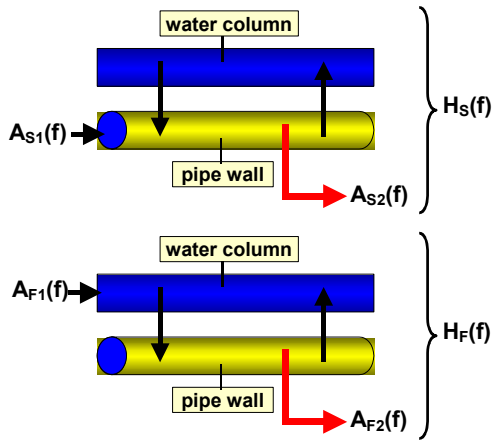


**Figure 1**: Excitation of total structure-borne sound $A_{2tot}$ composed by $A_{F2}$ (caused by fluid-borne sound $A_{F1}$) and by $A_{S2}$ (caused by primary structure-borne sound $A_{S1}$)

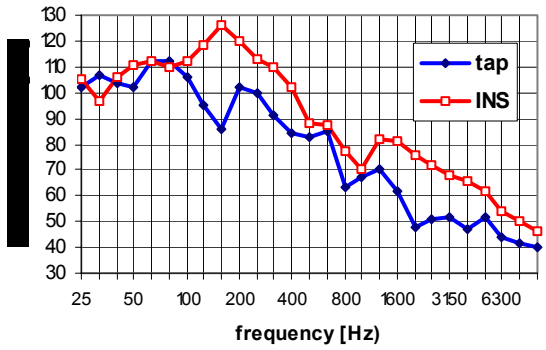


**Figure2**: level difference between fluid-borne and structure-borne sound in a simplified test rig for INS and tap (bath filler, 0,3 MPa)

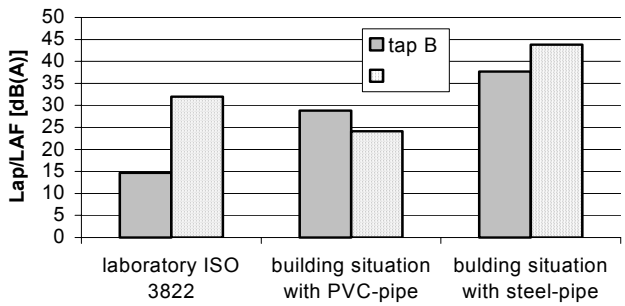


**Figure 3**: comparison of two taps (bath fillers, 0,5 MPa) in different measuring situations; ISO 3822-laboratory: $L_{ap}$ and building situation: $L_{AF}$