It will be clear now that we propose to test the acoustical noise of a transformer under four conditions:

a) clean mains at nominal mains voltage level and at defined nominal mains frequency:
unit: NC.. [dB,m,nom]
b) clean mains at 10 % over voltage level:
unit: NC.. [dB,m, +10%AC]
c) clean mains plus 250 mV-DCvoltage:
unit: NC.. [dB,m, +250mV-DC]
d) clean mains plus 10 % over voltage plus 250 mV-DC voltage:
unit: NC.. [dB,m, +10%AC,+250mV-DC].

4 MEASUREMENTS

From the many transformers we tested, we now will discuss four examples:

1. a special low noise (LoNo™) toroidal transformer, designed and manufactured at Plitron, as a result of the knowledge gained in this research (Plitron 6931 Toroid)
2. a standard Plitron toroidal transformer (Plitron 87053201 Toroid)
3. an EI transformer from unknown brand (Standard EI)
4. a low noise toroidal design from another manufacturer (Other Toroid)

The power rating of each transformer is at or close to 500kVA. See for more details Photo 15 and Table 2 where the results of the measurements are summarized.

All transformers were tested at their nominal frequency and voltage as specified by the manufacturer. All measurements were performed at 0.5 m distance. They are shown in detail in the Figures 17 and following. The conversion to one meter distance was performed by subtracting 6 dB from the measured half meter distance NC curve levels. The conditions of adverse mains are clearly defined above and given in the new units.

It is striking in Table 2 that the 250 mV DC-component causes the most noise. This is explained by the fact that in most transformer designs only over-voltage is taken into consideration. Proper dealing with a DC component asks for a totally different transformer construction. These measurements explain as well why a normally silent transformer suddenly starts humming. The most probable cause is a DC-component, caused by an asymmetrical loading somewhere on the mains.

Transformer	Plitron 6931 Toroid	Plitron 87053201 Toroid	Standard EI	Other Toroid
[dB,m,nom]	NC4	NC4	NC7	NC4
[dB,m,+10%AC]	NC4	NC4	NC14	NC4
[dB,m,+250mV-DC	NC4	NC19	NC10	NC16
[dB,m,+10%AC,+250mV-DC]	NC8	NC20	NC23	NC17

Table 2: results of acoustical noise measurements on four different transformers

5 CONCLUSIONS

Transformer cores can make acoustical noise like humming and rattling. The mechanisms that cause this noise inside the core have been explained. A method has been developed to measure and to scale the acoustic noise of a power transformer under four standardized conditions. They are: nominal mains voltage and mains frequency, 10 % over voltage, 250 mV-DC added and a combination of 10 % over voltage plus 250 mV-DC. The measured acoustical noise is compared to the widely accepted Balanced Noise Criterion curves, thus enabling world wide comparison of noise levels. A noise test chamber is proposed, based on absorbing all reflections and measuring only at the main axis, where the maximum noise level can be expected due to beam forming at high frequencies. Transformers are always mounted in cases, and a emulation of such a case is proposed by means of a steel plate with standardized dimensions. Distance plays an important role, and the distance relations are given for the "far field" condition, which has been verified in the actual noise test chamber, while a one meter distance is proposed as standard unit distance. Four units have been defined for quantifying the noise levels and the conditions of measurement. The tests on four transformers indicate that more attention should be paid to DC-voltage handling capabilities of transformers. The results show as well that the new Plitron LoNo[1] range is able to withstand adverse mains conditions of all the types discussed.

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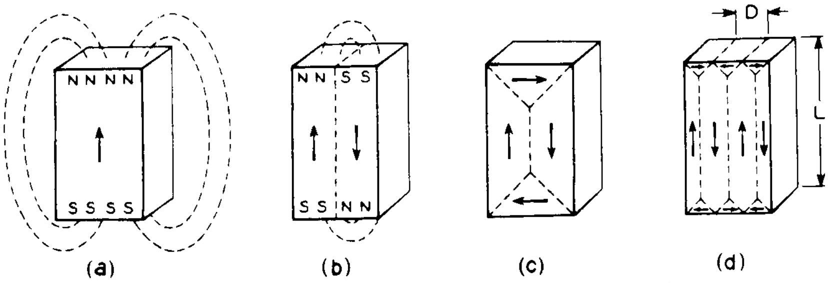

Figure 1: Possible domain structures, showing large magnetostatic energy associated with isolated domain (a), and successively lower energies associated with (b), (c) and (d). The last represents the kind of domain structure actually observed. In (c) and (d) the 90 degrees Bloch Walls are clearly visible at the top and bottom.
(Bozorth, reference [1], pp. 834)

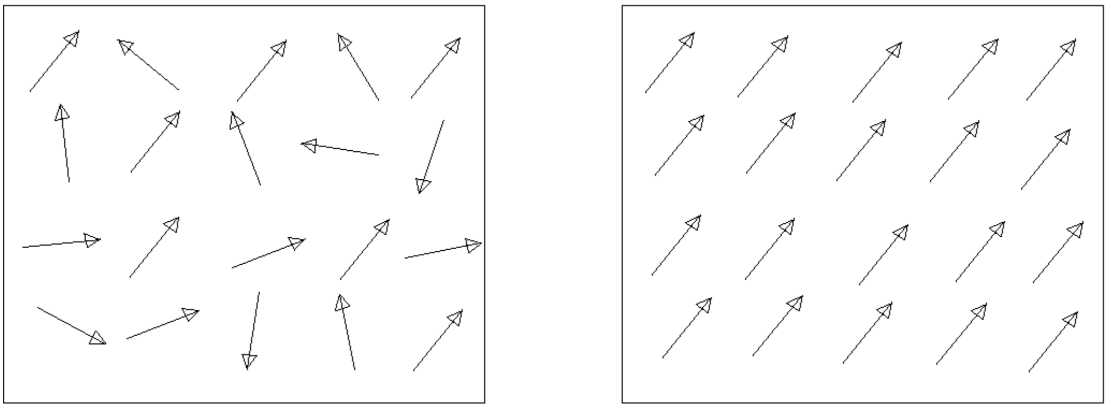

Figure 2: Rotation of magnetic domains, showing left random positioning and right the maximum orientation along the external magnetic field axis.

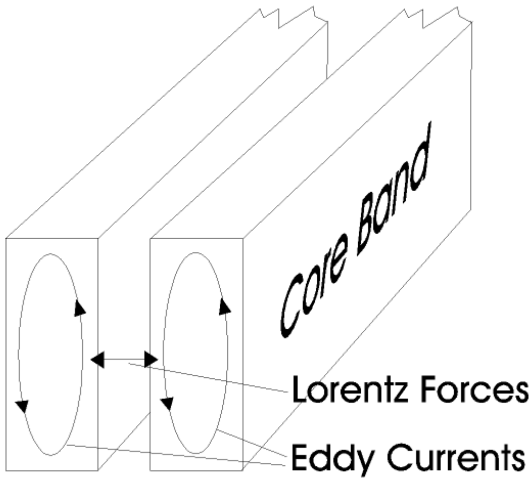

Figure 3: Two adjacent pieces of core band with their internal Eddy Currents. The Lorentz Forces are indicated, causing fibrational forces between the pieces of core band.