

NORD2000 VS. THE EXISTING NORDIC PROPAGATION MODELS

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Abstract: After more than 5 years the developers completed the new Nordic propagation model for outdoor noise, NORD2000, at the end of 2001 [1], [2], [3]. The model itself is very comprehensive and takes into account parameters and conditions that the old Nordic methods cannot handle. Now that the new model is completed it is time to compare results obtained with NORD2000 and the old methods. Also the technical and political consequences of the discrepancies that might appear should be discussed. The paper is a contribution to this debate. Comparisons between 'new' and 'old' results will be presented. The results shown have been obtained with the sound mapping software SoundPLAN® and the discrepancies between the two sets of results are illustrated using difference maps, i. e. the 'difference' between contour maps obtained with the new and old methods.

INTRODUCTION

Compared to the old methods NORD2000 has several obvious advantages. In the first place weather conditions can be taken into account. This makes it possible to predict the noise level under the same wind and temperature conditions no matter if we are dealing with industry noise or traffic noise. In the old methods certain fixed weather conditions are an integrated part of the method, and moreover these conditions depend on the type of source. General Prediction Method (GPM) for industry noise assumes moderate downwind and neutral temperature gradient whereas Road Traffic Noise, Nordic Prediction Method (Road 96) assumes light downwind and neutral temperature gradient. Railway Traffic Noise, Nordic Prediction Method (NMT 96) is more or less based on the same algorithms as GPM.

Secondly, NORD2000 was from the very beginning meant to be computerized. Discontinuities in the model have been avoided, whereas the old methods include several of these. E. g. GPM states that double screening occurs, if the distance between the two screens is more than $0,2d - 0,3d$ where d is the distance between source and receiver. No matter what you choose from $0,2d$ to $0,3d$ the screening effect will show a sudden jump when changing from single to double screening.

With NORD2000 much brainwork has been taken over by the PC. It takes no longer an expert to define the reflection plane as in Road 96. In general with NORD2000 the calculation result will depend very little on the user.

In the third place NORD2000 is expected to give more accurate results than the old methods, especially in complex situations. The old methods are more or less empirical, and really not meant to cover all situations (although this is forgotten now and then by some users). NORD2000, however is a highly detailed method taking into account e. g.

complex terrain profiles, the specific acoustic impedance of the terrain etc.

So far only few comparisons between measurements and calculation results obtained with NORD2000 have been made. Such verification is time consuming and costly to run. A lot of work still needs to be done within this field. Comparisons between calculation results are much easier to arrange.

PREMISES

In this paper results obtained with NORD2000 will be compared against results returned by GPM and Road 96. Most of the test cases state the sound pressure level at the receiver caused by a point source having the frequency spectrum shown in Fig. 1. Since the algorithms in GPM can handle the frequency range 63 – 8.000 Hz the used frequency spectrum has been limited accordingly even if NORD2000 is valid for 25 – 10.000 Hz.

Hz	63	125	250	500	1k	2k	4k	8k	Total
LWA	83,0	88,8	92,1	93,2	93,8	92,1	89,7	85,7	100,0

Fig.1 A-weighted sound power level per octave and overall for the point source used in this presentation.

Input data in NORD2000 are the sound power levels per 1/3 octave. 1/3 octave values have been derived from the octave values in Fig. 1 by spreading the energy in one octave uniformly over the relevant 1/3 octaves.

The frequency spectrum in Fig. 1 is an average of approx. 150 field measurements of sound power levels of fans, pumps, compressors, cooling towers etc. i. e. noise sources commonly found in the industry. Before averaging each spectrum was leveled to a total A-weighted level of 100 dB. As can be seen it is a fairly flat spectrum with maximum in the mid frequency range.

GROUND EFFECT

The reflection from the terrain has great influence on the frequency spectrum of the entire transfer function from source to receiver. The interference between direct transmission and ground reflections causes the frequency spectrum to change strongly with the absorbing properties of the surface as well as the distance from the source. The old methods characterized the ground properties either as 'soft' or 'hard' whereas NORD2000 defines 7 ground classes. The flow resistivity σ (normally in kNs/m^4) is used as a parameter.

The interference between direct and reflected sound creates a series of peaks and dips where the two waves are in-phase or out of phase. The lowest frequency at which the waves are 180° out of phase will be the most important to the ground effect. In Fig. 2, 3 and 5 some tendencies can be read. The figures show the ground effect (the sound pressure level relative to free field) as a function of frequency.

In Fig. 2 the source height H_s and the receiver height H_r is both 2 m and $\sigma = 20.000 \text{ kNs/m}^4$ (hard ground). The distance between source and receiver is the parameter. The interference dip is shifted towards higher frequencies with increasing distance between source and receiver.

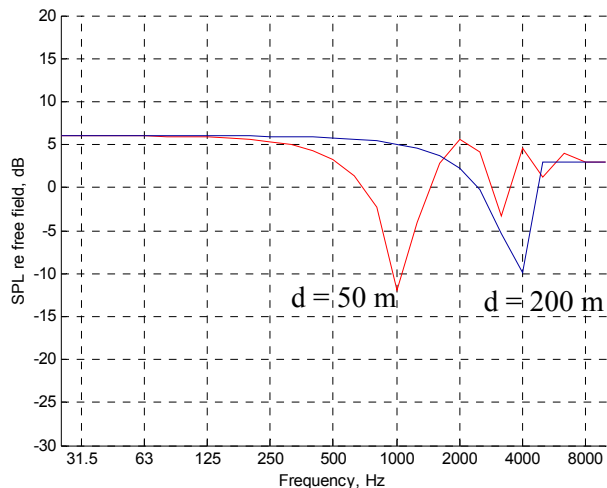


Fig 2. Ground effect. Parameter: Distance between source and receiver.

In Fig. 3 $H_s = 2 \text{ m}$, $d = 50 \text{ m}$ and $\sigma = 20.000 \text{ kNs/m}^4$. The parameter is the receiver height. The interference dip is shifted towards higher frequencies with decreasing receiver height. However, the depth of the interference dips varies with frequency in a very complex manner. This is the main reason why noise maps calculated with NORD2000 in general show very irregular contour lines. One example is shown in Fig 4. This figure shows a simple set up, an point

source above a flat and hard ground, yet the shape of the contour lines are very complex due to the ground effect.

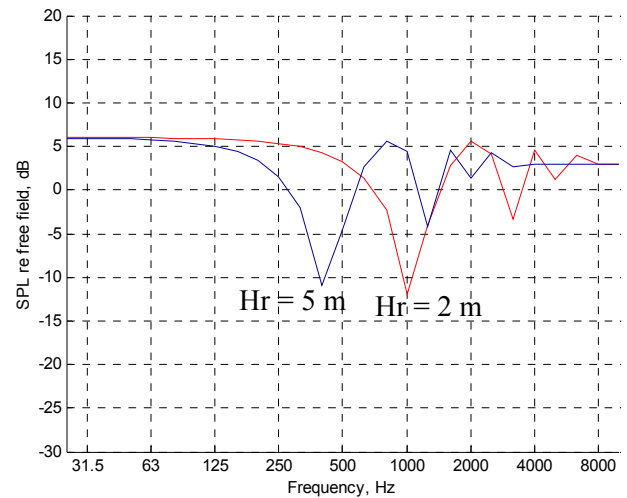


Fig 3. Ground effect. Parameter: Receiver height



Fig 4. Vertical noise map, point source, hard ground, NORD2000

In Fig. 5 $H_s = 2 \text{ m}$, $H_r = 2 \text{ m}$ and $d = 50 \text{ m}$. The flow resistivity is the parameter. The dip is shifted towards lower frequencies with increasing softness of the ground.

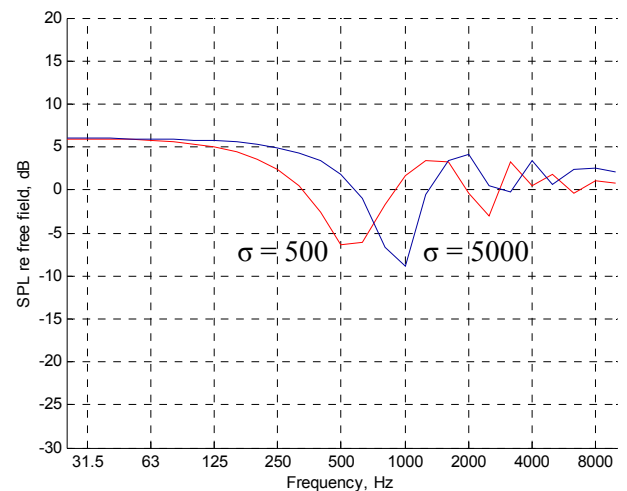


Fig 5. Ground effect. Parameter: Flow resistivity in kNs/m^4

Besides taking the flow resistivity of the terrain into account NORD200 goes one step further. The flow resistivity is evaluated not only for the reflection point but for a region around that point the area of which is frequency dependent. This area - the so called Fresnel-zone - is illustrated in Fig. 6.

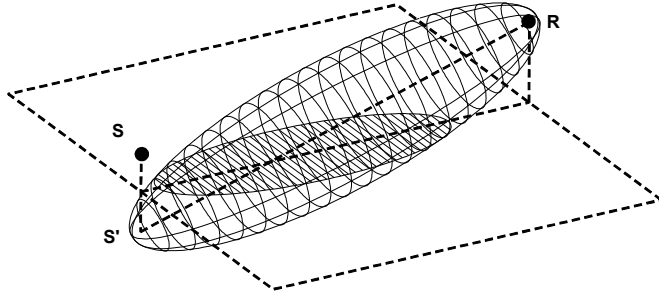


Fig 6. The Fresnel-zone on the ground around the reflection point.

The use of Fresnel-zones has the effect that the ground correction does not show a discontinuities when the point of reflection moves from hard to soft ground or vice versa. Fig. 7 and 8 shows this situation. These two figures show noise level contour lines in a cut perpendicular to a road. Outside the road the ground is soft. In Fig. 7 Road 96 was used whereas Fig. 8 is for NORD2000. At receiver points near the terrain the point of reflection might fall just outside the edge of the road. When this happens the ground effect in Road 96 suddenly causes the total level to decrease. This effect is not that profound with NORD2000. In this respect the contour lines look more 'natural' in Fig. 8. However, the ground effect makes the contour lines in Fig. 8 look rather complex in general.



Fig. 7 Vertical noise map around a road. Road 96.



Fig. 8 Vertical noise map around a road. NORD2000.

WEATHER CONDITIONS

One of the unique features included with NORD2000 is the capability of handling different weather conditions. No other method offers this to the same extent as NORD2000.

The parameters in NORD2000 are:

- Wind speed
- Standard deviation of wind speed
- Wind direction
- Temperature gradient
- Standard deviation of temperature gradient
- Turbulence strength parameter wind
- Turbulence strength parameter temperature
- Roughness length

The wind will decrease the level on the upwind side and increase the level on the downwind side compared to zero wind conditions. This over all tendency has been known for a long time. Now, with NORD2000 this effect can be quantified.

A normal (horizontal) noise map showing the noise level created by a point source above flat and hard ground would show concentric circles if produced using GPM. GPM assumes a moderate downwind in all directions. Fig. 9 shows a map produced using NORD2000 assuming a westerly wind with a speed of 5 m/s measured 10 m above the terrain.. The source is 2 m above ground, and the map is valid for receivers 2 m above ground. The map reflects the over all tendency mentioned above, a level decrease on the upwind side and an increase on the downwind side compared to zero wind conditions.

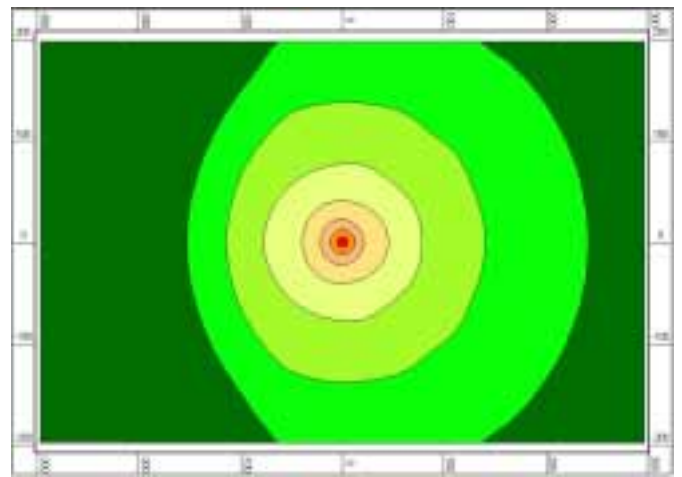


Fig. 9. Horizontal noise map assuming a westerly wind. NORD2000. $H_s = H_r = 2\text{m}$. $\sigma = 20.000 \text{ kNs/m}^4$

Fig. 10 is a difference map showing the difference between results obtained with GPM and NORD2000. The set-up is the same situation as just dealt with, i. e. $H_s = 2\text{m}$, $H_r = 2 \text{m}$, hard and flat ground.

From Fig. 10 it can be observed that GPM and NORD2000 within a few dB return the same results on the downwind side

(assuming wind speed 5 m/s and receiver height 2 m). This was expected since GPM is a 'downwind' method.

On the upwind side however, considerable discrepancies occur. At 200 m distance from the source GPM returns a result that is 6 - 7 dB higher than the result of NORD2000. At 300 m the difference is more than 10 dB.

Especially on the downwind side the contour lines are irregular. This must be explained by the ground effect and the fact that the wind has a different effect on the direct and the reflected sound.

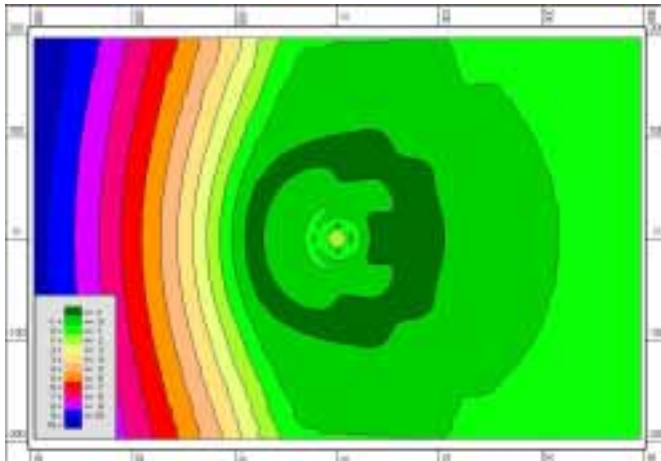


Fig 10. Horizontal difference map, GPM – NORD2000. $H_s = H_r = 2\text{m}$. $\sigma = 20.000 \text{ kNs/m}^4$. 5 m/s wind from west.

Fig. 11 is a vertical difference map of the situation in Fig. 10. From Fig. 11 it can be seen that the large discrepancies between GPM and NORD2000 appear only close to the ground (in the 'shadow zone'). The source is in the lower right corner of the picture, only the upwind side of the situation is shown.

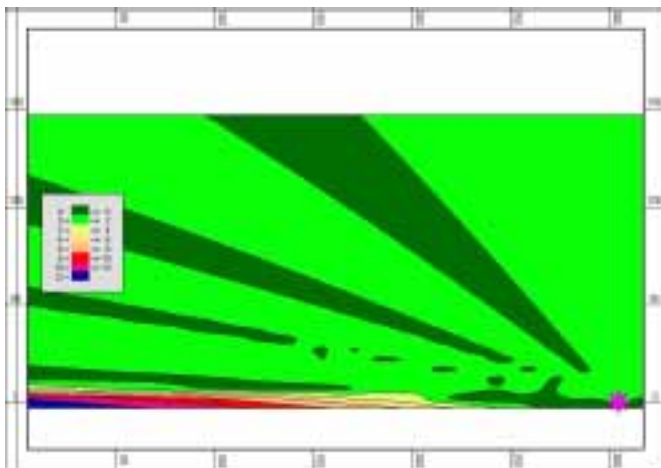


Fig 11. Vertical difference map, upwind side, GPM – NORD2000. $H_s = H_r = 2\text{m}$. $\sigma = 20.000 \text{ kNs/m}^4$. 5 m/s wind from west.

SCREENING

The screening effect in NORD2000 is based on existing theory although this theory has been modified in certain aspects. In order to avoid on/off effects for receivers near the border of the barrier shadow the height of the screen is evaluated using a Fresnel-zone approach. The side diffraction around vertical edges is also taken into account but will be no further discussed in this paper.

A big difference to the old methods appears when weather effects are combined with screening. Fig. 12, 13 and 14 show vertical noise map for a point source between two screens. The source height is 1 m and the screen top is 10 m above the terrain (flat and hard). Fig. 12 is done with GPM and Fig. 13 with NORD2000 assuming a westerly wind with 5 m/s.

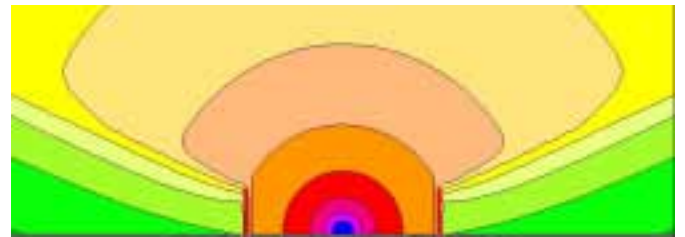


Fig 12 Vertical noise map, point source between two parallel and non-reflective screens. GPM.



Fig 13 Vertical noise map, point source between two parallel and non-reflective screens. NORD2000, westerly wind 5 m/s.

Comparisons between Fig. 12 and 13 clearly demonstrate two facts. First, the contour lines produced by NORD2000 are not as smooth as we are used to from the old methods, here GPM. This is caused by the ground effect. Secondly, GPM overestimates the level on both sides of the screen, especially on the upwind side. This is even clearer in Fig. 14 that shows the difference between the results in Fig. 12 and 13.

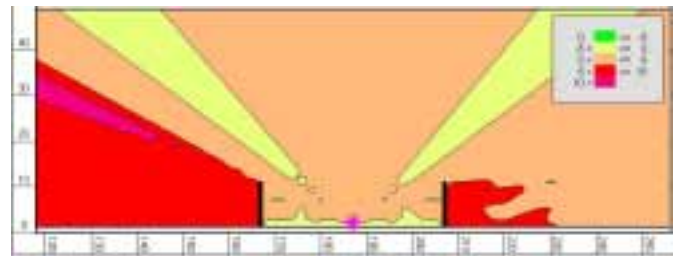


Fig 14 Vertical difference map, Fig 12 – Fig 13.

Please note this: For conventional reasons GPM normally restricts the screening effect to 20 dB. Since NORD2000 has no such limit (so far) this restriction has been omitted here.

REFLECTIONS

NORD2000 handles reflections by introducing a mirror source. This is not different from the existing Nordic methods. Fig. 15 shows how the position of the mirror source is found. To ensure continuity when the reflection point moves from inside to outside the building again a Fresnel-zone approach is used in NORD2000. This is new. The set-up in Fig. 15 would cause no reflection according to the old methods since the reflection point falls outside the building. In NORD2000 the reflected energy is proportional to the active part of the mirror.

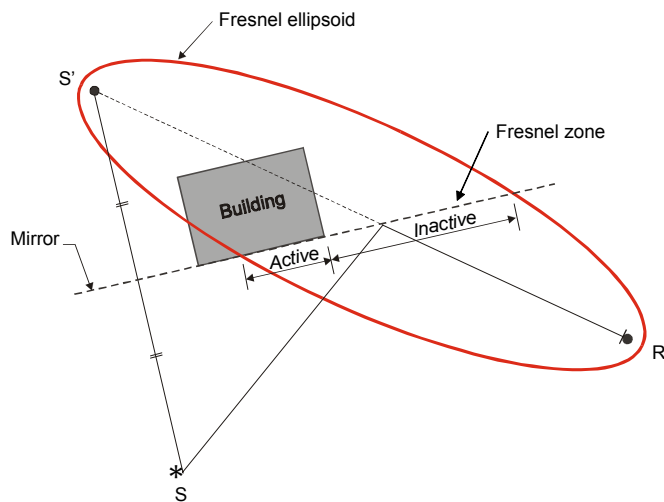


Fig. 15 Illustration of the active and inactive part of a mirror

The effect of this Fresnel-zone approach is illustrated in Fig. 17 and 18. A plan of the set-up is shown in Fig. 16. The set-up includes a point source and two (very high) screens. The screens are vertical and the surfaces are fully reflecting. The ground is flat and hard and the source is 1 m above the terrain. The shown noise maps are valid for receivers 1 m above the terrain.

The noise maps in Fig. 17 and 18 only include the contribution from the first reflection, i. e. the direct sound is omitted.

The size of the Fresnel – zones are frequency dependant, and therefore the size of the active and inactive part of the reflectors also depends on the frequency in question. To make the effect more clear in the figures only the octave 63 Hz is shown.

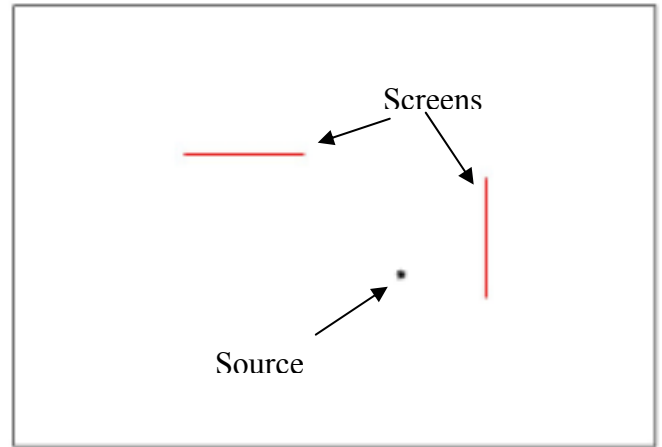


Fig. 16 Top view of the set-up

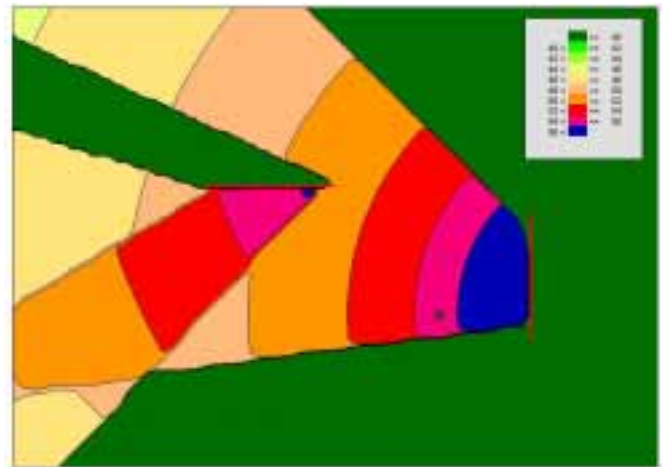


Fig 17. Horizontal noise map showing only the contribution from the first reflection. $H_s = H_r = 1\text{ m}$. $\sigma = 20.000\text{ kNs/m}^4$. GPM.

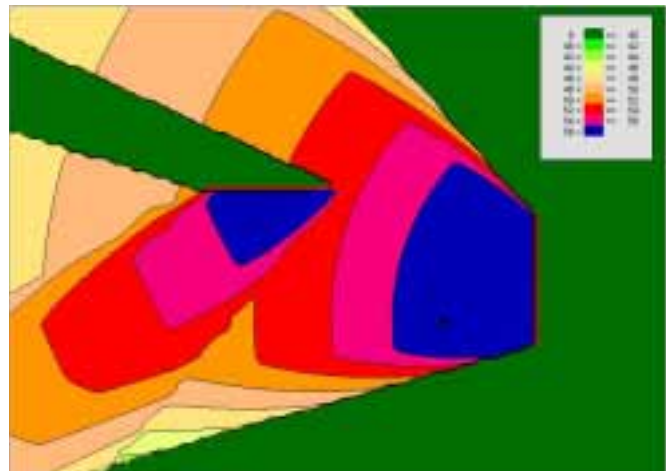


Fig 18. Horizontal noise map showing only the contribution from the first reflection. $H_s = H_r = 1\text{ m}$. $\sigma = 20.000\text{ kNs/m}^4$. NORD2000.

From Fig. 17 and 18 it is quite clear that NORD2000 generates a much smoother shift from reflection zone to free field. This fact contributes to more 'natural' looking noise maps with NORD2000, especially in areas where the direct transmission is shielded.

CONCLUSION

From the test cases shown in this paper it can be concluded that the capability of NORD2000 offers several advantages when it comes to noise mapping. Weather conditions can be taken into consideration and screens/reflectors are handled in a way that will lead to more reliable and 'natural' looking noise maps than if the old methods were used. On the other hand the complex ground effect will contribute to irregular contour lines. This problem however, will mainly occur in situations with one or a few point sources. With line sources – such as roads – it will be a minor problem.

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REFERENCES

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