CONVEYOR NOISE SPECIFICATION AND CONTROL

Brown, S.C.

Heggies Australia Pty Ltd, Sydney, Australia

Abstract

Large, outdoor Belt Conveyor Systems for bulk materials are major sources of industrial noise and frequently become an environmental emissions issue for many existing and proposed plants. Deficiencies in the industry's understanding of the complex, underlying conveyor noise generating mechanisms has meant there are relatively few practical and cost-effective noise management strategies. On the other hand, pressure from regulators and the community generally has frequently led to unachievable conveyor noise specifications. This paper presents the results of an innovative programme of research and testing of conveyors and conveyor components. Conveyor noise is shown to be a composite of noise generating mechanisms, the most dominant of which is the dynamic interaction at the belt/idler roll interface. The Idler Roll surface profile is shown to be a major input to excitation of vibration and noise radiation for most conveyors. An idler roll surface profile measurement parameter is proposed - the Maximum Instantaneous Slope, (MIS) - which can be used to evaluate and assess the operating condition and noise generation potential of existing equipment, as well as to provide a practical basis for specification of new conveyor systems.

Introduction

Large, outdoor Belt Conveyor Systems for bulk materials (refer Figure 1) are major sources of industrial noise and frequently become an environmental compliance issue for many existing and proposed plants.

Figure 1. Typical Large Conveyor Belt System.

Measured Sound Power Levels of conventional belt conveyors range from 113 dBA to 119 dBA per 100 m for typical 10,000 TPH 5 m/s coal conveyors. This paper presents results for standard and alternative idler roll designs, referred to as "low noise" and "super low noise" conveyors. Such conveyors produce sound power levels of 107 dBA and 101 dBA per 100 m respectively, while almost identical in all other respects.

A literature survey revealed very little published information implying a general lack of understanding with respect to conveyor noise generation mechanisms. Horstmeir [4], as far back as 1980 presents results of conveyor noise investigations which identifies the idler roll/belt interaction and structure-borne noise as major sources. Horstmeir concludes that improvement of the idler roll surface as well as damping treatments were possible noise reduction strategies.

Other studies have shown little or no benefit from the application of idler roll damping treatments, whereas some conveyor component suppliers were suggesting that idler rolls with low, total indicator run-out values, (TIR)*, produced quiet conveyors.

Deficiencies in the industry's understanding of the complex, underlying conveyor noise generating mechanisms has meant there are relatively few practical and cost-effective noise management strategies. On the other hand, pressure from regulators and the community generally has often led to the unsuccessful application of unachievable conveyor noise specifications.

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[*] TIR is a measure of the gross "out of roundness" of the roller. As the roller surface is rotated past the head of a contact dial gauge, resting on that surface, the TIR is measured as difference between the maximum contact gauge deflection versus the minimum contact gauge deflection (ie effectively the maximum radius versus the minimum radius).

To use the analogy of the earth's surface, for a nominally circular path flown around the earth the TIR would measure the difference between the altitude of the highest mountain on the path versus the depth of the deepest point on the ocean on that same path.

In any event TIR correlates poorly with noise level due to roller belt interaction.

The development of an effective method of conveyor noise specification for new plant also presented a significant challenge. To date, attempts to specify conveyor noise levels had been unsuccessful due in part to the complex interaction of all conveyor components, which are typically sourced from a variety of suppliers.

Specifications which set out global conveyor sound pressure or sound power levels were clearly inadequate as respective component suppliers had no control over interacting components. Furthermore noise emission limits placed on individual components were also impractical as separate components would generally comply with such limits when tested in isolation. Once installed in the completed conveyor it was often impossible to separate the individual component contributions, even though the composite noise level may have been well over such limits.

This paper presents the results of an extensive programme of research and testing of conveyors and conveyor components. Conveyor noise is shown to be a composite of noise generating mechanisms, the most dominant of which is the dynamic interaction at the belt/idler roll interface. The Idler Roll surface profile is shown to be a major input to excitation of vibration and noise radiation for most conveyors.

An idler roll surface profile measurement parameter is proposed - the Maximum Instantaneous Slope, (MIS) - which can be used to evaluate and assess the operating condition and noise generation potential of existing equipment, as well as to provide a practical basis for specification of new conveyor systems.

The current research has not include detailed investigation of the conveyor belt surface characteristics, however it is likely that the belt surface profile is every bit as important as the idler roll surface profile and could probably be assessed and specified in a similar manner if required. The belt surface profiles of the conveyors reported here were apparently sufficiently smooth so as not to control the belt/idler roll interaction, and hence could be ignored. This may of course not always be the case.

It is not the intention of this paper to address conveyor noise issues due to wear of components.

Preliminary Conveyor Noise Tests

Early investigations included the measurement and analysis of farfield conveyor noise. Noise emanating from typical sections of 8000 TPH and 10000 TPH conveyors was recorded and analysed to produce narrowband and time domain plots. Figure 2 shows a sample time history of conveyor noise while Figure 3 shows a sample narrow band noise spectrum at 5 m from such a conveyor, (8000 TPH 5m/s).

The strong appearance of harmonic activity, (Figure 3), spaced at the idler rotational speed supported the obvious amplitude modulation, (Figure 2).

This amplitude modulation is subjectively a distinct character of most conveyors, and is sometimes referred to as “helicopter” noise. In some areas the conveyor noise character could be almost described as a repetitive impulse.

These simple observations led to the premise that the somewhat synchronized action of the idler roll was a major noise generating mechanism.

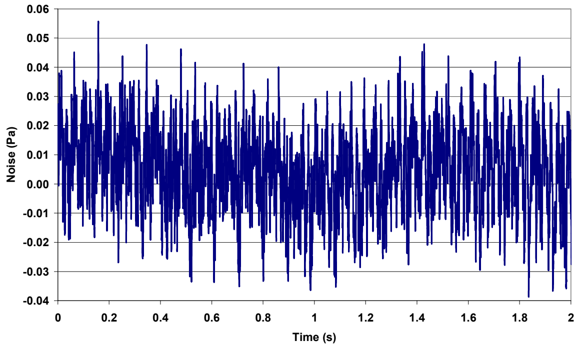

Figure 2. Typical Conveyor Noise Time History-AC Waveform

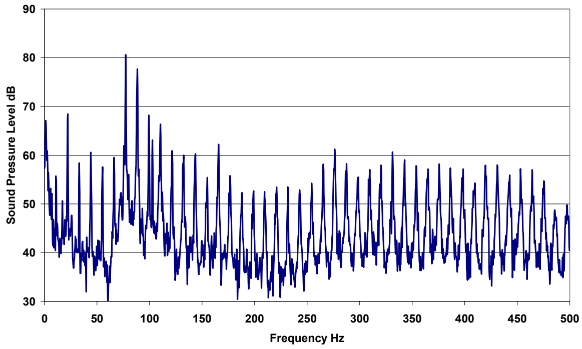

Figure 3. Typical Conveyor Narrow Band Noise Spectrum

Some Fundamental Conveyor Noise Generation Mechanisms

Conveyor Noise generation mechanisms thought to be of acoustical significance can be summarized as follows:

- Idler Roll Bearing Noise
- Idler Roll Shell Noise
- Belt Idler Interaction
- Air Pumping, Belt/Idler Roll
- Structure-borne Noise – conveyor support structure

These mechanisms are symbolised in Figure **4.**

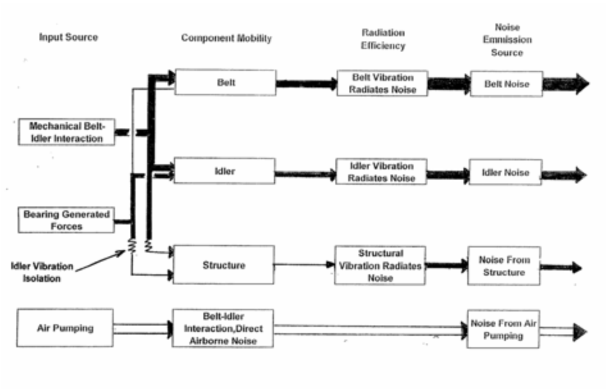

Figure 4. Conveyor Noise Generation Mechanisms

The results of even the preliminary noise study suggested that the Idler Roll rotational frequency was fundamental to noise generation.

Insitu Conveyor Noise Tests

A trial was undertaken in an attempt to rank some of the major noise generation mechanisms. The intention was to carry out a parametric study, and to vary only one parameter on each test section. In practice however this was not practical, (or at least not cost effective), and multiple parameters were an inevitable part of the tests. Table 1 shows the idler roll types inserted in each test section.

Test Section Number	Description of Trial Idler Rolls	Belt Speed (m/s)	Belt Capacity (Tph)	Belt Width (m)	Number Carry / Return Idler Rolls
T1	Aluminium	5	10,500	2.5	3/3
T2	Standard Steel	5	10,500	2.5	3/3
T3	Standard Steel (Reference)	5	10,500	2.5	3/3
T4	Aluminium	5	8,000	2.5	3/3
T5	Standard Steel	5	8,000	2.5	3/3
T6	Low Noise Steel	5	8,000	2.5	3/3
T7	Super Low Noise Aluminium	5.2	10,000	2.5	3/3

Table 1. Insitu Conveyor Noise Test-Idler Roll Types

Methodology

A readily accessible conveyor was chosen to trial the subject idler rolls. The conveyor was a nominal 10,000 TPH conveyor, belt speed 5.2 m/s, belt width 2.5 m.

Sound intensity measurements were used in preference to sound pressure as the directional characteristics of sound intensity provided a means for minimising corruption of measurements with noise from adjacent conveyor segments as well as to eliminate reflected noise from barriers etc (note that in a free acoustic field at any distance from a single noise source, the sound intensity and sound pressure are equal).

Tests on the super low noise idler rolls could only be carried out on a separate conveyor of similar capacity and belt speed.

A baseline measurement was first conducted to measure the average sound intensity of existing “worn” standard idler rolls. Further measurements were then conducted following the installation of the trial idlers in respective test sections.

Measurement Procedure

Each trial section of the conveyor was divided (by conveyor hangers) into nominally nine segments approximately 3 m long.

A rectangular measurement surface for each segment was chosen which was 3 m long and 1.5 m high and 200 mm outside the conveyor stringers.

The average A-weighted sound intensity spectrum for each segment was determined using the scanning method and in general accordance with ISO 9614-2 “Determination of Sound Power Levels of Noise Sources Using Sound Intensity - Measurement by Scanning”.

Note that all testing was conducted with the belt in a loaded condition.

Idler Roll Surface Profile Measurements

A minimum sample of five idlers from each test section was taken to the Richard Heggie Associates Laboratory at Lane Cove for testing. Figure 5 illustrates a photograph of the test used to measure the idler roll surface profiles.

The laser distance transducer was fixed sequentially at three locations along the idler roll being at Midspan, Midspan plus 40% span length and Midspan minus 40% span length.

The analogue output of the laser distance transducer was recorded during a slow roll of the idler roll for subsequent analysis and post processing.

Post processing included preparation of a polar plot of the surface profile as well as determination of the Total Indicator Run-out (TIR, Pk-Pk displacement, µm) and Pk velocity of the surface profile, (mm/s), referred to henceforth as the surface profile velocity. Note that the surface profile velocity for these idler rolls was derived for the in service idler roll rotational speed, in our case 11Hz.

Figure 5. Photograph of Surface Profile Measurement Set Up

Measurement Results

Surface Profile Parameters

Figure 6 presents a sample of derived polar plots of the surface profile of each type of idler roll tested.

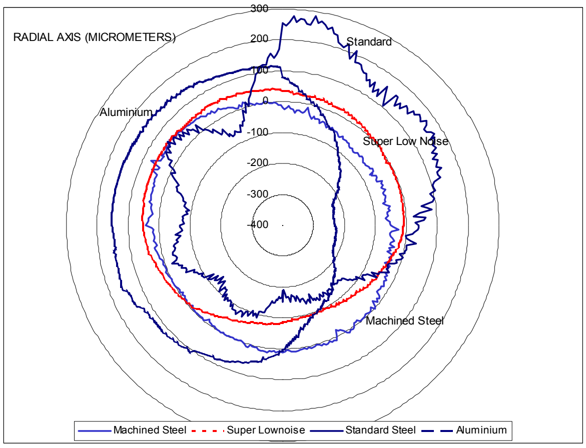

Figure 6. Sample Polar Plots of Measured Surface Profile for Each Type of Idler Tested

Sound Intensity Levels

Table 2 presents the overall average results of each test section, as well as the measured and predicted noise reductions.

The surface profile was developed from 1024 measurement points around the circumference of the idler roll and low pass filtered at 500 Hz, nominal idler speed was 11 Hz

Test Section	**Test Description**	**Test No.**	**Nominal Load (Tphr)**	**Overall Average "A" Weighted Sound Intensity Level (dBA)**	**Measured Noise Reduction Over Standard Steel "Worn" Idler Rolls**	***Predicted Noise Reduction Over Standard Steel "New" Idler Rolls**
T1	Baseline Standard	1	10,000	85	-	-
T1	Aluminium	2	10,000	76	9	7
T1	Aluminium	3	10,000	76	9	7
T2	Baseline Standard	1	10,000	84	-	-
T2	New Standard	2	10,000	83	1	0
T2	New Standard	3	10,000	83	1	0
T3	Worn Standard	1	10,000	85	-	-
T3	Worn Standard	2	10,000	84	-	-
T3	Worn Standard	3	10,000	86	-	-
T4	Baseline Standard	1	8,000	85	-	-
T4	Aluminium	2	8,000	76	9	7
T4	Aluminium	3	8,000	76	9	7
T5	Baseline Standard	1	8,000	87	-	-
T5	New Standard	2	8,000	83	4	0
T5	New Standard	3		83	4	0
T6	Standard	1	8,000	84	-	-
T6	Low Noise Steel	2	8,000	77	9	6
T6	Low Noise Steel	3	8,000	77	9	6
T7	Baseline Standard	1	10,000	86	-	-
T7	Super Low Noise	2	10,000	71	15	12
T7	Super Low Noise	3	10,000	71	15	12

Table 2. Summary of Sound Intensity Levels and Noise Reductions

Table 3 presents a summary of the parameters derived from the surface profile measurements.

The results reveal a significant difference in surface profile velocity levels and MIS values between the idler rolls tested, (see section "Implications For Conveyor Noise Specification" for description of MIS).

Description	TIR (mm) Pk-Pk	Surface Profile Velocity (mm/sec)	Maximum Indicated Slope (MIS, µm per 6 deg)
Aluminium			
Maximum	600	102	84
Average	420	53	48
Standard Steel (new)			
Maximum	770	284	210
Average	480	123	111
Standard Steel (worn) from Conveyor 05:31			
Maximum	820	467	280
Average	510	150	135
Low Noise Steel (Machined then Galvanised)			
Maximum	330	96	76
Average	275	65	65
Super Low Noise (Aluminium)			
Maximum	500	40	32
Average	380	27	27

Note: that the Peak Velocity of the surface profile was derived for a nominal idler roll notational speed of 11 Hz, all results have been low pass filtered at 500 Hz.

Table 3. Summary of the Resulting Surface Profile Parameters

Table 4 presents a further summary of these results showing only the average of all measurement results for each idler type. The results for the parameters velocity have been presented as decibels re 1 mm/sec.

Description	Surface Profile Velocity (dB re 1 mm/sec Pk)	Total Indicator Runout Profile (micrometer)	Maximum Indicated Slope (um/6deg)	Average Sound Intensity (2m from centre conveyor) (dBA)	Sound Power Level per 100m (dBA)
Aluminium	34	420	48	76	106
Steel (new)	42	480	111	83	113
Standard Steel (worn)	44	400	135	86	116
Low Noise (Machined Steel then galvanised)	36	275	60	77	107
Super Low Noise (Aluminium)	29	380	24	71	101

Table 4. Summary of Results

It is interesting to note that the reduction in dB of the velocity surface profile parameter correlates well to the measured average noise reductions for respective idler roll types.

On the assumption that the small sample of idler roll surface profiles tested was representative of the respective idler roll types, the average value of the TIR and velocity of surface profile was calculated for each type of idler tested.

Figure 7 is a plot of the resulting average TIR levels vs sound intensity, which does not show any meaningful correlation. Furthermore it can be demonstrated that idlers with the same TIR can generate significantly different noise levels due to entirely different surface profiles.

In contrast a strong, almost linear relationship between sound intensity (dBA) and the velocity of surface profile is apparent in Figure 8.

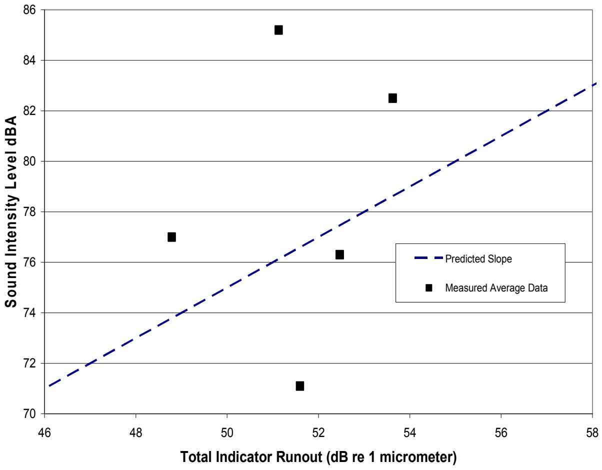

Figure 7. Average TIR vs Sound Intensity

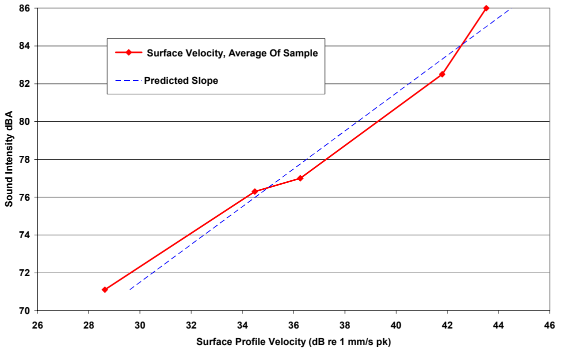

Figure 8. Average Surface Profile Velocity vs Sound Intensity

Note, that no testing of the conveyor belt surface profile was carried out during these trials. While there is rather obvious potential for belt surface irregularities to produce noise in the same way that irregularities in the idler surface do, the belt surfaces here were very smooth by comparison and therefore not a controlling influence on the idler roll/belt interaction mechanism.

Figure 9 shows typical sound power spectra for standard, low noise and super low noise conveyors, nominal 10,000 TPH and belt speed 5.2 m/s. The overall sound power level for the low noise and super low noise idler rolls were 8 dBA and 14 dBA lower than the standard idler rolls respectively. Comparison of the spectral content shows that the highest noise reductions have been achieved at lower end of the frequency spectrum where the idler/belt noise generation is most dominant.

As may be noted from comparison of these spectra there is a broadband noise reduction of approximately 7 dB, in going from the standard to low noise rollers, with the further improvement in surface parameters of the super-low noise profile major reductions are achieved at the low-frequency end of the spectrum (ie below 500 Hz).

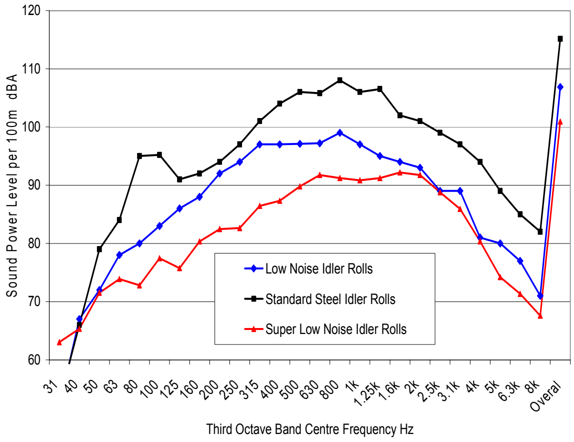

Figure 9. Typical Conveyor Sound Power Spectra: Standard, Low Noise and Super Low Noise Idler Rolls

Idler Roll Self Noise Generation Measurements

Additional noise tests were undertaken using the idler samples above, in order to assess the self noise generation affect, ie the idler roll noise was measured in a test set up in which the idler roll was rotated at a representative speed in the absence of conveyor belt contact.

Table 5 shows a summary of the resulting average sound power levels for each type of idler roll, as well as the calculated sound power level per 100 m of conveyor, from idler roll self noise for the test conveyor configuration.

This table also shows that the sound power of the idler rolls alone, (rotating at conveyor design speed, in the absence of other components), is at least 20 dBA below the actual measured conveyor sound power levels. This observation does not mean that worn idler rolls will not increase conveyor noise levels; as they certainly do in severe cases, through injection of increased structure-borne energy as well as direct radiation.

Idler Roll type	**Average SWL per Idler Roll (dBA)**	**Predicted SWL per 100m (dBA)**	**Level Below Measured Conveyor Noise (dBA)**
New Standard	53	76	35
Aluminum	50	73	32
Worn Steel	70	94	21
Low Noise Steel	52	75	31
Super Low Noise	50	73	28

Table 5. Idler Roll Self Noise Test Results

Implications for Conveyor Noise Specification

The results of this investigation have demonstrated that within the range of idler types tested, there is a strong correlation between the velocity of idler roll surface profile parameter with conveyor noise emissions. The basis of conveyor noise control and specification must therefore begin with the idler roll surface profile.

The results also indicate that the conveyor noise emissions are much less sensitive to the TIR parameters.

Table 6 presents suggested idler roll surface parametric criteria.

Maximum TIR	**Maximum Surface Profile Velocity**
600 μm	100 mm/sec Pk (40 dB re 1 mm/sec)

Table 6. Suggested Low Noise Idler Roll Specification

The surface profile velocity criterion of Table 6 is a maximum limit set with the aim of achieving an average level of approximately 36 dB or lower. This limit was chosen as an achievable level for machined and post galvanised idler rolls. Note that the galvanising process was found to be the limiting factor in machined idler rolls; much lower surface profile velocity levels could be achieved without galvanising.

As the velocity parameter in Table 6 requires a large number of measurement points to generate the surface profile, (see Figure 6), with further analysis to calculate the surface profile velocity, a simplified surface profile parameter was proposed, which defines the Maximum Indicated Slope, (MIS), rather than the surface profile velocity.

This alternative method of specification provides for a more simple or manual measurement of the indicator runout of the idler surface at a minimum of 60 locations around the circumference (ie every 6 degrees). The surface profile parameter proposed is the Maximum Indicated Slope, (MIS). The maximum sequential difference in indicator runout would be noted and compared to the criterion.

More automated or computer controlled test rigs have also be developed for production batch sampling or compliance testing, such rigs take 360 measurements around the idler surface in three planes simultaneously with the complete MIS/TIR test obtained in seconds.

Table 7 presents recommended alternative parametric specifications prepared using the MIS and TIR specific to the nominal 152 mm diameter idler rolls operating at rotational speed of 11 Hz, (utilized at the trial site).

Criteria Description	**Surface Profile Parameter**	**Low Noise Conveyor Limit (refer *)**	**Super Low Noise Conveyor Limit (refer **)**
TIR	Total indicator runout	600 µm (Pk-Pk)	600 µm (Pk-Pk)
MIS	Maximum Indicated Slope (per 6^0 of idler rotation)	90 µm	40 µm

* *Limits found to be achievable for machined and galvanized seam welded steel idler rolls and most extruded Aluminium Idler rolls*

** *Limits found achievable for machined idler rolls and some types extruded Aluminium idler rolls*

Table 7. Idler Roll Parametric Specification for Low Noise and Super Low Noise Belt Conveyors

As the conveyor noise is not particularly sensitive to idler roll self noise, the length of the idler roll can be ignored and a blanket criteria is suggested as shown in Table 8.

Idler Roll Surface Speed	**7m/s**	**5m/s**	**3m/s**
Sound Power Level/Idler Roll	68 dBA	66 dBA	62 dBA

Table 8. Idler Roll Self Noise Criteria

Conclusions

The results of this investigation have demonstrated that for the range of idler types tested, a strong correlation exists between the velocity of idler roll surface profile parameter and the conveyor noise emissions. Of the possible conveyor noise generation mechanisms identified, the mechanical idler roll belt interaction was found to be dominant.

A simplified idler roll specification has been proposed. Compliance with this specification has been found to provide a 6 dB noise reduction for the low noise criteria and a 12 dB reduction for the super low noise criteria, relative to standard steel seam welded tubular idler rolls.

Acknowledgements

We acknowledge the initiative of Port Waratah Coal Services, (PWCS) Newcastle, Australia. As part of the PWCS Kooragang Coal Terminal and Carrington Coal Terminal environmental noise reduction programs, Richard Heggie Associates was commissioned to investigate many aspects of conveyor noise emission, mitigation and specification. PWCS has also made conveyors available for such test and development work.

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