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Rail grinding operations in Sweden

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Over the last few years, rail grinding operations at Banverket in Sweden has become a natural and important part of the total maintenance track work. The number of track metres that were ground during 2006 was almost 1 million (exactly 997272 track metres) and almost 400 switches. The way of grinding and planning these operations are described, both on the ore line in the northern part, Swedish only heavy haul line, as well as on conventional lines.

Banverket (BV), The Swedish National Railway Administration, has overall responsibility for the entire railway system, meaning that BV follows and promotes development throughout the entire Swedish railway sector. Banverket's administrative

units plan and procure operation and maintenance as well as the conversion and extension of state railway installations. Sweden may be a small country in area size, but the distance in north-south direction is more than 2,000km. This means that the climate varies

considerably; from more continental weather in the south to longer and colder winters in the north. This difference also affects the maintenance conditions in general.

The Swedish heavy haul line, 'Malmbanan'

Located in the northern part of Sweden is Sweden's only heavy haul line. The 473km long ore line runs from Narvik on the coast of the Norwegian Sea to Luleå on the coast of the Gulf of Bothnia. The construction of the standard gauge rail line began in 1898 and includes 25 tunnels and 125 bridges through rugged terrain characterised by numerous sharp curves and steep elevation changes. The line was completed and became operational in 1902. The Swedish part of this line is named 'Malmbanan'. The axle load has for some time been limited to 25 tons but an upgrading to 30 tons was recently completed. This implies that each car will be able to carry 100 tonnes instead of 80, and that each train set will consist of 68 cars instead of today's 52. The total train weight has increased from 5,200 to 8,160 tons. The annual traffic load on the

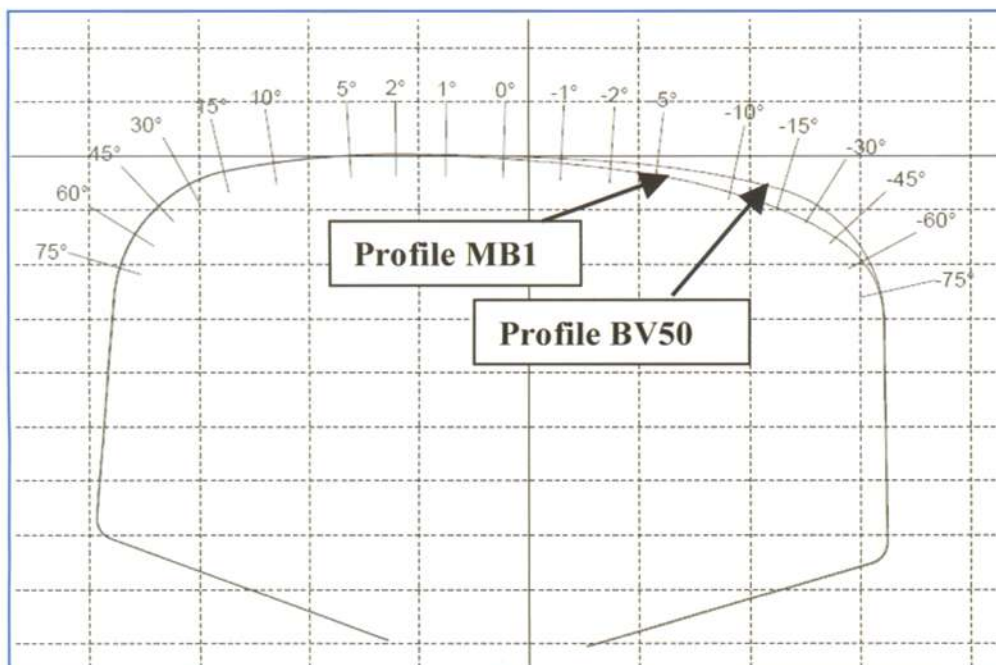


Figure 1: Target profile MB1 compared to the Swedish standard profile BV50

northern part of the line is 27 million gross tons.

On 'Malmbanan', a large portion of the operational budget has been given to the maintenance and replacement of rails. Various elements contribute to the total cost of managing factors as rail breakage, RCF-problem and wheel/rail and track geometry. Some of the most critical factors on a heavy haul line are wheel/rail contact and rail condition.

In heavy haul applications, grinding and lubrication are routinely used as a maintenance tool

A grinding program was initiated by Banverket in 1997 at 'Malmbanan' between Kiruna and the Norwegian border and a new target profile was introduced at this time. This target profile is a wear adopted profile, called "MB1" (see Figure 1), and aimed to cope better to the somewhat hollow worn wheels of the ore trains. The MB1-profile was at first only ground on the high-rail and with standard BV50-profile still ground on the low rail. As the contact path in this MB1-profile is wider than previous standard profiles, the onset of RCF was

values shown in Figure 2.

The launching of the grinding project was an important step in increasing the axle loads to 30 tons and was also one of the main strategies to prolong the renewal of existing 50kg rails. Even after only a short time, measurable cost savings for both infrastructure and traffic were seen. We are convinced that a strategic rail maintenance program has delayed necessary maintenance costs. Optimizing the grinding process and continuing to develop the rail profile are all possible steps to further increase rail

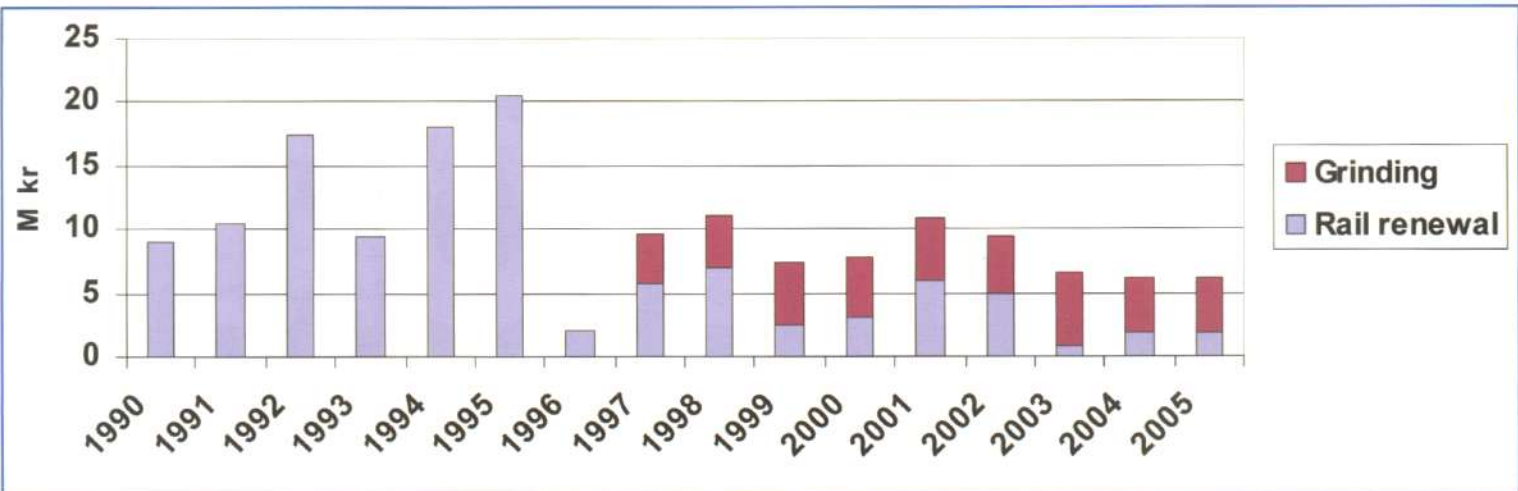


Figure 2: Quantity of annual rail renewals and grinding on the heavy haul ore track between Kiruna and the Norwegian border

in curved track sections to reduce friction, wear, and RCF. However, proper lubrication can reduce wear rates by a factor of 20 (Elkins et al.¹ and Waara²) while grinding programs can also produce significant cost savings for both the wheel and infrastructure owner.

Rail grinding on 'Malmbanan'

Both the maintenance strategy and maintenance plan on 'Malmbanan' includes activities such as yearly maintenance grinding (including rail head re-profiling) and extensive rail lubrication in curves less than 600 metres in radii. The required function is to reduce the influence of surface initiated RCF and reduce rail head wear. The grinding activity with its given instance of duration and time interval is achieved via a subcontractor from outside Sweden (between 2006 and 2008, with an option for an additional two years, the company Speno is the grinding contractor).

expected to be delayed. Soon, the results fulfilled to a great extent these expectations. The amount of RCF-defects like head-checking, spalling and shelling were in a pronounced way decreased.

An economic evaluation between 1990 to 2005 of the heavy haul grinding program is shown in Figure 2.

The cost level in Figure 2 is significantly reduced when the years before and after the initiation of the grinding program is compared. The rail renewal need, due to severe rail damages, soon gave a 'pay-back' of the cost for rail grinding. The first two years of the rail grinding program, the total cost of grinding plus rail replacements was reduced by almost 40%, while both the rail and track quality generally improved immensely. However, after several years of grinding, the track may degrade and an accumulated volume of rail will probably need to be replaced. It is likely that the future cost level will be slightly over the

life. Neither grinding campaigns nor objective measurements to increase wheel life using a new rail profile, seems to negatively affect the total wheel/rail system. Although it may not be possible to reproduce such savings everywhere that RCF damage occurs, some lessons from the test are of general relevance.

Today, grinding on 'Malmbanan' is performed once a year. The curves are ground every year which is each 27 million gross tons. The tangent track is ground every third year, i.e. after approximately 80 million gross tons. Some curves may need to be ground earlier than after 27 million gross tons. As the grinding of 'Malmbanan' takes place in the summer to autumn period, grinding at another period would have to be solved logistically together with the availability of a grinding machine.

The metal removal rate is a minimum of 0.2mm for both preventive (new rails) and maintenance grinding. This metal removal amount is a compromise

between taking away enough fatigued material and the artificial wear by grinding.

The evaluation of the adopted wear profile "MB1" has been followed by more optimised target profiles on 'Malmaban'. The profile "MB3" (see Figure 3) is a further development characterized by slightly modified gauge corner shape and results in an optimised gauge corner relief.

The highest point is at the same time located more to the field side. For the years to come the increasing traffic with 30 tons axle load and its effect on the track will be monitored closely. The increasing traffic load might lead to some changes regarding grinding strategy, for example grinding cycles, metal removal and optimizing of adopted grinding profiles.

Rail grinding on conventional lines

The grinding of BV tracks started on a larger scale in the northern part of Sweden, on 'Malmaban'. The results achieved on this track inspired BV to look for a better strategic solution also for the grinding of conventional lines in the south and middle part of Sweden. Most of these lines have a mixed traffic situation. Passenger trains (up to a speed of 200km/h) as well as freight trains with axle loads of up to 25 tons share these lines together with regional commuter trains. By grinding of these lines, the existing corrugation is removed in order to achieve good comfort for the passenger. At the same time,

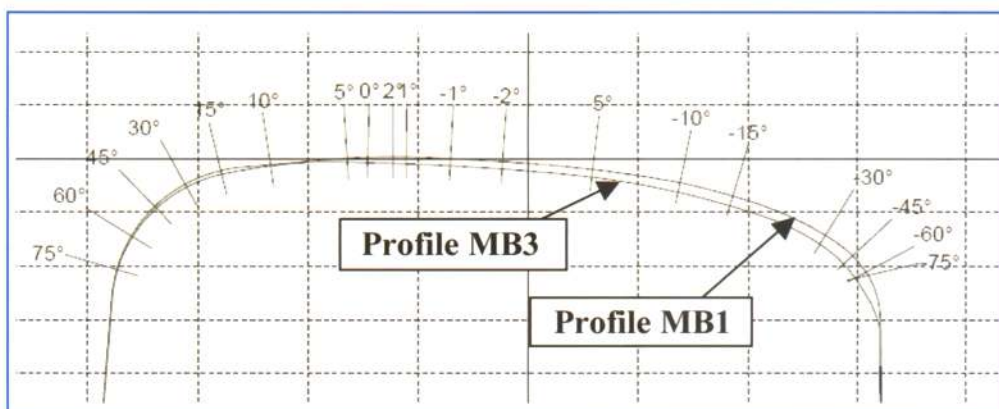


Figure 3: Target profile MB3 compared to profile MB1

the tracks are ground with the aim of removing defects like RCF, if not completely, at least to minimise the size and amount, together with a re-profiling of the rail head in order to receive good steering of the bogies. In densely built-up areas the noise from the train traffic may be reduced by grinding the rails.

Approximately 100% of all new rails are ground by preventive grinding. Regarding maintenance grinding of tracks that have been used for some time, the local hubs at BV decide which tracks or part of tracks are those that need grinding from measurement results of the track geometry (i.e. corrugation) and visual monitoring. As a start, BV has written in a handbook some strategic recommendations when to grind. Basis for forming judgements how and when to grind are given, for example how and when to deal with cracks from head-checking, limits for acceptable

irregularities such as short pitch corrugation and short wave formation.

Recommendations are also given for grinding after a certain load cycle. For example, with an axle load of a maximum of 22.5 tons, curves with radius 500 metres or lower are to be ground each 30 million brutto tons. Curves larger than 500 metres are to be ground each 40 million brutto tons and tangent tracks to be ground each 70 million gross tons. These values are recommendations. What finally decides when to grind is the actual condition of the rails compared to use of the track in question, i.e. the speed, type of traffic etc. Aids to be used in making a grinding decision are different measuring results, e.g. corrugation, rail profile, non-destructive testing.

Special grinding or corrective grinding may be needed for example to re-profile very bad ('flat') profiles or when the wave formation has become very severe. To remove deep cracks or other large defects completely, it may not be possible from both an economical or technical point of view. The aim in such cases is to un-load the gauge corner and to achieve an improved contact patch between the wheel and rail and lower the contact stresses.

Grinding of switches

The switches are ground from the same standpoints as the open track. The presence of corrugations, wear, RCF-defects and out of geometry of the rail head are parameters which decide when and how to grind a specific switch.

In 2006, 397 switches were ground at Banverket. Of these were 80 switches located on 'Malmaban'. The switches are ground either in the main track

Effectively controlling Rolling Contact Fatigue

Rolling Contact Fatigue (RCF) is a widespread phenomenon found on rails subjected to intense traffic conditions such as heavy axle loads or high train speeds. Removal of the fatigued surface layer off the rails eliminates the problem as it prevents cracks from growing into severe defects.

It is important to shape the railhead to a profile geometry, which corresponds optimally to the profiles of the passing wheels. Thus, stresses in the small contact area between wheel and rail are reduced. Therefore re-occurrence of headchecks is delayed and the crack growth rate decreased. Speno International SA has participated in several research projects with respect to RCF treatment, resulting in propositions for suitable anti-headcheck profiles and respective production tolerances.

As metal removal needs to be repeated in cycles depending on line tonnage, it must be kept to a minimum in order to reduce artificially created rail wear and assure long rail service life. Consequently monitoring of crack removal has come into focus.

In 2006 a new recording device "Headcheck Grinding Scanner" has been presented at the IAF show in Münster/Germany. This system measures the depths of the headchecks continuously during each grinding pass and documents headcheck removal precisely. Up to now three Speno grinding machines have been equipped with such a device. With the use of this new recording tool and the correct application of anti-headcheck profiles Speno International SA contributes to controlling rolling contact fatigue in a more effective way.

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solely or both in main track and diverting track.

On 'Malmaban', almost every switch is ground every year – at least the switches in the main track and the most often both the main and diverting track. At the beginning, the target profile was 'standard' profile BV50 with an inclination of 1:30 instead of vertical profile which the switches are installed with. However, with this standard profile the result were the same as in open track, i.e. unacceptable wear and the presence of RCF-defects. Therefore, the target profile "MB4" was tested. This profile also has a gauge corner relief but not to the same extent as profile "MB1". The reason for not grinding directly to "MB1" was mainly due to reduced production capacity of the switch grinder. To grind "MB1" from a deformed profile would have been very time consuming. Grinding in steps was for this reason decided. However, in 2007, most of the switches will be ground to the target profile "MB1".

On conventional tracks the switches are ground to standard profile 60E1 or 50E3 with inclination 1:30. Some tests have been performed with other target profile, e.g. 60E2 with inclination 1:40. However, so far the results with these profiles show no improvements compared to the standard profiles.

In some cases, mainly on 'Malmaban' but also to some extent on conventional tracks, the upper part of the switch blade point is exposed to cracking. The reason is a local overload when the wheels are moving from the stock rail to the switch blade. Due to wear, both natural and 'artificial' by repeatedly grinding, the stock rail is lowered over time with respect to the tip of the switch blade. To avoid and to minimise the risk for cracking of the upper part of the switch blade point, the switch blade is lifted some few millimetres. This results in the grinding of the top part of the blade and after grinding with lifted blade the transition point is moved towards the inner part of the blade.

Planning of grinding operations

The annual grinding budget was earlier decided by each region or local hub. In many cases, the grinding budget was deleted due to economy measures and postponed to the following year.

In 2001, this procedure was changed. A central money 'pot' was earmarked annually at the head office in order to strengthen the grinding maintenance. From each region the need for grinding with respect to both open track grinding and switch grinding was reported to the head office. In case the money was less than the need, the head office in consultation with all the regions decided the grinding priority.

So far, this procedure has shown good results and rail grinding has become a much higher status compared to previous years. The interest in rail grinding has spread from the north to the other regions at Banverket.

The planning of the grinding operations has today a 'turn-key' solution. This means that all planning work is performed by one organisation; a private company in Sweden named Spark Trade AB. They do all the detail planning according to the requested grinding from the regions including supporting with a pilot on the grinding trains, road guards and other service arrangements in connection with grinding of both open track as well as switch grinding.

Future work

New challenges have to be dealt with in future years. The increasing traffic on the heavy haul line, 'Malmaban', both in axle loads, 30 tons, and growing total load of the track, means continuation of the work to optimise grinding profiles. Testing of new modifications of adopted profiles will be monitored closely. Depending on the achieved results, the grinding strategy may be changed regarding grinding cycles, metal removal and optimised profiles.

On conventional lines, the increasing traffic in general and the growing amount of trains with

axle loads 25 tons together with increasing speeds for passenger trains, leads to continued development of best-practice for the track maintenance work. This work includes rail grinding as an important part together with other operations such as tamping and straightening. □

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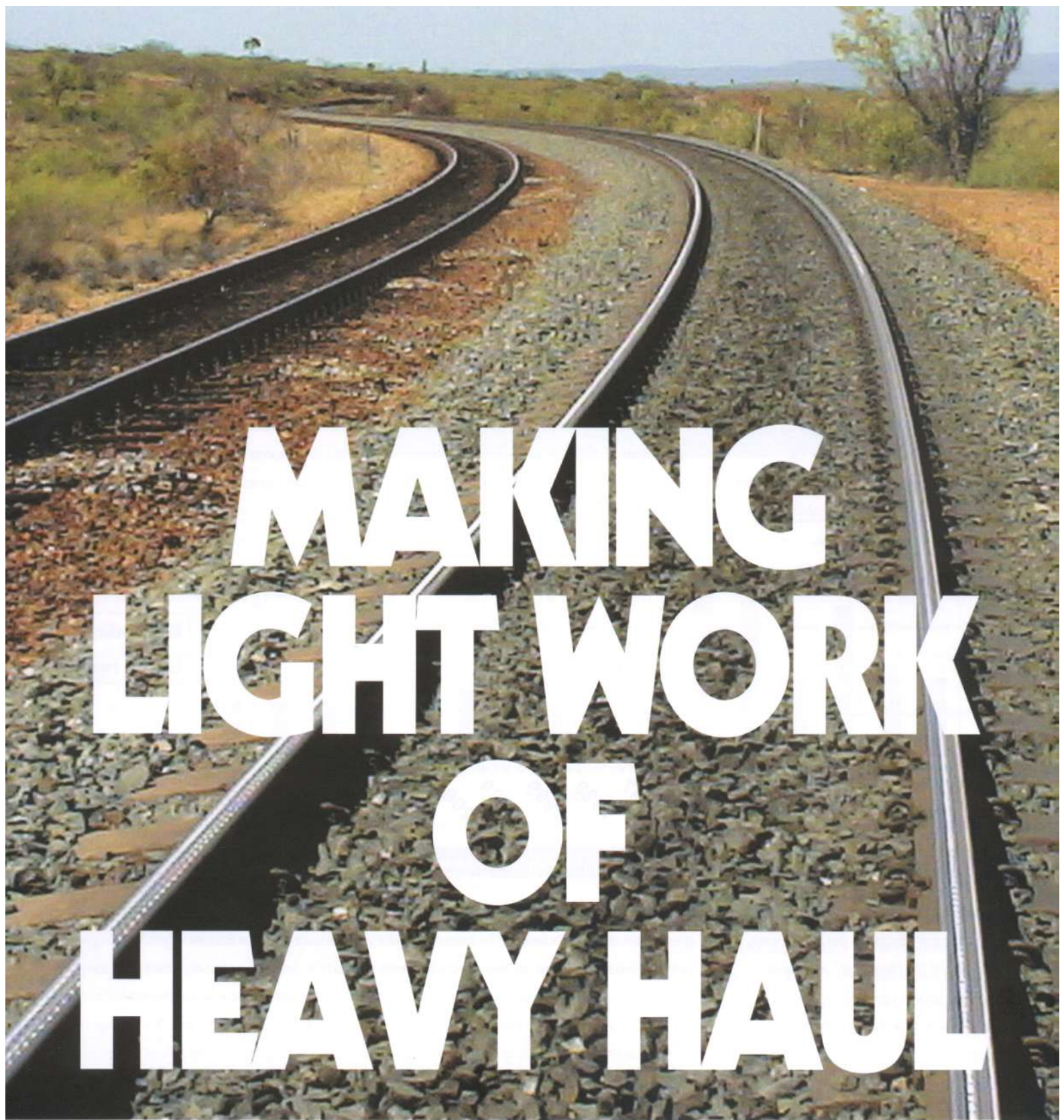


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