ROUND LINK CHAIN – CONVEYOR APPLICATIONS IN A SUGAR MILL

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Abstract

Round link chain has been used for many years in the coal mining and timber industries, but it has only recently made its appearance in the sugar industry. Its possible benefits over other forms of conveyor chain are discussed, and its uses in the cane yard and on slatted carriers at Amatikulu are evaluated.

Introduction

An engineer at Amatikulu visited a mining exhibition in Johannesburg, and saw a chain, normally used as a hoist or cane chain, demonstrated for use in a conveyor. This chain was much bigger than the usual cane chain and the idea was studied by the engineering staff at Amatikulu. It was found that this "round link" chain had three main advantages over pin type chains. These were :—

1. *Cost.*
   It is much cheaper than roller chain, and costs a quarter of the price of roller chain with an attachment every 4th link and one tenth of the price of roller chain with an attachment on every link.
2. *Strength : Mass Ratio*
   This was found to be as much as 2 : 1 in favour of round link chain.
3. *Simplicty.*
   Round link chain is simple in construction, rugged and flexible.

Chain Design

This type of chain has been available for a long time. The first use of this chain is lost in antiquity; the inventor and date of origin unknown. It is reported to have been used as far back as the third century BC in war machinery and even before that in precious jewellery in ancient Egypt. However, its intrinsic properties inherent in its construction are not as well known and are discussed briefly below.

Chain Damage.

Damage to round link chain from external causes such as corrosion, wear, nicks and gouges is readily seen. The chain has no hidden core where corrosion can attack unnoticed. Also, its geometry is quite insensitive to mechanical surface damage. Figure 1 shows that the outsides of the long straight barrels and the insides of the curved end portions are in zones of compressive stress when placed under load. Therefore, scuffing on the exposed portions of the barrels and moderate interlink wear at the crowns is negligible.

Wear.

Wear can occur in any portion of a link that is subject to rubbing contact with another surface. Wear is confined for practical purposes to :—

(a) interlink contact;

(b) the outsides of the straight side barrels.

Interlink wear may be easily inspected by separating the links from the chain. It is debatable as to how far this wear can be allowed to proceed before the chain should be replaced. This amount will be discussed more fully below. However, it should be noticed that wear takes place in the compressive zones of the link, and therefore can be tolerated to a point. Wear on the side barrels can also be tolerated for the same reason. This wear can be reduced by the use of some form of lubrication — even if this lubrication is water.

Chain stretch.

There are two main reasons for the chain stretch, namely:–

(a) interlink wear;

(b) ductile elongation in the barrels.

Interlink wear is due to corrosion, abrasion and flexing of the chain whilst in use. A newly installed chain working within its designed capacity will always seem to "stretch" significantly at the beginning of its working life. This is because the interlink faces bed in. The high spots are removed and a decarbonized layer 0,2 – 0,35 mm thick is penetrated so that the chain can bed into the actual hard core of the link. This decarbonized layer is caused by the rolling and forming processes used in the manufacture of the chain.

Ductile elongation in the barrels results from the chain being too heavily loaded. Referring to Figure 2, if the interlink wear has occurred then the chain will get out of pitch. However, if the dimension L + 2d has increased, then ductile elongation has occurred and the chain will also get out of pitch. Various authorities have advised certain recommended maximum pitches for this chain. ISO recommends that overall maximum pitch should not be more than 3% greater than nominal pitch. Manufacturers of coal mining round link chain recommend that interlink wear must not be greater than 8% on diameter. Loghaul round link chain can be out of pitch by as much as 12%. However, at Amatikulu chain has been used that has been as much as 20% out of pitch. This has been possible because the chain was lightly loaded and a toothed sprocket was used. Further, when an anvil is used on the side of the sprocket to support the horizontal link, an even greater out of pitch condition can be

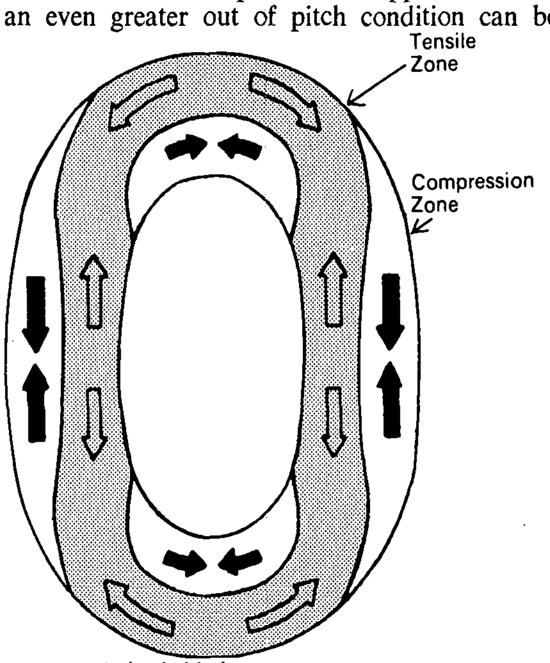

FIGURE 1 Stress zones in loaded link.

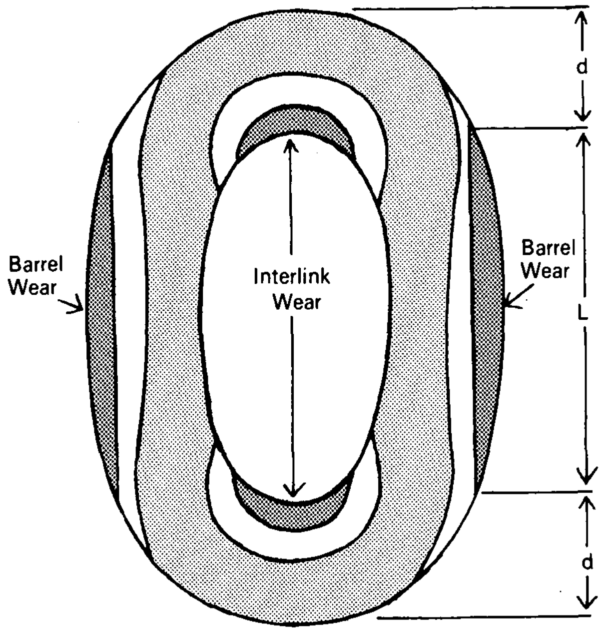

FIGURE 2 Link wear and dimensions.

tolerated. This will be discussed later. Coal conveyor chain only uses pocketed wheels and the close fit of the pocket demands that the chain remain as near as possible to its designed pitch. Basically, the moment a chain has to be taken out of service is a function of sprocket design and loading conditions.

Chain stress and welding.

If a chain is examined to ascertain where the maximum and minimum stresses are in a link under tension, it is seen that the stresses are low in the barrel of the link when compared with the stresses that exist in the crowns (Figure 3). Further if a barrel of a link had one third of its diameter removed and the chain was tested to destruction, the chain would still fail where shear force is greatest, i.e., where the bending moment is zero. This is at the shoulder of the link as shown in Figures 3 and 4. For this reason the chain can relatively safely be joined or shortened, merely by cutting and welding on the barrel. This practice is not openly condoned by the chain manufacturers but by using the correct welding electrode and keeping the heat down, we have successfully welded many strands of round link chain together. We have not had any failures due to this practice either.

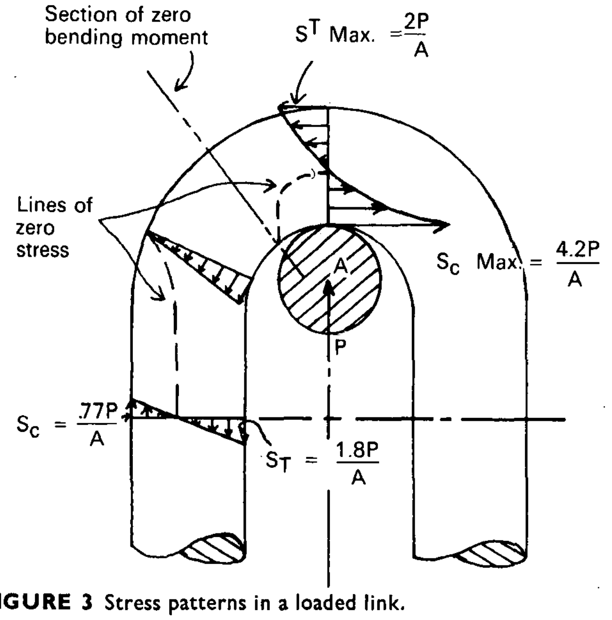

FIGURE 3 Stress patterns in a loaded link.

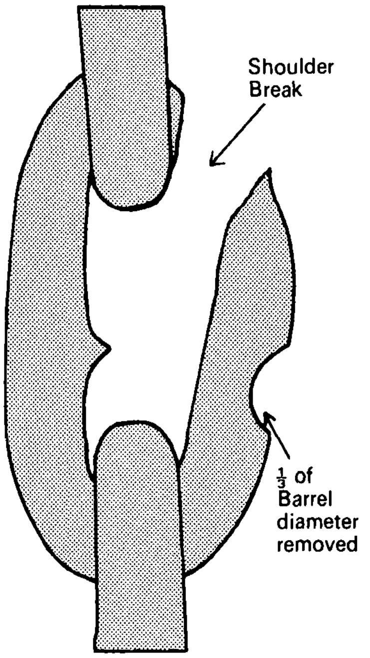

FIGURE 4 Grooved test link pulled to destruction.

Simplicity.

Finally, this is a very simple chain to operate and maintain. It is mechanically strong and reliable. Compared with pin type chains, high-strength round link chains have double strength/mass ratio or more and can be used in the same application. Moreover, their three-dimensional flexibility makes it possible for a single endless chain to drive many components in different planes — opening up interesting possibilities in conveyor design. Also the simple and rugged construction of round link chain makes it self-cleaning, easy to inspect and relatively immune to galling damage that can occur unnoticed to the bearing surfaces of pin type chain.

Types of Round Link Conveyor Chain

There are two main types that an be used. These are

(a) loghaul chain and

(b) coal conveyor chain.

Loghaul Chain.

Loghaul chain was originally made by a Swedish chain company and was introduced into this country about 1930. It was designed for use in saw mills and was made as a wrought iron chain in those early years. This chain was also supplied by the Canadian company, Columbus–McKinnon and wrought iron was changed to high tensile carbon steel and alloy round bar, when import problems were experienced during the second world war.

Coal Conveyor Chain.

This chain was first used in Germany during the war to replace chain normally used in coal mines that became unobtainable at the time. After the war, its use spread rapidly to other industries related to coal, such as smuts handling in power stations. It is being used to an ever increasing extent in South African mines and for a variety of applications.

The Differences between Loghaul and Coal Conveyor Chain

Loghaul is a much longer link chain than coal conveyor as shown in Figure 5. If the pitch/diameter ratio is compared in both chains, it is found that the loghaul is 4,8 : 1 and the coal conveyor is 3,4 : 1. Pitch is the longest possible inside link dimension while the diameter of the chain is the diameter of the roundbar used in its construction.

Because loghaul has a longer pitch it can be used with a toothed wheel or sprocket, whereas coal conveyor can only be used with a pocketed wheel. An example of a pocketed wheel is shown in Figure 6. The loghaul/toothed wheel combination therefore has a number of advantages over the coal conveyor/pocketed wheel. These are :—

1. *Toothed wheel is self cleaning.*

   The action of the tooth engaging with the chain automatically cleans the the sprocket whereas the pocketed wheel traps the dirt and can cause the chain to jump out of the pocket.

2. *Toothed wheel is easier to manufacture and maintain.*

   The toothed wheel can be made from plate whereas most pocketed wheels have to be cast. Teeth can easily be hardfaced, built up and ground back whilst in service, but pocketed wheels cannot. The toothed wheel also lends itself to the idea of segmented rims or individually bolted teeth for easy maintenance but pocketed wheels do not.

3. *Toothed wheel is not so sensitive to chain pitch change.*

   As the chain and/or wheel wears, the toothed wheel is more likely to stay in pitch than the pocketed wheel because the toothed wheel allows the chain to slide down the tooth if it is slightly out of pitch, whereas the design of the pocketed wheel requires the chain to stay in pitch all the time otherwise the chain will override the sprocket. This fact allows the toothed wheel to give a much smoother action.

4. *Toothed wheel has a longer life.*

   This is because it can accommodate wear far easier than a pocketed wheel, as explained above. Also it does not wear as fast as a pocketed wheel as there are less critical points of contact. Anvils can be installed on the sides of the teeth to support the horizontal links and as the chain wears or stretches, so these anvils can be moved out, thus increasing the PCD allowing the chain to stay in mesh for longer periods.

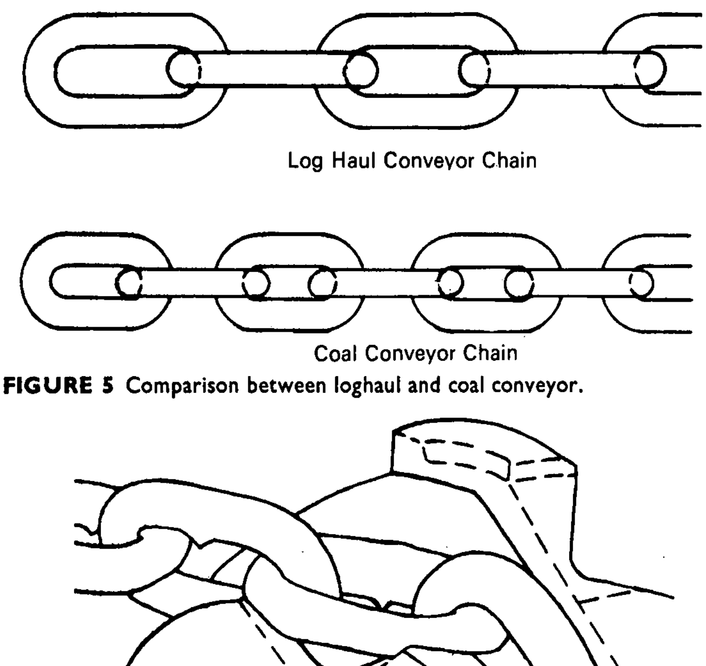

FIGURE 5 Comparison between loghaul and coal conveyor.

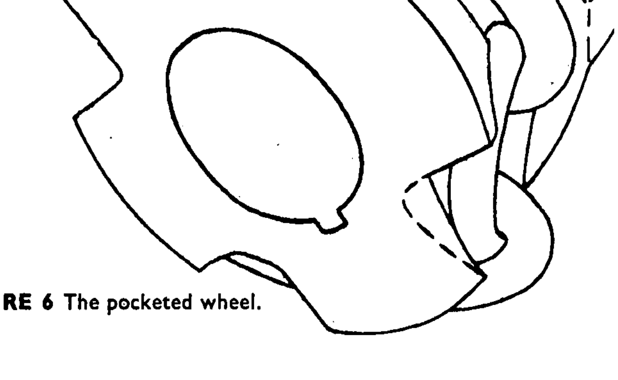

FIGURE 6 The pocketed wheel.

5. *Cheaper Chain.*

   Loghaul chain is much cheaper to manufacture than coal conveyor chain as:—

   (a) there are less welds/metre run;

   (b) only one dimension, the pitch has to be fairly accurate for the chain to work, whereas coal conveyor chain has to be made far more precise to accommodate the pocketed wheels.

However, coal conveyor/pocketed wheels do have some advantages, associated mainly with the chain rather than the wheel. These are :—

1. *Less interlink wear.*

   A longer link chain will have a greater articulation about a sprocket than a short link chain. The short link has less interlink rubbing action and therefore wear. From this it could be theoretically assumed that shorter link chain will stay in pitch longer.

2. *Higher loading.*

   Coal conveyor will take a higher loading than loghaul chain for the same diameter chain of the same material, as the accompanying graph in Figure 7 illustrates. This is because the bending moment over the sprocket is less for a shorter link chain than a longer link chain for a given tension. The manufacturer of these chains recognises in this fact in that coal conveyor chain is proof loaded to within 90% of the materials UTS whereas loghaul chain is proof loaded to within 50% of the UTS. In both cases the working load is half of the chain proof load. This gives loghaul a lower working load than coal conveyor.

3. *Higher speed.*

   Coal conveyor chains are capable of a higher speed than loghaul chains and it has been reported in some journals where the p/d ratio is approximately 2 : 1, speeds of up to 915 metres/min have been achieved under test. Coal conveyor chain is capable of speeds of up to 30 m/min conveying 100 th.

Chain Manufacture

Round-link chain is made in a fairly highly automated plant from coils of round bar from ISCOR. It is first wire drawn to any particular size of chain. It is then made into loops in automatic forming machines that cut the bar material to the correct blank lengh, bend the blank into the link shape, thread another blank through the previously formed link, then repeat the process.

After forming, links are made endless by one of several welding methods. The one used mostly is electro-resistance welding. Various thermal and calibration treatments may then be applied depending upon the chain chemistry and the application. For example Loghaul chain is heat treated in a neutral furnace and then quenched in water to remove any stresses that might be present due to manufacure. Coal conveyor chain is calibrated so that it will fit its pocketed wheel.

Finally the chain is proof loaded and samples tested to destruction to make sure that the correct properties exist in the chain. It is then given a light coating of oil and dispatched to the customer.

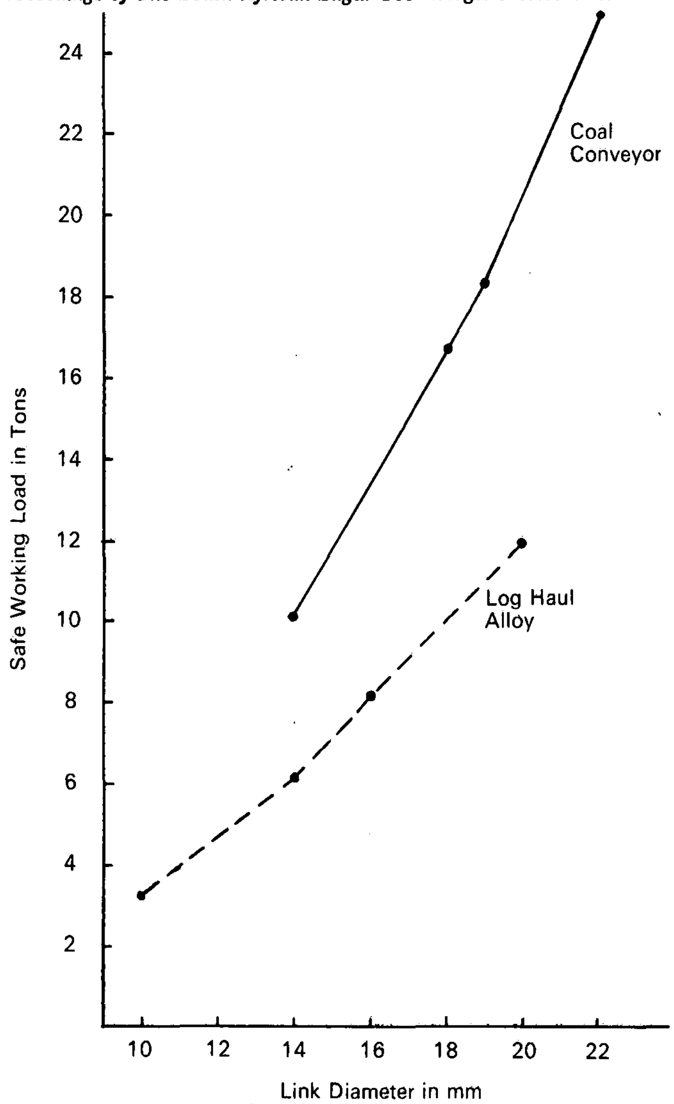

FIGURE 7 Load versus chain diameter curves.

Chain Material

Chain characteristics depend to a large extent on the material used in its construction. Conveyor chains are chiefly made from high tensile carbon steel and steel alloy round bar. The HT carbon steel chain is not case hardened and has a brinell hardness between 285 and 302. Whereas the alloy chain is through hardened and has a brinell hardness between 380 and 415. It is possible for alloy chain to be case hardened and the case has a brinell hardness of about 550. However, the manufacture of this type of chain is a specialised business and varies between manufacturers. Case hardened alloy chain is usually used in chain hoists where wear resistance is important for frequent link articulation. However this chain can be brittle so it could only be used for conveyors if no shock loading exists. The hardwearing properties of this chain make it attractive to conveyor applications.

Through-hardened alloy chain is recommended for applications where the loading is in straight tension and where maximum toughness and impact resistance are required. HT carbon steel chains on the other hand are less tough than alloy chains, and the fatigue endurance limit can be expected to be somewhat lower. But where these considerations are not of vital importance, heat treated carbon steel chain often is the most economical choice.

The chain manufacturer will consider any request for chain to be made out of any other metal. For example a small amount of grade 300 stainless steel chain has been made for a purely corrosive application. Perhaps grade 400 stainless steel chain should be considered as this steel is usually both corrosion and abrasion resistant.

Sprocket Design

When AK first used round link chain for conveyors, there was very little information available on sprocket design for round link chain. It was found, however, that it was not necessary to use toothed sprockets or pocketed wheels anywhere other than at the head shaft. At the tail shaft or any other non-driving point, grooved wheels could be used. A grooved wheel, as shown in Figure 8, consists of two rings welded or bolted to the central hub forming a groove between them. The horizontal links of the chain rest on the edge of the ring whereas the vertical links pass into the groove.

The choice of using a toothed sprocket rather than a pocketed wheel was decided on for the reasons given earlier in this paper.

The information available on these sprockets was very limited. Types of sprockets used in the timber industry were investigated. One type had flame cut teeth secured in a hub by bolts as shown in Figure 9, while another type was a cast sprocket as shown in Figure 10. Both these types were found to be very roughly made with no proper tooth profiles such as involute curves, so AK made its own design. The first attempt was to modify an existing roller chain sprocket to carry the round link chain as shown in Figure 11. It consisted of a segmented rim bolted on to the modified hub. This sprocket had involute teeth but it was found that the vertical link bore down heavily on the sprocket between the teeth and also sometimes the chain would cock quite badly when rounding the sprocket. By placing bearers or anvils on the side of each tooth for the horizontal link to rest on both problems were solved. Such a sprocket was designed as shown in Figure 12.

However, this was soon shown to be a defective design as the dirt and trash from a cane yard would now get trapped in the cavity formed by the anvils. Therefore a sprocket was again used as shown in Figure 11 but with square bar welded on the side of each tooth to act as an anvil. This is, however, a rather rough arrangement and at the moment a sprocket is being developed with teeth that can be independently removed. Longer teeth can then be installed with an anvil welded on the side. So, as the chain wears and increases in pitch, the PCD of the anvils can be changed along with the teeth and this will bring the chain back into pitch.

Chain Attachment Links

There have been several types of attachment links that have been suggested by the makers of round-link chain, but just about all of them have been too bulky or heavy for the purpose. On cane carriers, all that is required was some

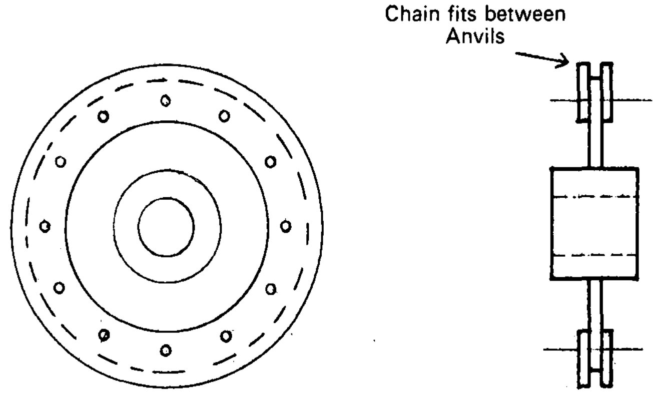

FIGURE 8 The grooved wheel.

form of masterlink to join the chain together other than by welding. It was suggested that a die should be made to drop forge a masterlink similar to that made for Herc Alloy Chain, but this was turned down due to the cost. On the slatted carrier chain application AK have developed a link that has been found to suit the purpose perfectly (See Figure 13).

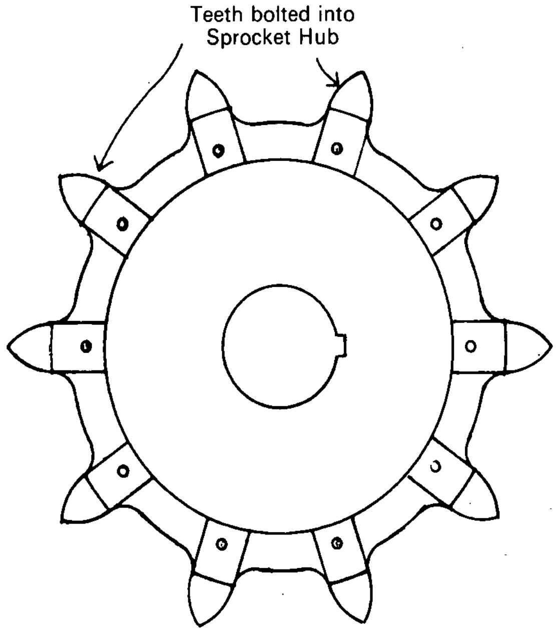

FIGURE 9 Flame cut sprocket in use in the timber industry.

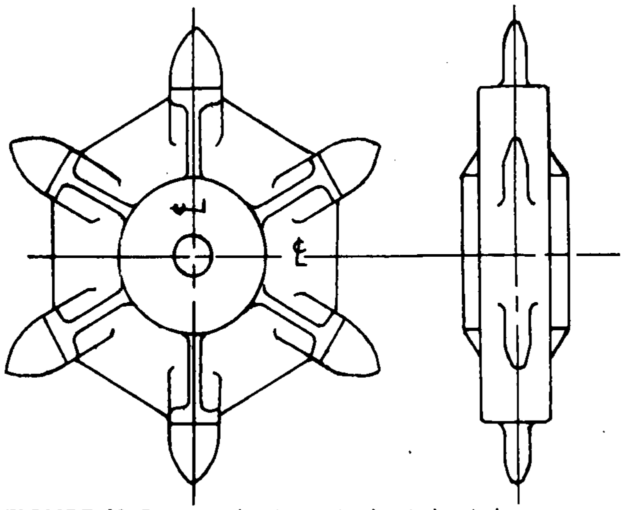

FIGURE 10 Cast sprocket in use in the timber industry.

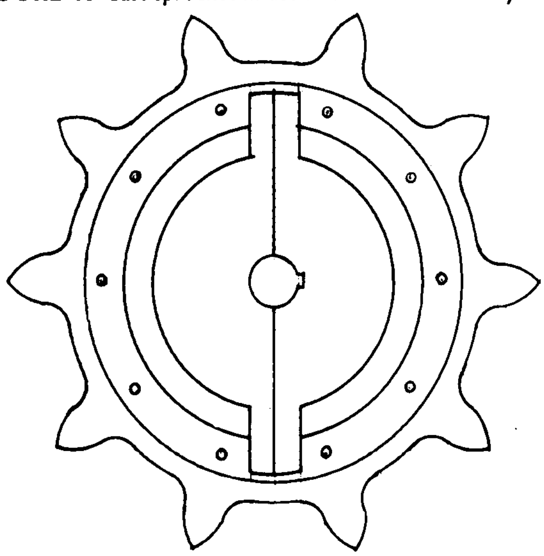

FIGURE 11 Round link chain sprocket without anvils.

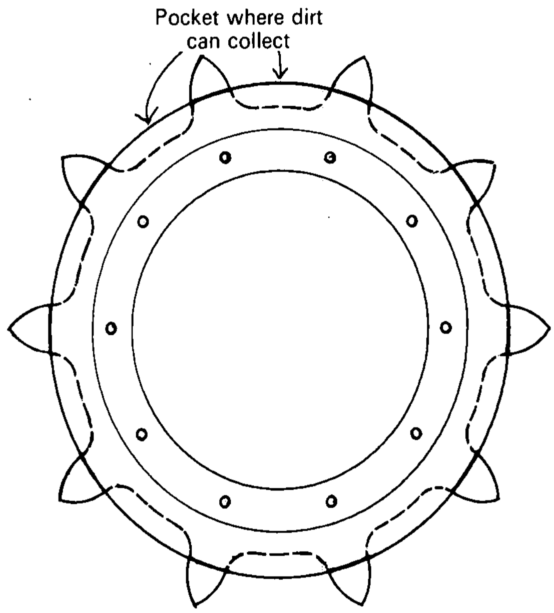

FIGURE 12 Round link chain sprocket with anvils.

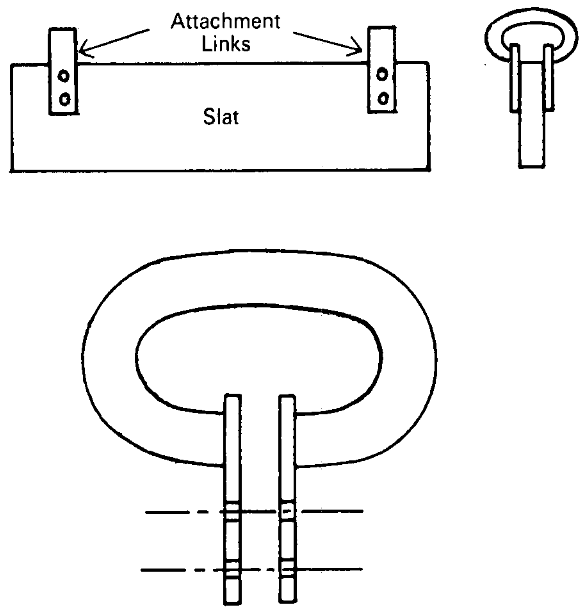

FIGURE 13 Amatikulu designed attachment link for slat carriers.

Cane Yard Carriers

Perhaps the main motivation for the use of round link chain was its design and cost effectiveness in the cane yard. The Amatikulu cane yard is a large one by sugar mill standards and has eight different carriers in it. Approximately two million tons of cane is handled by this cane yard every year, of which the Hilo tables take 60%. So the average carrier, apart from the main cane carrier, handles half a million tons of cane in a season. Three carriers have been converted to the use of round link chain. These are a Hilo feeder table, a cross carrier and a bundle feeder table. The layout of the cane yard is shown in Figure 14. The following are a list of some of the problems that occurred with these carriers :—

1. *Spillage.*

   This was excessive on both the Hilo feeder tables and the wooden slat carriers. A considerable amount of cane had to be cleared away from under these carriers on a continuous basis. This problem was solved on the Hilo tables by installing deflector plates under the headshafts as shown in Figure 15. These deflector plates caught the cane as it was freed from the sprockets and discharged it into the next carrier.

On the wooden slat carriers, however, cane would fall between the slats as they opened round the head shaft (Figure 16) and get caught in the slat as the slats came off the head shaft. The only solution found to this problem, that was not an effective one, was to place barrels in-between the sprockets on the headshaft. The OD of these barrels would just miss the underside of the slat as shown in Figure 16. However, cane was still pulled through although to a lesser extent.

On a round link chain carrier, there are no slats for the cane to get stuck between. Instead the whole carrier is decked in and the chain, with triangular dogs welded to every fourth vertical link, protrudes between the plates. It is extremely hard for cane to get into the chain, and consequently very little is pulled through and labour is saved in the cane yard.

2. *Chain and Slat Maintenance.*

Every three years two strands of a six strand carrier would have to be completely overhauled. Bearing in mind the number of carriers, this would keep twenty non-skilled workers busy for a whole off-crop. In an average off-crop 3 000 pins, rollers and bushes would have to be ordered at a total cost of R10 800,00 per year.

Added to this there is constant maintenance of slats. Approximately 500 wooden slats and 20 steel slats have to be replaced every off-crop at a cost of R4 500. Also during the season a further 500 wooden slats have to be replaced at a cost of R4 000. On the Hilo tables, every strand has to be replaced every five years. This works out to an annual cost of R9 720,00.

With a round link chain, the carrier is decked in like a feeder table. The chain runs in closed-in grooves as illustrated in Figure 17 with a dog welded every fourth link. These dogs protrude out of the groove and push the cane as a roller chain does with an F1 attachment on a Hilo table. After a year's service on a Hilo table, the interlink wear was measured and found to be less than 1 mm. This would seem to indicate that the chain will last at least for more than five years without replacement, with a consequent saving on carrier slats, chain repairs and the labour involved.

To summarise, for roller chain :—

	Cost/Annum
Chain overhaul	10 800
Slat replacement	8 500
Hilo chain replacement	9 720
Labour in off-crop	12 500
	R41,520

If this is compared to round link chain that might need to be replaced every seven to ten years, 2 400 metres replaced at R12,00/metre :—

Cost of chain replacement		28 800
Labour cost to weld on dogs		2 000
		30 800
∴ Cost per annum	=	R3 850

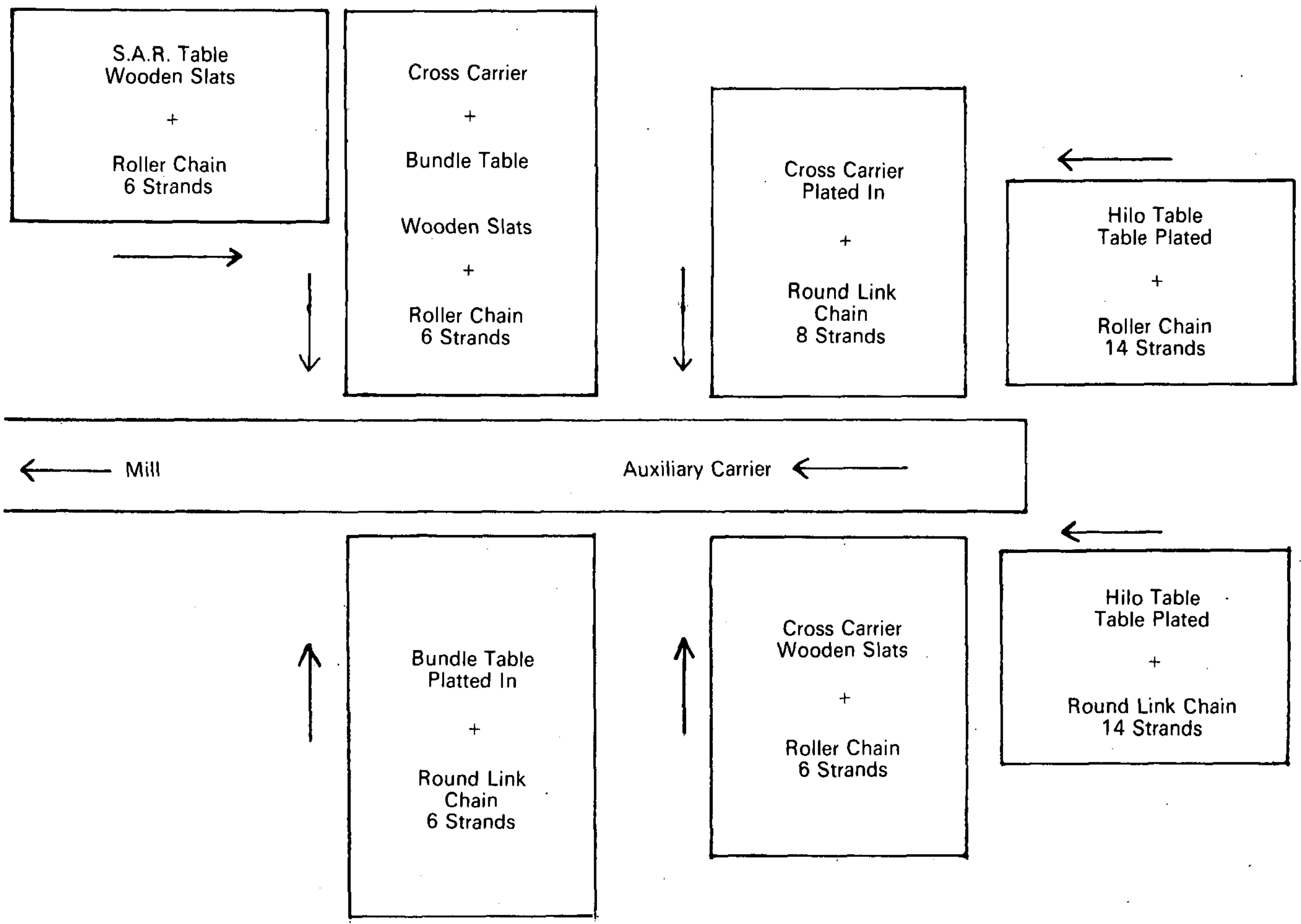

FIGURE 14 Plan view of Amatikulu cane yard.

3. *Chain Cost.*

The following table is self explanatory :—

TABLE 1
Comparison of chain costs

Chain Type	Attachment	Components	Cost/metre
SS 600	K2 every link	Stainless	R140
SS 600	K2 every link	Carbon Steel	R90
09060	Fl every 4th link	Stainless	R80
09060	Fl every 4th link	Carbon Steel	R60
20 mm Alloy Round Link Chain			R12
20 mm High Tensile Round Link Chain			R7

4. *Chain Physical Characteristics.*

Table 2 illustrates that high strength loghaul (round link) chain compares very favourably with the normal roller chains used in sugar mills.

TABLE 2
Comparison of chain strengths and mass

Chain Type	Safe working Load (tons)	Breaking Load (tons)	Mass/Metre (kg/m)	Strength/ Mass Ratio
SS 600 ..	3,07	44,6	20,83	2,14
09060	2,83	26,8	20,68	1,30
20 mm Alloy Loghaul	10	45	7,38	6,10
20 mm HT Loghaul ..	6,5	30	7,38	4,07

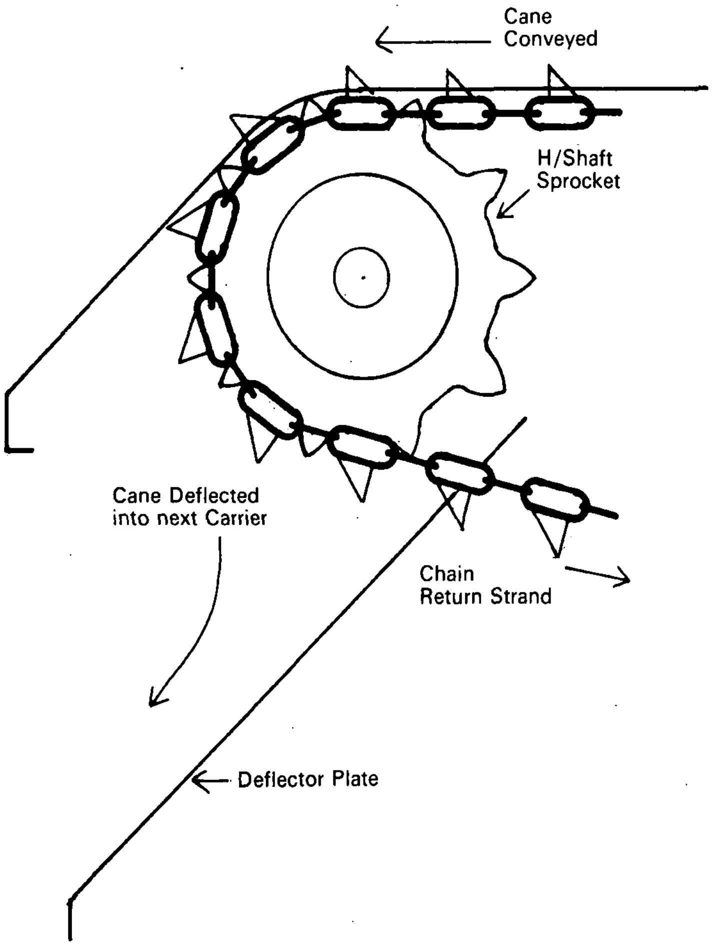

FIGURE 15 Hilo table head shaft deflector plates.

5. *Downtime.*

If a Hilo feeder table or a wooden slat carrier chain breaks, there is always an extended downtime lasting a day on a Hilo table and even longer on a wooden slat carrier. If a round link chain parts, it can easily be welded back together again or alternatively, it can be run out of the carrier and a new one installed in an hour.

Cane Carrier Design for Round Link Chain

There are some general considerations that must be mentioned here.

1. *Keep Chain enclosed on conveying side.*

This point is well illustrated in Figure 17. The reason for this is that if the chain runs in a slot on top of the carrier the cane has the effect of derailing the chains, no matter how tight the tension is.

2. *Allow for individual Chain stretch.*

This type of chain stretches far more than roller or pin type chain and different strands on the same carrier will

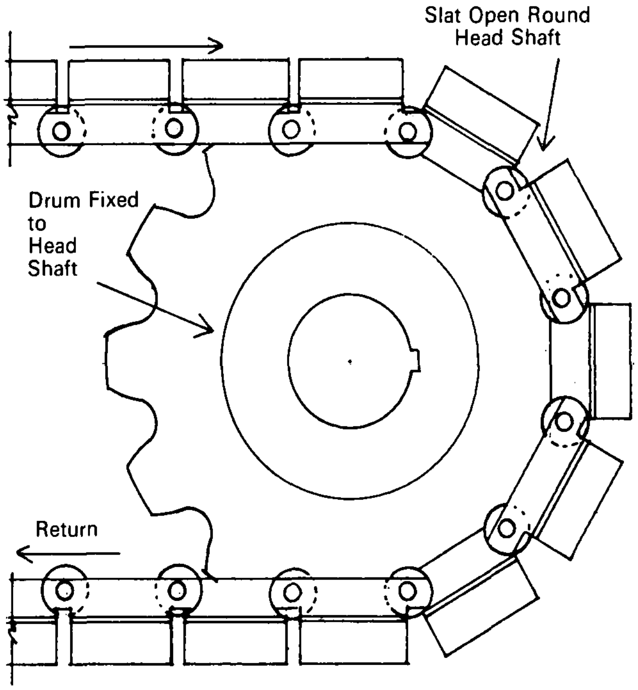

FIGURE 16 Wooden slats on the head shaft.

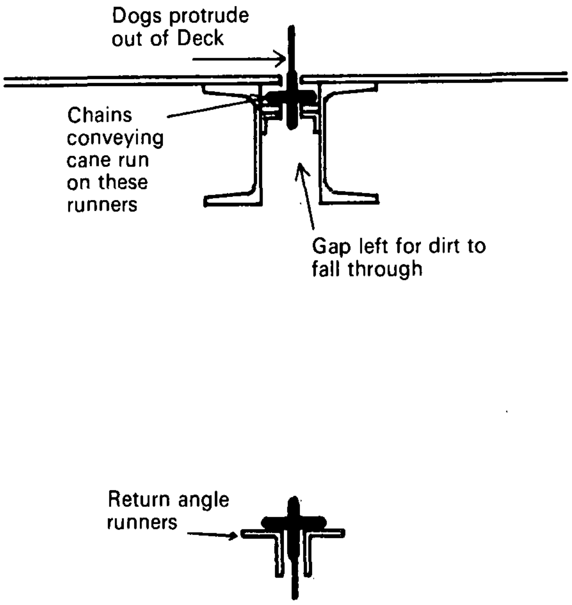

FIGURE 17 Construction of round link chain carrier.

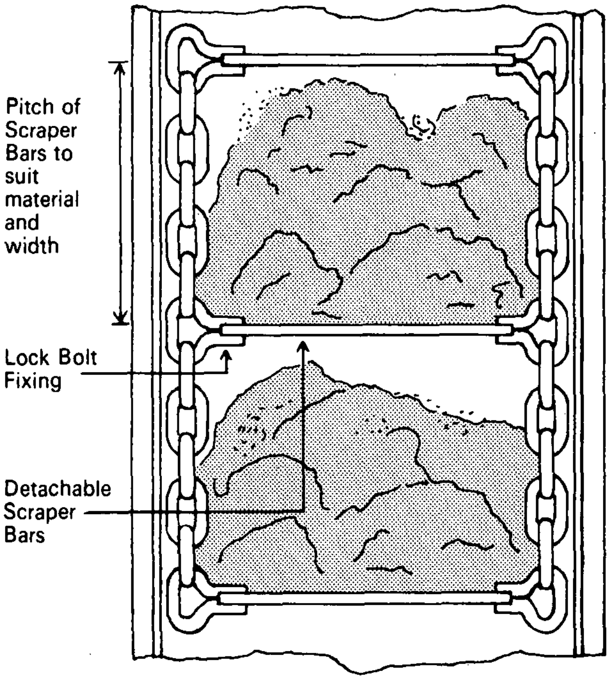

FIGURE 18 Slat carrier using round link chain.

stretch by different amounts. For this reason each chain must be tensioned individually. Also the sprockets PCD should be altered as has been discussed above.

3. *Cross Carriers.*
Where cane drops say from a Hilo table onto a cross carrier, ensure that the pitch between stands nearer the Hilo table is smaller than away from it. The reason for this is that the cane sticks will be laying in the direction of travel and not across it, so it is necessary to ensure that the chain will convey the cane. Also there will be more cane on that side of the cross carrier.
4. *Self cleaning grooves.*
If possible it should be arranged for the chain groove on the conveying side to be self cleaning. This can be easily arranged by allowing the area below the vertical link to remain open (See Figure 17 for further explanation). It has been found that a considerable amount of dirt gets lodged in the chain groove.
5. *Chain Return Runners.*
Idler sprockets or wheels should not be used on the return, but two angle irons as shown in Figure 17 with no runner. The return angle should not be started immediately after the head sprocket. A distance of approximately 2 metres should be allowed for the chain to hang free so that any cane caught in the sprocket can escape. An arrangement can be made so that the chain can only enter the runner in one plane — with the dog downwards.
6. *Lubrication.*
Although it is desirable to lubricate this chain, lubrication by oil is taboo in the cane yard as when the oil mixes with the sand it forms a very efficient grinding paste. Water lubrication has also been mooted, but this is not looked on kindly by the Central Board. However, it is recommended that before the carrier is put to work, it should be allowed to turn for a few days and any old oil can be fed into the chainstrands. This will help the chain to be bed in before it is used. The oil can be washed off once this has been done.
7. *Deflector Plates.*
If possible deflector plates should be used under the head shaft of the conveyor. These will catch any loose sticks that get pulled through.

Slat Conveyors

Round link chain can also be used on slatted carriers. A typical carrier is shown in Figure 18. As can be seen every 6th link is formed into an attachment link to carry the slat. The type of chain used in these carriers is usually the coal conveyor variety with the pocketed wheel at the head shaft to drive it. However, at AK the long link loghaul chain has been used in this application to elevate miala and smuts into a miala bin. This conveyor is 26 metres long and elevates the miala and smuts through a height of 13 metres at a speed of 10 metres/minute. The amount of miala and smuts elevated is 50 th. There is only one driving sprocket with teeth, all the others are grooved wheels as illustrated in Figure 8.

It is important to note that when a very corrosive medium such as smuts is conveyed in a conveyor, it (the smuts) must be loaded in the centre of the conveyor. If it is not loaded in the centre then one chain gets more corroded than the other resulting in one chain getting more out of pitch than the other.

This results in the slats not coming round the sprocket square and the chain jumps off. This happened initially to AK's conveyor but the fault was corrected.

It is interesting to note that after a season's run, the interlink wear was 16%, and in some cases as much as 20%. However, the chain was still meshing with the sprockets and there was no ductile elongation in the barrel due to overloading. For comparison a roller chain lasted only three months in this particular conveyor.

Some other mills have begun to use the coal conveyor form of round link chain in their smuts tanks apparently with a fair degree of success. However, the use of coal conveyor chain is not recommended in this application for the reasons given above.

Round Link Chain — The Future

So far round link chain has only been used in slow moving relatively unimportant conveying applications. Provided that its peculiar properties, such as chain stretch, are catered for in conveyor design, there appears to be no reason why this type of chain could not be used in applications such as bagasse conveyors where chain speeds reach 30 metres/minutes. At this moment coal conveyor chain is being used at these speeds and equivalent loads under-ground.

Round link chain has interesting possibilities for applications such as diffuser chain. It is possible to make a 50 mm chain with a breaking load of 250 tons, giving a working load of about 50 tons. Due to the advance of technology, strength availability has more than tripled in the past three decades from $0{,}056d^2$ tons to $0{,}176^2$ tons for some special chains.

It is fairly widely held that conveyor chain constitutes the second highest single item on a sugar mill's maintenance budget after mill rolls. If round link chain finds a home in the conveyors of a mill, maybe it will become one of the lowest.

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