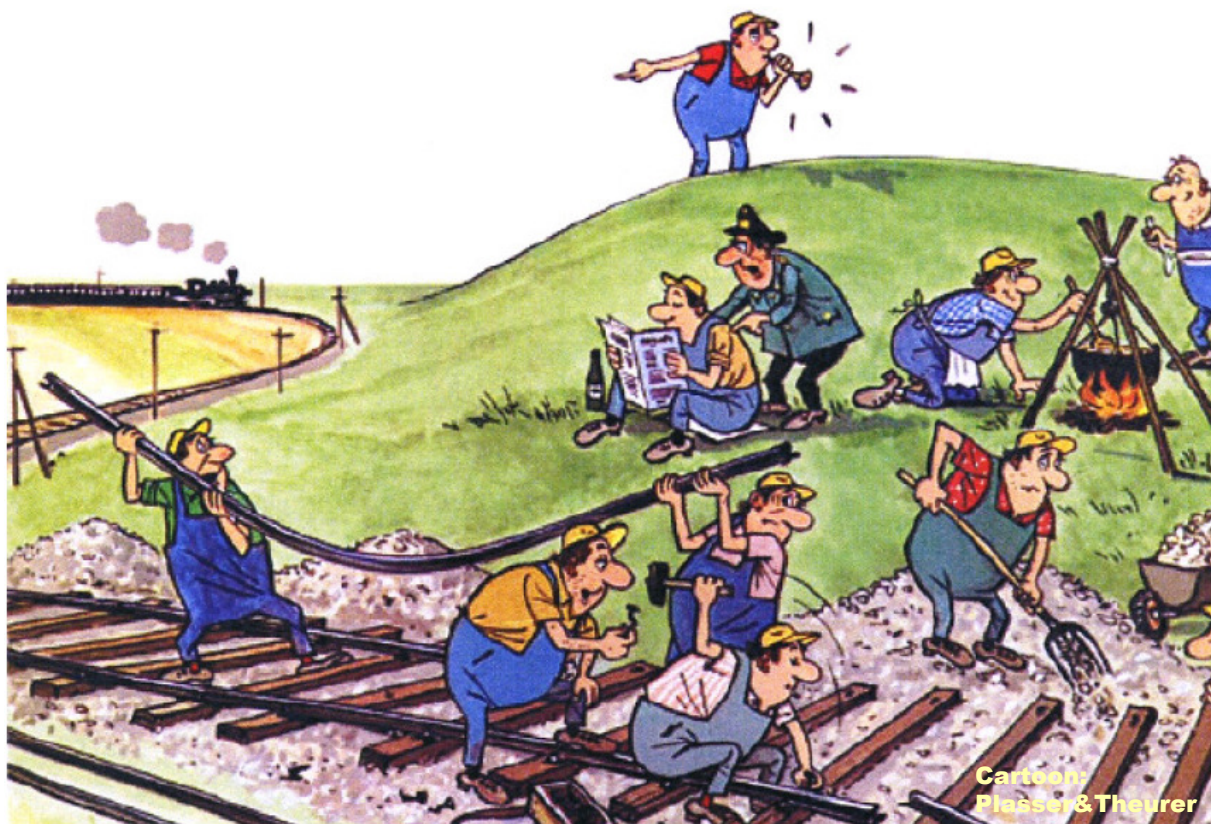


RAIL TRACK GEOMETRY

**Elaborated for a Seminar and a Railway Technology
Exhibition**

**with Students of the Richmond Hill College, Galle,
SRI LANKA, Oct. 2014**



By Dr. Frank Wingler

GAUGE

The **GAUGE** is the distance between the two rails measured between the inner running corners 16 mm below the rail-table.

The “**STANDARD GAUGE**”, used nowadays around the globe, measures “**4 foot 8 and a half inch**” or **1.435 metre** and had been exported to the world by George Stephenson with his steam locomotives from England. This gauge had been used in England by mines for carts running on wooden rails, and it goes presumably back to the gauge of the Roman Carriage Grooves. “**STANDARD GAUGE**” is the optimal Gauge for High-Speed Lines.

Although the British wanted to introduce the standard gauge in India, Indian Engineers under Lord Dalhousie, the British Colonial Administrator in India from 1848 to 1856, opted for the main trunk routes a broader gauge of 5 foot 6 inch or 1.676 metre, the so-called “**Indian Broad Gauge**”, which equals the so-called “**Iberian Broad Gauge**” of 1.668 metre in Spain, Portugal and of some lines in South America, based on 6 “**Catellion Feet**”.

But for economical reasons most of the Lines in India had not been built in Broad Gauge (BG) but in Meter-Gauge (MG). For logistic reason under the “**UNI-GAUGE POLICY**” most of the Meter Gauge Lines have been converted in recent decades to Broad Gauge. At present about 1500 km Meter gauge left in service are waiting for conversion. In future only the famous **OOTY Hill Pinion and Rack Railway** will be left in Meter Gauge.

In Gujarat around Baroda and in Maharashtra around Nagpur local rulers have built extended networks in 2 ½ feet Narrow Gauge (NG). NG had been cheaper to build. Some of those NG lines will be converted in future or have already been converted to Broad Gauge; only few of them might survive in NG.

The Indian **SHIMLA HILL RAILWAY** and the **KANGRA VALLEY RAILWAY** will survive as 2 ½ feet NG.

The UNESCO heritage **DARJEELING** Himalayan Railway build along the old cart road as well the **MATHERAN HILL LIGHT RAILWAY** near Mumbai will remain in the tighter 2 feet NG. In Madhya Pradesh a former Maharaja from the Scindia Dynasty and ruler of **GWALIOR**, a Railway Enthusiast, had built a 198 km long 2 feet NG line to his hunting grounds from Gwalior to Sheopur. This heavily used line might be also converted to BG in future.



Darjeeling NG Railway; near Ghum

In England, North Wales, 25 miles of the nostalgic and scenic **WELSH HIGHLAND RAILWAY** has been recently rebuild in 2 ft Narrow Gauge with new Steel-Sleepers on a well ballasted trace. The trace had been once used for the transport of slate.



WELSH HIGHLAND RAILWAY, 2014, on a modern completely new rebuild 2 ft NG Rail Road, UK, with a well ballasted Rail Track and Steel Sleepers

To bring the **Broad Gauge** to Ceylon had been in the 1860-ties a big mistake. Meter Gauge would have been much more advisable and suitable for the terrain. But that time one thought, that the Indian BG would become the “**Standard Gauge**” of South Asia. But this did not realise. “**Meter-Gauge**” respectively the broader “**CAP-Gauge** with 1067 mm have become the “**Standard Gauge**” in Burma, Indonesia, Malaysia, Philippines, Vietnam and Cambodia.

On difficult terrain in mountainous areas many lines in Europe, Germany, Austria, France, Spain, Switzerland, Italy and Poland have been build on tight curvy traces in **Meter Gauge**. The tighter **3feet, 914 mm, Gauge** we find in the South American Countries, especially in the Andes, as well in USA in the Rocky Mountains of the once vast Denver-Rio Grande Railway network. The longest and most heavy Mining-Trains around the globe run in Brazil and South Africa on **Meter-Gauge/Cape-Gauge**. Transnet delivers on **1067 mm “Cape Gauge”** a high capacity in South Africa by operating regular 342-wagon trains on the Shinsen-Saldanha line

The so-called “**CAP-GAUGE**” is the “bigger brother” of **Meter Gauge** with 3 foot 6 inch or 1.067 metre going back to the engineer **Carl Abraham Pil** in Norway. This Gauge is used for nearly all lines in south Sahara Countries of Africa, in New-Zeeland and Japan. It is also denominated as “**DUTCH KAAP-SPOOR**” or “**CAPE-GAUGE**”. In the Rocky Mountains in USA an extended network in **3 Feet Gauge** had been once served the Miners, Mines, Farms and Ranches. The Durango & Silverton, as well the Cumbres & Toltec lines of the once vast **DENVER-RIO GRANDE** Railway Empire are left as nostalgic and vintage scenic Rail Roads for tourists.



Durango Silverton Denver-Rio-Grande Scenic Railway, USA on 3 feet NG



Cumbres&Toltec Scenic Railway on 3 feet NG, USA

For High Speed Lines, dedicated routes in **Standard-Gauge** had been introduced in Japan, Taiwan and Spain.

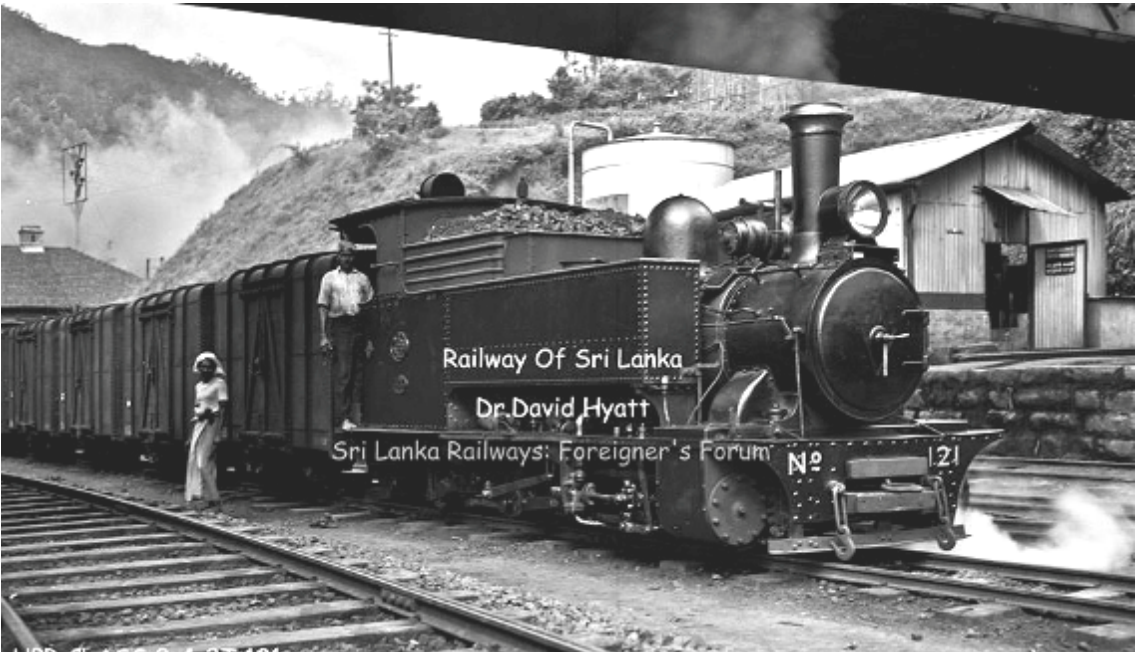
In Africa as well in Myanmar with the help of China new **Standard Gauge** Lines are under construction or operate already to transport Mining Products from the inner countries to the sea harbours.

In Germany, Austria, Bosnian/Balkans Countries and Greece 760 mm (similar to 2 ½ ft NG) lines for tourists are left running with steam traction.

Once Ceylon had up to 1976 a 2 ½ feet NG Railway from Maradana up the Kelani Valley via Ratnapura to Opanayake and from Nanu-Oya up to Ragala via Nuwara Eliya. Latter had been closed 1948.



KV 2 ½ feet NG-Line 1973



Nanu-Oya; "Down the Memory Line"

But those routes are now only **“MEMORY LINES”**. The rails from Avissawella to Opanayake have been dismantled – only some bridges and some parts of the embankments are left – and the trace from Maradana to Avissawella had been converted on the curvy old NG alignment to BG – another big mistake.

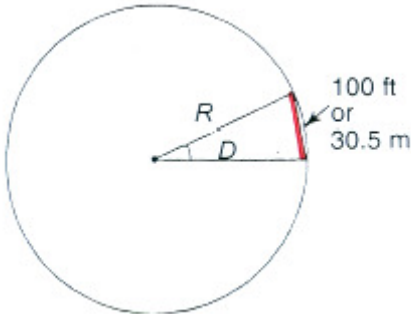


NG Railway Bridge left near Opanayake

The NG should have been preserved and commuter service to the townships rendered with modern 80 kmph running Rail Cars, or the track should have been converted to Meter Gauge for a modern **Rapid Mass Transit** system with intermodal Rail/Road Services. On BG the present Rail Service on the old alignment with extraordinary tight curvatures of up to 18 Degree is with max. 35 kmph too slow for a viable **Mass Transit System**. But this unfortunately is not well understood by the “experts” for **“FEASIBILITY STUDIES”**.

CURVES and SUPER-ELEVATION

The angle between the directions of a rail track is covered by **CURVES**. A **CIRCULAR or BODY CURVE** is defined either by its **RADIUS** or by its **DEGREE**. The Degree of a Curve (D) is the angle subtended at its centre by a 100ft or 30.5 metre cord. The value of the Degree (D) of the curve can be determined as indicated below:



Circumference of a Circle = $2\pi R$; R = Radius in metres [m].
 Angle subtended at the centre by a Circle with this Circumference = 360° .

Angle subtended at the centre by a 30.5 metre chord, or Degree of the Curve

$$= \frac{360^\circ}{2\pi R} \times 30.5 = 1750/R$$

The **DEGREE** (D) of the Curve is thus given by the following formula:

$$D = 1750/R.$$

And the **RADIUS** is thus given by:

$$R = 1750/ D.$$

A "2-Degree Curve", therefore, has a Radius of $1750/2 = 875$ m.

The Track Engineers in Sri Lanka are used to define a Curve by its Radius (R) measured in "**CHAIN**", which is an old fashioned length measurement. One **CHAIN** is the length of 66 feet and equals approximately 20 m. The "**CHAIN**" had been once used by British Engineers for illiterate workers. They had to use chains and to count links of a chain to measure length.

Indian Engineers are going "metric" and determine the **TIGHTNESS** of Curves in **DEGREE (D)**. This has the advantage that by just looking on a curve one gets a feeling for the tightness, and that the tightness in Degree can be easily measured with a 11.8 m cord. A "2-Degree Curve" is a "lean" Curve and a 6 Degree Curve is a "tight" Curve, which needs a permanent **SPEED RESTRICTION** less than 60 kmph.

The Sri Lankan Engineers are used to measure the tightness of a curve by the radius in **CHAIN** or metre.

In India the Tightness of a Broad Gauge Curve is limited to 10 Degree. SLR is plagued with tight Curves up to 18.5 Degree.

Curves have to serve trains of different speed, fast moving passenger trains as well slow moving freight trains.

To counterbalance centrifugal forces of a train running in a curve, the outer curve rail is kept higher than the inner curve rail.

A vehicle has a tendency to travel in a straight direction, which is tangential to the curve, even when it runs on a circular curve. As a result, the vehicle is subjected to a constant radial acceleration by centrifugal force away from the curve centre:

[g] is the Acceleration in m/sec². Gravity due to earth acceleration is defined as "mach"; 1 mach = 9.8 m/sec²; [V] is the Speed (Velocity) in [m/sec].

The radial acceleration = $g = V^2/R$.

The radial acceleration produces a centrifugal force, which acts in the radial direction away from the centre. The value of the centrifugal force is given by the formula:

[F] = Force and [m] = Mass, measured in 1000 kg

$$F = m \times (V^2/R).$$

[W] is the Weight of the Vehicle measured in tonnes; F equals W/1.

$$F = (W/g) \times (V^2/R).$$

In order to counterbalance the effect of the centrifugal force, the outer rail of the curve is elevated with respect to the inner rail by an amount equal to the **SUPER-ELEVATION** or so-called **TRACK-CANT** measured in mm. A state of equilibrium is

reached, when both the wheels exert equal pressure on both rails, on the lower inner curve-rail as well on the higher outer curve-rail. And the **SUPER-ELEVATION** is thus enough to bring the resultant of the centrifugal force and the force exerted by the weight of the vehicle at right angles to the plane of the outer ("**HIGH RAIL**") and inner ("**LOW RAIL**") of the curve known as **EQUILIBRIUM SUPER-ELEVATION**.

In regard of the **SUPER-ELEVATION** a solid **COMPROMISE** has to be achieved between the provisions for a faster moving passenger train (let's say 100 kmph) and for a slower moving freight train (let's say 50 to 60 kmph).

The fast moving passenger train needs a higher super-elevation than the slow moving freight train. The compromise is calculated on basis of the so-called "**EQUILIBRIUM-SPEED**".

By such a compromise the centrifugal forces of the faster moving train are **under-balanced** and centrifugal forces of the slower train are **over-balanced**.

Each Railway has its own standards for under- and over-balancing. They lay down their own limits of under- and over-balancing.

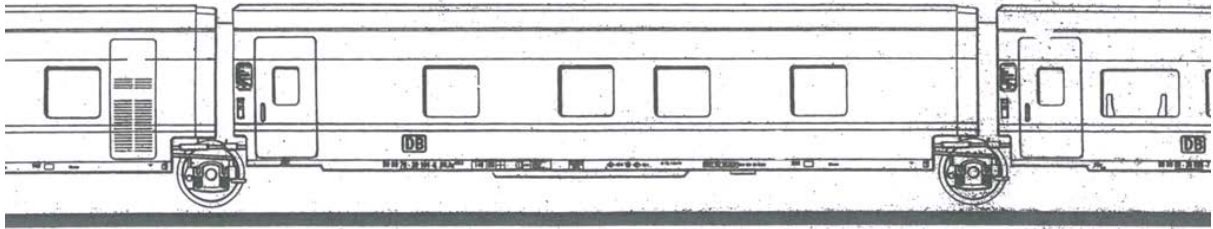
If a train negotiates around a curve at a speed or with a velocity higher as the equilibrium-speed compensated by the elevation of the outer curve rail over the inner curve rail (latter normally maintained at its original level) a **DEFICIENCY OF THE CANT** occurs. The outer rail is not elevated high enough to compensate the centrifugal forces. The passengers inside the train will feel the centrifugal forces like in a bus or car taking a curve. To a certain extent this can be tolerated. But this means also that centrifugal forces are exerted on the rails and thus on the track components. The stability of the track has to be kept accordingly.

From the view-point of the track stability, for a lighter train a higher **CANT-DEFFICIENCY [Cd]** respectively a higher centrifugal Force can be allowed than for a heavier train.

Modern High-Speed Trains and Tilting Trains have no heavy Locomotives any more. They are of light weight shell-structures with distributed traction unite dispatched in nearly all bogies. They are **RAIL CARS**.

For those light Weight Designs a higher **CANT DEFFICIENCY** can be tolerated than for heavy Locomotive hauled train-sets. **Lighter Trains can be allowed to run faster over a curve than heavy Trains.**

In 1942 two Spanish Engineers constructed an articulated Light Weight Train Set with only one wheel-set shared by two Aluminum Coaches with a low centre of gravity called **TALGO TRAIN**. The wheels can be adjusted variable for the 1.668 m Iberian Broad Gauge as well for the 1.435 m Standard Gauge. The shell-coach bodies are constructed like aero plane bodies. The self steering wheel-sets with individual running wheels trail in curves track friendly in a right angle spinning without friction and hence with less wear of rails and wheels. The trains can trail tight curvatures with higher speed with fewer centrifugal forces. A higher Cant Deficiency can be tolerated for Talgo Train-Sets:



Sketch of an articulated Talgo Train-Set

With Talgo Trains RENFE managed in Spain after World War II to increase the speed on its conventional windy network. The variable gauge adjusting system allows Talgo Trains to proceed from the Spanish Border to France on Standard Gauge.

The newer generations of Talgo Trains run nowadays also as High-Speed Trains up to 330 kmph on Standard Gauge



AVE Talgo High-Speed Train, Spain

Indian Railways are interested in Talgo Trains for Semi-High Speed as well for High-Speed. The variable Gauge may be an advantage, when India will have to introduce dedicated 1.435 m Standard Gauge High-Speed Lines. In May 2016 RDSO started test trials with a RENFE train set between Moradabad and Bareilly with 120 kmph and is undergoing tests runs with 180 kmph at the Palwal-Mathura Section:



Talgo Train-Set Test Run at Moradabad, India

Tilting does not reduce the centrifugal forces exerted on the track. But it gives the passengers more comfort, when tilting-trains negotiate curves with a high cant deficiency.

Tilting Trains, so-called “*Pendolino`s*”, are running in England, Sweden and Italy. They are very cost intensive for service and maintenance. In Germany they failed:



ALSTOM Pendolino Tilting Train, VIRGIN-Train, West-Coast-Line, UK

A CANT-EXCESS, a too high super-elevation, leads to a higher wear on the lower inner curve rail and to uncomfortable for passengers inside a train. This you feel, when a passenger train runs with slow speed on a super-elevated curve.

There are laid down limits for under- and over- balancing. Each Railway will have its own standards for under- and over- balancing (cant-deficiency and cant-excess).

In the appendix you find the mathematical coherences and criteria for the “**EQUILIBRIUM SPEED**” with the maximum speed of trains in curves laid down in Indian Track Handbooks.; see also: <http://indianrailways.gov.in/railayboard/uploads/codesmanual> **CHAPTER IV, CURVED TRACK AND REALIGNMENTS OF CURVES.**

Indian Railways has laid down **MAXIMUM VALUES for SUPER-ELEVATION or CANT** for Broad Gauge, measured in millimetres, under “normal conditions” with 165 mm and under “special permission” by the authorities with 185 mm.

The permanent permissible speed on the upgraded Sri Lanka Coast-Line Curves is calculated accordingly Indian rules although under perspective of Safety, at many sections the speed should be lower because of hindered visibility, missing repeater signalling, risky level crossings and pedestrians using the track.

TRANSITION-CURVE

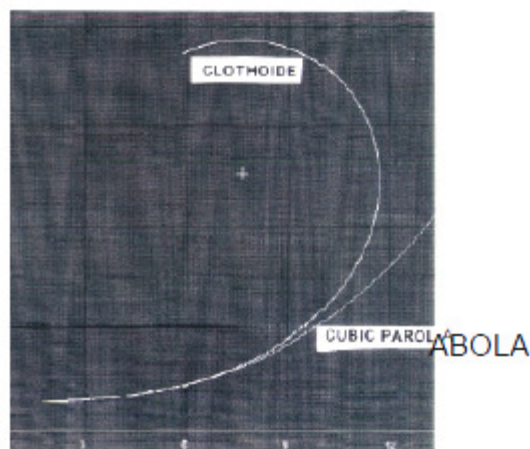
The train should not be suddenly guided from a straight track onto a curved track. This would exert strong lateral or horizontal forces on rails, wheels and carriages.

The “**BODY**” or “**CIRCULAR**” curve begins and ends with the transition-curve. Without latter there would be additional higher lateral acting load factors.

The transition curve is a **SPIRAL** slowly increasing its tightness on a ramp from straight to the final angle of the circular- or body-curve and slowly increasing the super-elevation onto the height of the circular or body-curve.

The run from straight to the curve-angle has to be guided smoothly, easily and steadily. The guiding forces have to overcome the torsional moment of inertia of the rail-vehicles. In addition the super-elevation or track-cant must be gradually introduced by the so-called **TRANSITION-CURVE**. The Transition-Curve is an easement ramp. With the inserted transition the radius is gradually decreased from infinity (radius of straight track) to that of the circular- or body-curve. The centrifugal forces starting from zero on the straight section build up on the transition. The super-elevation or cant increases correspondingly to the curvature. At the end of the circular- or body-curve the **TRANSITION-CURVE** runs the radius and super-elevation smoothly out to the straight track.

The transition geometry is commonly a **CLOTHOIDE-SPIRALE** or **CUBIC PARABOLA** although other types are in use by worldwide railways.



Up to 4 Degree there is not much difference between clothoide and cubic parabola. The rate of change of radius with the length does not differ much between a clothoide and cubic parabola at the begin of the spiral The cubic parabola is a linear ramp, which can be calculated without advanced mathematic, easy to install and preferred by Indian and Sri Lanka Railways. European Railways prefer clothoides, which tighten the curvature with the length like a watch spring. A clothoide starts smoother and ends sharper. The French High Speed lines have clothoide type transitions.

Length of the transition and tightness on the body-curve determine the **PERMISSABLE SAFE SPEED:**



Speed-Board for the 6 Degree Curve No. 49, SLR-Coast Line

Sometimes it comes more complicated, when the body or circular-curve has to be designed with two different radii (“**COMPOUND-CURVE**”) or by two circular curves of opposite curvatures (“**REVERSE-CURVE**”). On the SLR KV-Line and on the Up-Country Line we can find several **REVERSE-CURVES** without the provision of **TRANSITIONS** of appropriate length.

Seldom there is enough room to lay a transition curve of appropriate length. The Permissible Speed has to be reduced accordingly. On the upgraded SL Coast Line Track at the south Gintota Bridge abutment there had been no space for a proper transition. When entering or leaving the curve the trains exert high forces onto the track, and the passenger inside the coaches can feel the jerk.

Along the upgraded SL Coast Line the curves are numbered. We find the geometry data for “SE” in mm for the Super-Elevation, the Radius in m and the length of the two Transitions in m marked on a plate alongside the track:



Railways have their own mathematical equations, formulas, rule books and data sheets. In the appendix you find the mathematical equations, formulas, rules and data used in India.

UNFAVOURABLE CURVE GEOMETRY ON SLR COAST LINE

IRCON from India had been called to upgrade the Sri Lanka Coast-Line Track from Matara up to Kalutara South. The Politicians had the dream that after the upgrade trains will run with 100 kmph. But this is can not be realised for several reasons:

SLR has no Rolling Stocks with enough traction effort to accelerate on short distances (less than 2 to 3 km) up to 100 kmph.

IRCON had to lay the upgraded track on the old curvy trace with 6 to 7 Degree Curvatures, Reverse-Curvatures and without enough room for adequate transition lengths. There are only few straight stretches of 3 to 5 km length (Kosgoda, Kahawe, Koggala). Mostly the Coast line consists of curvatures. The distances between the railway stations and train halts are relatively short. There are plenty of risky and tricky

Road Level Crossings. Pedestrians (School Children with Parents and even Teachers) use the track as a foot-path.



The Track Geometry Parameters allow 60 kmph at Ambalangoda, but the Risk Situation demands 15 kmph for Safety Reasons.

Besides, there had been no proper Surface Water Management possible, to drain the water appropriately out the rail bed and to keep it away from the rail bed. The falling and rising water levels with the climate seasons are one of the culprits for the “**Memory Effects**” of lateral and vertical Track Misalignments.

IRCON did its best to adjust the curve geometry with short transitions for smoother train running wherever it was possible, although the appropriated length of the transitions could not be achieved at many sections; see picture above.

At Gintota the needed land acquisition for a new alignment with transitions at the Gintota River Bridge and at the south entrance to the Railway Station Siding was not possible.

The dilemma with the old trace geometry, not allowing transitions of appropriate length, can be demonstrated by the following picture:



Left-Curve combined with a right-Hand-Turnout without a Transition; with a Change of the Gradient on the right diverging Route. Gintota, Sri Lanka, after the IRCON Upgrade

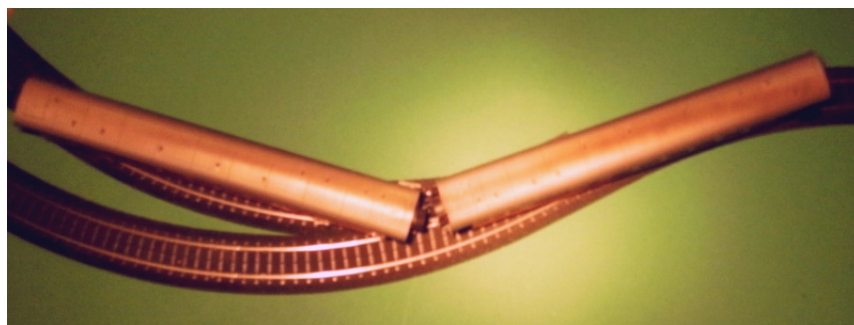
The left curve is combined without any transition with a right-hand turnout. In addition there is a down-gradient change, a vertical curvature, of the diverging siding starting at the Vee-Crossing of the point. This “**wrong alignment**” has already led to derailments of freight trains as expected. The US-type freight bogies with only primary coil suspension can not follow the twist.

A train coming from the south and entering the right siding will exert high forces on the left tongue rail, which is bending. Trains coming from the south Galle-side should in consequences not be allowed to enter this siding. The max. permissible speed has to be restricted anyway.

Mostly track-engineers are not aware of the “**OFF-SET**” of Coach-ends and its track distorting factors, when the curve direction of trailing coaches is changed. When coaches trail in two different directions, it comes at the ends to an **OFF-SET** as demonstrated with the 1 in 87 scale Passenger Coach Models:

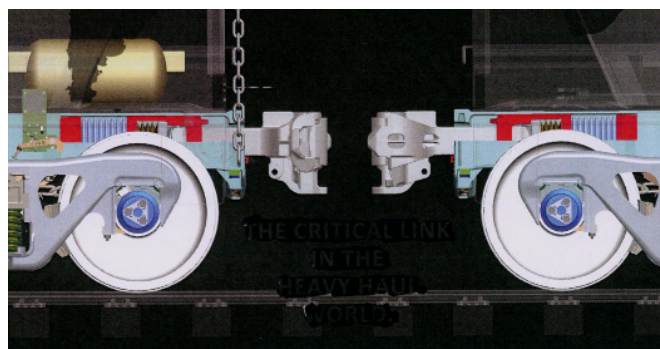


The moment, both coaches proceed few metres and trail again in the same direction, this **OFF-SET** closes as delineated by the next picture:

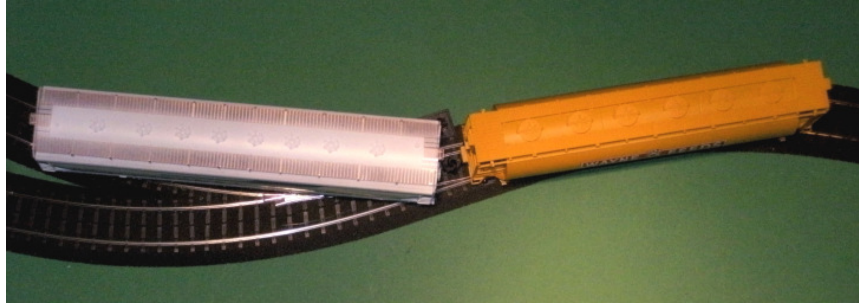


If there is **NO TRANSITION** between the different curvatures, this opening and closing of an **Off-Set** causes high momentums, which according the so-called dynamic "**NEWTON'S LAW MECHANISM**" (Actio=Reactio) exert high forces onto the rails. Coaches coupled with centre auto-coupler instead of screw coupler can develop jerks, if the auto-coupler is not properly maintained. This has become now an increasing problem in India with Passenger Coaches converted to centre auto-couplers.

The magnitude of the **OFF-SET** depends not only by the differences in curve tightness and transition length but also by the distance from the bogie centre to the coupler. In USA, to keep this Off-Set small and hence the jerks low, this distance between the pivot of the freight car bogies and the centre-auto-coupler is kept very short. The next picture delineates models of US Freight Cars, where the centre-auto-couplers are close to the bogies. The Off-Set on the same reverse curvature becomes smaller, and hence the rail distorting forces are less:



Centre Auto-Coupler arranged close to the bogie (truck) of US Freight Cars resulting in small Off-Set when entering Curves and Turnouts.

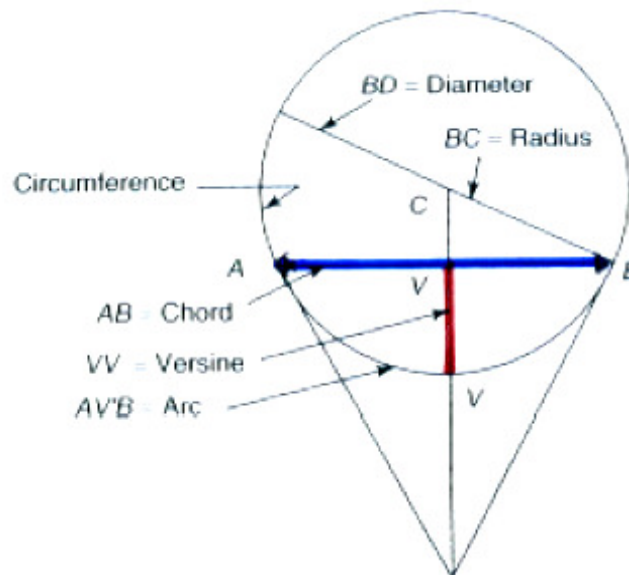


Off-Set of US Freight Cars

Note: Without a **TRANSITION** of appropriate length a left-curve should not be combined with a right-hand turnout and vice-versa a right curve with a left-hand turnout. A change of gradient (vertical curve) should not be allowed at a turnout!

THE VERSINE METHOD TO MEASURE THE RADIUS AND DEGREE OF A CURVE

The “**VERSINE**” is an easy measurement to determine in the field the Degree or Radius of a curve. One needs a measuring cord of any length. For Inspectors a cord length of either 11.8 meter or 62 ft is adopted:



The “**VERSINE**” is the perpendicular distance of the mid-point of a chord stretched over the curve to the arc of the circle:

The Radius can be calculated by the Formula:

$$R = \frac{C^2 \times 100}{8V} \quad R = \text{Radius in metre; } C = \text{length of Chord in metre [m] ; } V = \text{Versine in centimetres [cm].}$$

$$D = \frac{1750}{R} \quad ; \quad D = \text{Degree}$$

R

If we choose a chord length of 11.8 metre, then the **VERSINE** measured in centimetre gives the **DEGREE** of the Curve. This relation is frequently made use of in the field

by measuring the versine of a curve with an 11.8 metre chord and thereby getting the **DEGREE** of the curve. The Versine is a simple tool for realigning a curve. Track Inspectors keep the given values for each point of a curve documented in charts. They can take the necessary steps for corrections.

DURABLE TRACK GEOMETRY AND QUALITY BY TRACK MACHINERY

Modern Tracks for trains with higher speed and higher axle load and tracks for higher route capacity/traffic load can not any more engineered and maintained by conventional manual work. **Quality is no Luxury.**

See ***MAINTENANCE & RENEWAL, RTR-SPECIAL***, July 2007, ISBN 978-3-7771-0367-9; DVV Media Group/Eurailpress, Hamburg, Germany.

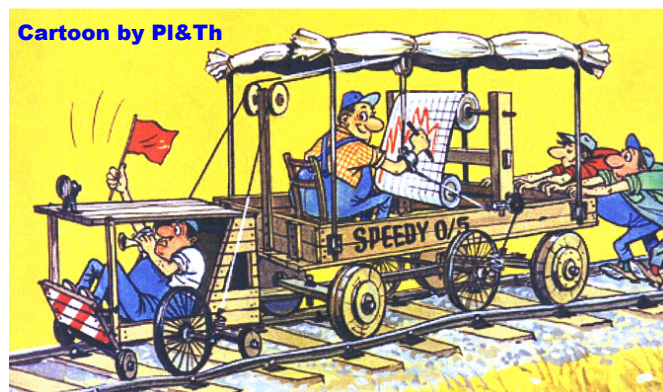
An **initial high Quality Rail Road** keeps its alignment under given traffic load far longer than a poor Quality Track. The **Deterioration Rate** (loss of alignment with the time under given traffic load) of a poor quality rail road is must faster. The **QUALITY** of a railroad can be measured in physical/mechanical terms by the velocity, with which the alignment parameters deteriorate. The maintenance expenditures for a poor quality track can be 8 times higher than the maintenance costs for a high quality track.

Initial High Track Quality is also a must to cut overall **LIVE CYCLE COSTS** plus the **AGGREGATED HINDERANCE COSTS**, the costs generated, when the trains can not run, can run only with reduced speed or even if there are accidents and mishaps, so-called “unwanted events”.

To engineer and maintain **HIGH QUALITY RAIL ROADS** modern Track Machineries are needed. The heart of this machinery are a computerised **TAMPING MACHINES**.

Nowadays all geometry track-parameter data can be stored on an on-board computer of the **TAMPING MACHINE**. The Tamping Machine lifts, levels, lines corrects and slews the alignment automatically like a robot.

A Tamping Machine lifts the rails, slews and shifts the rails to the wanted straight as well curve-alignments. Transition, Super-Elevation, Body-Curve Parameters are corrected automatically.

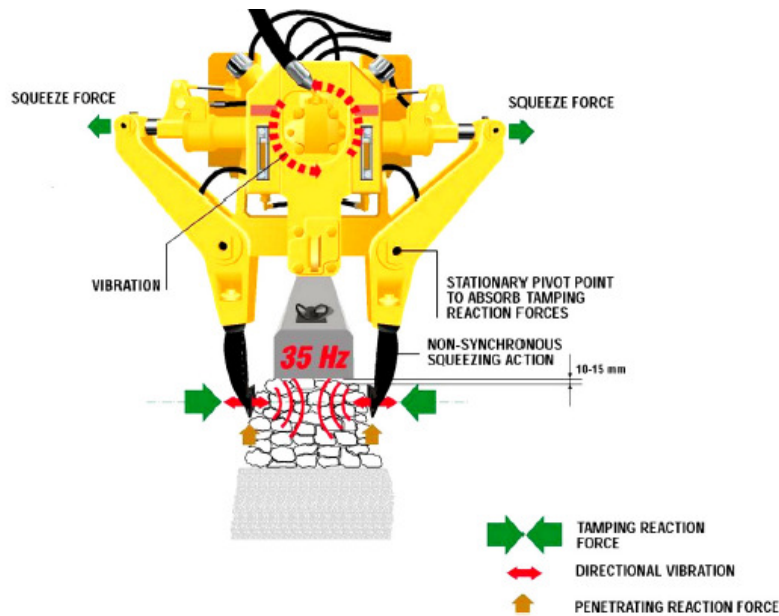


Track Recording

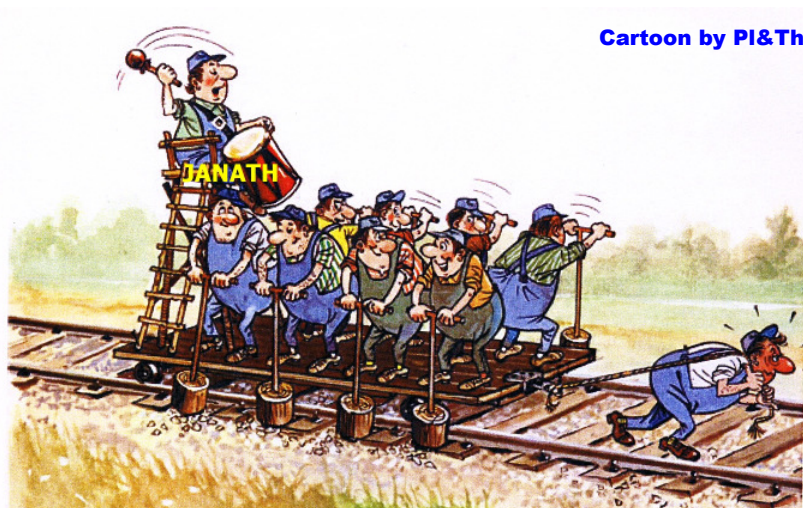
Nowadays there are **TRACK RECORDING** Vehicles at hand, which measure and record the misalignments before corrections with a Tamping Machine.

The entire track is an elastic/dynamic system, which deforms under traffic load and returns to its original position. But slowly the track geometry deteriorates under frequent traffic load and develops abnormalities. If the ideal geometry is no longer assured it becomes necessary to impose **SPEED RESTRICTIONS**.

With a Tamping Machine the Geometry of the track can be restored. **Tamping Tines** pack the ballast under the sleeper to produce a stable sleeper bed. The Tamping Tines penetrate the ballast bed from above and compact the ballast under the sleeper with a squeezing movement. It is decisive that the tamping tines vibrate with the ideal frequency of 35 Hz. The tines are driven hydraulically by oil-pressure; see www.plassertheurer.com/en/machines-systems/tamping.htm.; see also RAILROADWORKINGMACHINE–Plasser&Theurer-UNIMATIC 08 You Tube and the “**MEDIA LIBRARY**” in **PLASSER&THEURER MACHINES&SYSTEMS-MOBILE RAIL RECTIFICATIONS (-TAMPING)**.



Hydraulic driven Tamping Unite with Tines



Track Tamping

A Tamping Machine lifts the rails, slews and shifts the rails to the wanted straight. Curve-alignments, Transition, Super-Elevation and Body-Curve Parameters are corrected automatically as well.



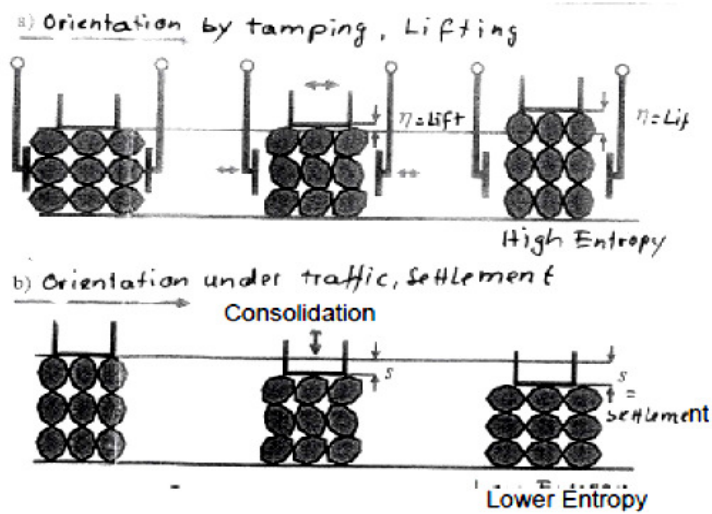
Machine Track-Tamping of a well profiled Track with Border Foot Path in North Afghanistan



Plasser&Theurer Tamping Machine Unimat 08-3S

Since the ballast stones are not spherical round, by machine tamping they get vertically orientated creating a lower “**ENTROPY**” of the ballast-bed. (Entropy is a thermo-dynamic measure for **DISORDER**). After tamping there is a lack of density. The stones settle and arrange under traffic load after a time to an irregular arrangement of higher density (at a lower volume with higher entropy). The track consolidates to a higher stability at a lower level. For the consolidation period

temporary staggered speed restrictions have to be imposed. This can take about 6 month and will need about 0.5 to 2 million tons traffic load.

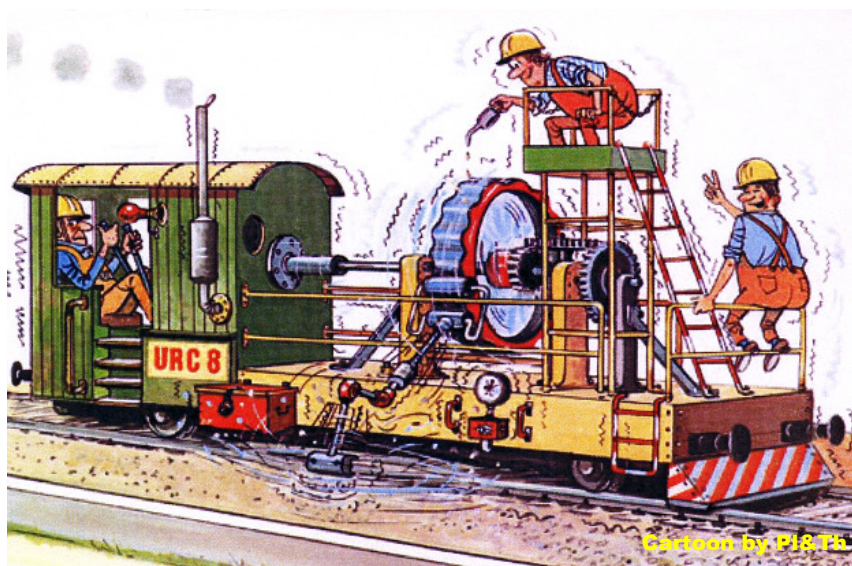


Orientation by Tine-Tamping and Settlement by Consolidation after Traffic or by Dynamic-Machine Stabilisation

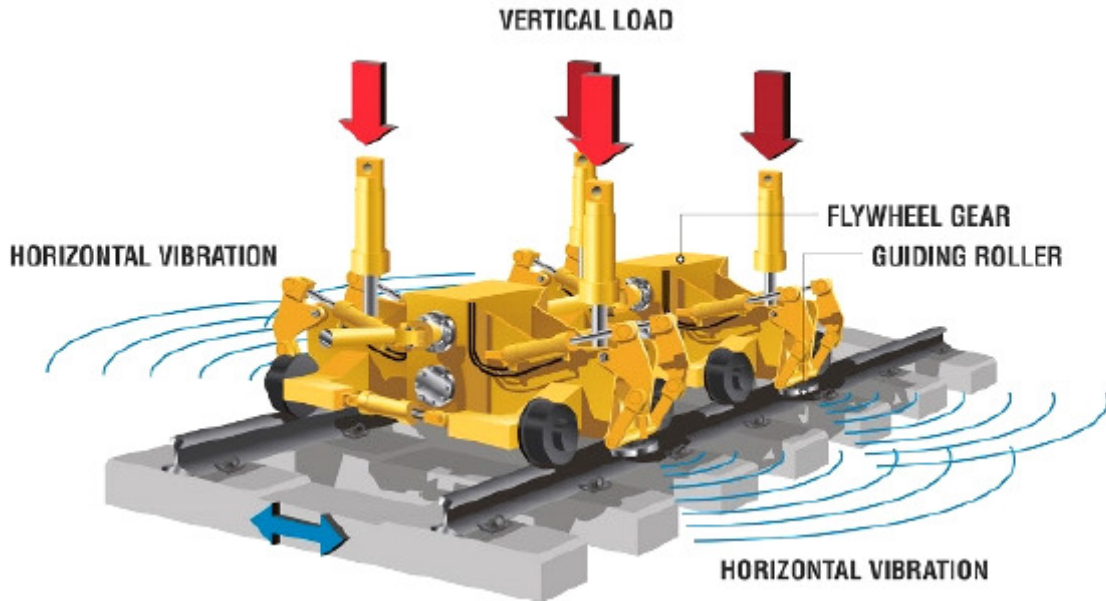
The consolidation can nowadays be achieved by a **DYNAMIC TRACK STABILISER (DTS)** running behind the Tamping Machine:



Plasser&Theurer Tamping-Express 09 cum Dynamic Track Stabiliser



Dynamic Track Stabiliser

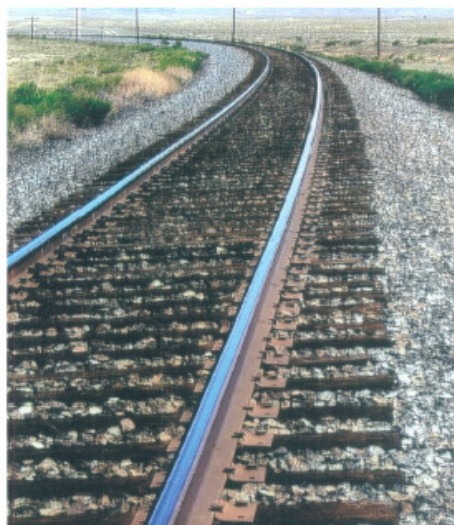


Horizontal Vibration for Track-Settlement achieved by DTS

The stabilisation units of the **Dynamic Track Stabiliser** are friction-locked via rollers to both rails. Fly-Wheels produce horizontal vibration acting crosswise to the track. The vibration is transmitted to the ballast by achieving an arrangement of the ballast stones to produce a denser structure with a higher Disorder (higher Entropy). A higher Disorder provides the more stable condition. Dynamic Track-Stabilisation by a machine anticipates in a deliberately and in a controlled way the unavoidable initial settlement-period. This increases the quality-reserve of the track and produces a more **DURABLE TRACK GEOMETRY**.

Consolidation with a **Dynamic Track Stabilizer** allows using the track after tamping with max. permissible speed. The track-Stabilisation with a Dynamic Track Stabiliser increases the lateral track-resistance in curves, essential for Pendolino (tilting) Train Routes like the West-Coast Line in England with its tight curvatures.

LONG and CONTINUOUS WELDED RAILS



Continuous Welded Rail Track USA on well ballasted Track-Bed, Ogden-Denver; called "The Ribbons"

The resistance offered to the sleepers arranged in a modern, well ballasted track-bed and on a well bearing subgrade allows clamping the expansion and/or contracting forces of rails with temperature-changes over many kilometres in length without the use of Rail-Joints with bolted and screwed fish-plates. In the daily heating and cooling cycle, there is somewhere in between a point, where there will be no compression or tension. The relevant temperature is called **Rail Neutral Temperature, RNT**. The compression and tension forces will be balanced by the resistance offered by the sleepers and the track bed. The rails clamp themselves by their own weight on the sleepers. There will be hardly any movements under varying temperature conditions. Only the ends of a Long Welded Rail or Continuous Welded Rail (LWR/CWR) by a length of 70 to 100 meter on either end are subjected to movements with expansion and contraction due to temperature changes. This length on either side is called the “**BREATHING LENGTH**”.

Long Welded Rails have been laid even in 50 m Curves without curve check-rails on **ThyssenKrupp Y-Steel Sleepers** in Switzerland on the Alpine Meter Gauge Bernina Line. Y-Steel Sleepers offer excellent geometry retention in curves:



ThyssenKrupp Y-Steel Sleepers; 160 kmph CWR Line, Germany

In Sri Lanka there is not much change in the rail-temperature with climate- and day-night rhythm. The maximum rail-temperature is approximately 60 Centigrade and the minimum temperature is in the region of 20 Centigrade. This permitted to lay on the upgraded Coast Line Sections LWR over the length of several kilometres on the curvy trace after rehabilitation of the subgrade and ballast bed, even on reverse

curves. When laying the rails on the Coast Line, the welded rails have been distressed by opening all rail fastenings at 40 Centigrade. This is noted on way-side panels.



It is essential to maintain a clean and unfouled ballast cushion with ballast humped on both the shoulders, especially on the outer-sides of the curves. In Sri Lanka there is the problem that people walking or crossing over the tracks trample down the ballast shoulders and that the Inspectors and working gangs are not used to keep and maintain a proper ballast profile.

At Railway-Stations with turnouts and before and after Reverse Curvatures so-called “**Switch-Expansion-Joints (SEJ)**” are installed controlling the temperature-expansion of the Breathing Length in order to prevent rail buckling. On the upgraded Coast Line, they are numbered: The SEJs have to be constantly monitored and lubricated:



SEJ No. 30; IRCON, SLR Coast Line

Sri Lanka has to import the rails from overseas. The length is therefore limited to approx. 20 meter. IRCON, used to work with 13 meter rails, has welded three to five 13 meter rails on the field side on **STATIONARY FIELD PLANTS** by electric arch welding, by the so-called “**FLASH-BUTT WELDING**” by means of mobile Flash-Butt

Welding plants mounted on a lorry with its own Electric Generator and with automatic rail positioning device:

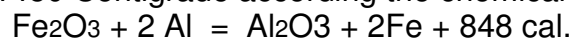


Flash-Butt Rail Welding with mobile Unite in India

The rail ends are headed electrically and pressed together. The off-set is cut of and the weld finished by grinding.

The average automatic and microprocessor-computerised weld-productivity is of approx. 20 welds per hour.

Only bare minimum welding should be done using the so-called “**ALUMINO THERMIC THERMIT-WELDING**” with an ignited mixture of Iron-Oxide and Aluminium. When ignited the mixture reacts exothermically and heats up to a temperature of about 1450 Centigrade according the chemical formula:



Alumino-Thermic Thermit-Welding on Rail Track in India

The molten Iron mixture ignited in a container flows into the mould holding both rail ends. The slag, Aluminium-Oxide, rises up.

Qualified Preheating with Petrol or Propane and Air/Oxygen and strict Temperature Control by skilled workers under supervision is essential for the quality of the final rail weld. A Thermit-Weld yields only 30 % of the rail strength, whereas an electric Flash-Butt Weld 80 to 90%. In India the Alumino-Thermic Rail Welds are often of poor quality and have to be secured with so-called Joggle-Joints. The newer generation of harder high strength Rail-Alloys, so-called “bainitic rail grades” and “heat treated rails”, pose new problems for the rail welders. The procedures have to be adjusted to steel grade.

It is desirable to deliver longer rail panels from the Rail-Milling Plant to the track side.

Nowadays it is possible to mill 121 meter long rail panels in the Steel Manufacturing Plant and to weld the long rails to 363 meter panels in a well controlled high quality way in the plant itself. Those long rails are transported on long rail trailers, so-called **“SPAGHETTI TRAILORS”**:



The world’s longest Rails transported on a Trailer Train-Set in India like “Spaghettis” for the Line-Doubling Programme on the Guntakal–Londa Section

The trailers can negotiate track curves and do not derail due to their load; the rails bend with the negotiated curvatures. Those long rails have to be loaded and de-loaded in a well supervised and controlled way, not to get damaged before railed to the sleepers. Rails once kinked by bad handling can only be straightened with difficulties and special tools, mostly not at hand.

The new rail track on the SLR Coast Line has many misalignments due to bad handling, which can not be rectified any more with the tamping machine. A rail has a

memory for ill-treatment, like an Elephant! To a certain extent it can tolerate lot ill-treatment, but suddenly it will take revenge.

On the SLR Coast line, also used and already bend rails had been incorporated in the welded rail panels. Several misalignments are caused by the memory of those rails for their past, improper handling and treatment. Rail-ends, once damaged must be cropped off, and only straight rail-ends should be welded together.

This had not been always the case under the IRCON SLR Coast Line Project.

Longer rails from the Steel-Mills means less trouble with bad welds on the track, a better alignment and less weld failures. The introduction of long 121 to 363 m long **JINDAL-RAIL** panels in India has been a “milestone” for increasing the speed over 130 kmph on modern higher quality tracks.

ANNEXURE:

**ALUMINO-THERMIC THERMIT-WELDING;
Picture Gallery**



Fig. 20-6: Adjusting and positioning the mould

Photo: Elektro-Thermit GmbH & Co. KG

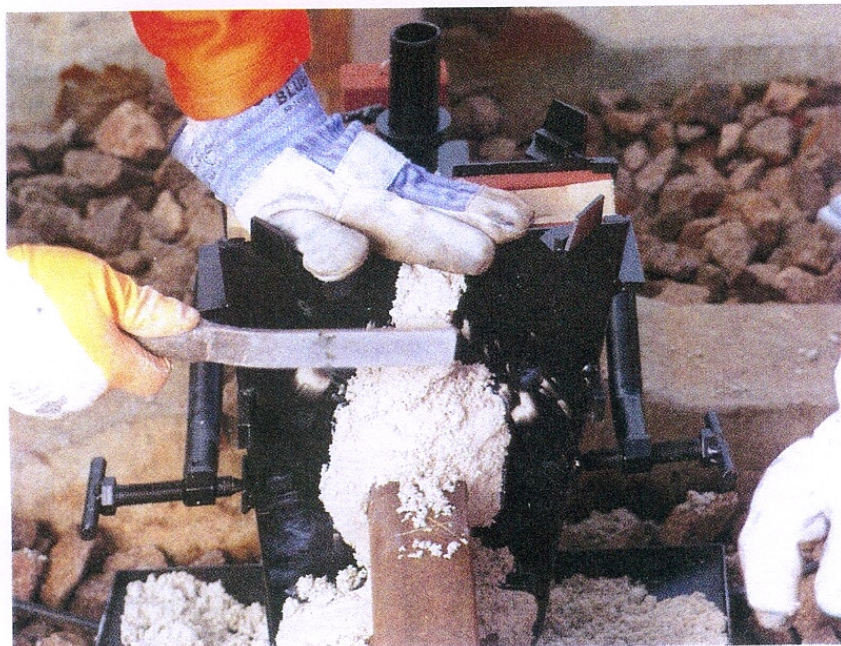


Fig. 20-7: Sealing the mould with sand

Photo: Elektro-Thermit GmbH & Co. KG

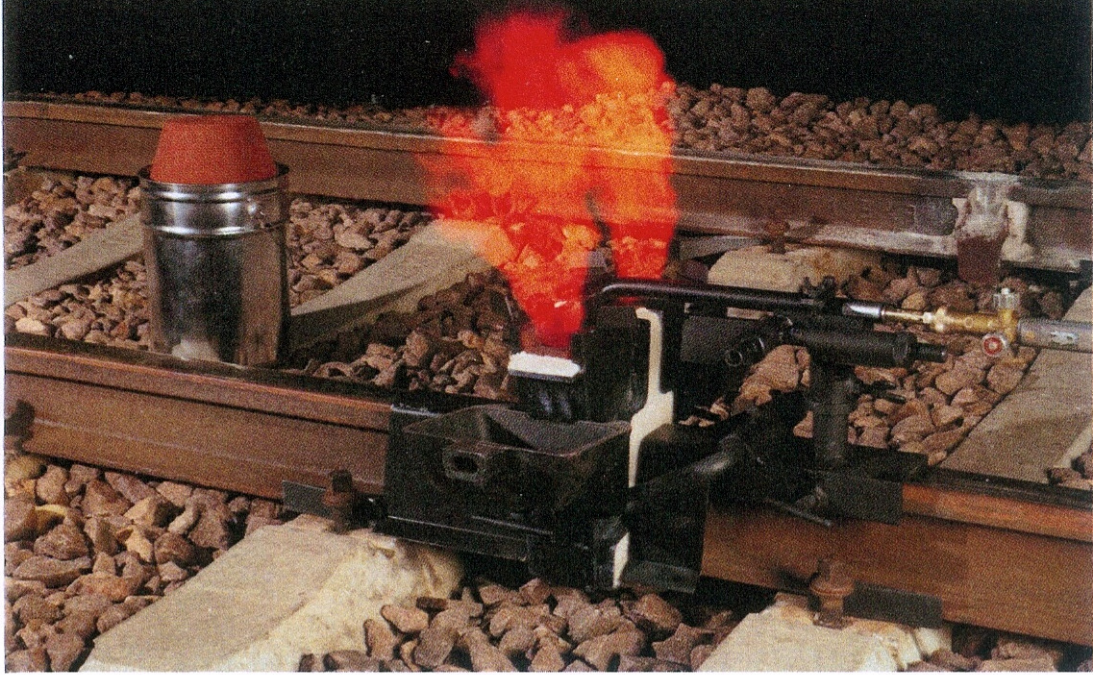


Fig. 20-8: Pre-heating

Photo: Elektro-Thermit GmbH & Co. KG.



Fig. 20-9: Igniting the welding portion

Photo: Elektro-Thermit GmbH & Co. KG.

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The Centre for Railway Reserach in Kharagpur offers in India Studies in Railway Technologies



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The Centre for Railway Research (CRR) was set up at IIT Kharagpur based on the MoU signed between the Ministry of Railways, Government of India and Indian Institute of Technology Kharagpur on February 13, 2010, to develop a long-term framework for research collaboration. This is the first such research centre set up in an academic institute with direct and full funding by the Indian Railways.


Indian Railways is the nation's premier organization for providing transport service. Ministry of Railways is operating one of the largest railway systems in the world. Its countrywide network of approximately 64480 kms carries over 7651 million passengers per annum and moves 922 million tonnes of freight traffic.

With the growth in Indian economy, Indian Railways transport business is expected to grow at an average rate of 10% per annum over the next ten years. To achieve this phenomenal growth Indian Railways considers it essential to make use of the technological advancements in the field of Railway Technology, as technology plays a major role not only in improving safety standards and the quality of service but also in productive utilisation of the rail infrastructure and reducing costs. Moreover, Indian Railways, which at present is an importer of technology, intends to develop cutting edge indigenous technologies and turn a net exporter of technology by 2020. To achieve the above goals, the Indian Railways has decided to develop a long-term framework for research collaboration with IIT Kharagpur through a special centre of excellence that is CRR.

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