FROM STEAM TO DIESEL TRACTION
in 189 years from 1825 to 2014

A Technical Paper prepared for a Railway Technology Exhibition and Seminar at Richmond Hill College, Galle, Sri Lanka; October 2104

By Dr. Frank Wingler, April 2014

1825 had been the year of birth for Steam-Traction for a Passenger Service, exactly on the 27th September 1825, when a mixed train consisting of 6 coal-wagons and one passenger wagon prepared with seats for 21 invited guests opened the first public rail-transport from Stockton to Darlington in North England with the Steam Locomotive ***“LOCOMOTION”,*** constructed by George Stephenson (see **Pict. No. 1**):

Pict. No. 1: Replica of “*LOCOMOTION”,* York National Railway Museum, UK

In October 1829 Stephenson won with his Steam Locomotive ***“ROCKET***” the competition for the most reliable Steam Locomotive at Rainhill near Liverpool. Together with his locomotives Stephenson exported the **“Standard-Gauge”** of 1.435 metre worldwide. The gauge had been used by horse hauled coal carts in English mines and presumably is going back to the Roman Carts. Stephenson introduced also the first milled steel rails.

For over 100 years ***Steam-Trains*** have been a synonym for Railways. Steam Locomotives reached the technological climax during World War II.

Steam Locomotives have a very low thermal efficiency. At the begin of the development the locomotives wasted 94% of the thermal fuel energy on the way by burning coal or oil, converting water into steam and than by moving pistons with the expanding steam in the cylinders. The expanded water vapour is discharged through the chimney. At the end of the Steam-Locomotive era the thermal efficiency reached 10-12 %.

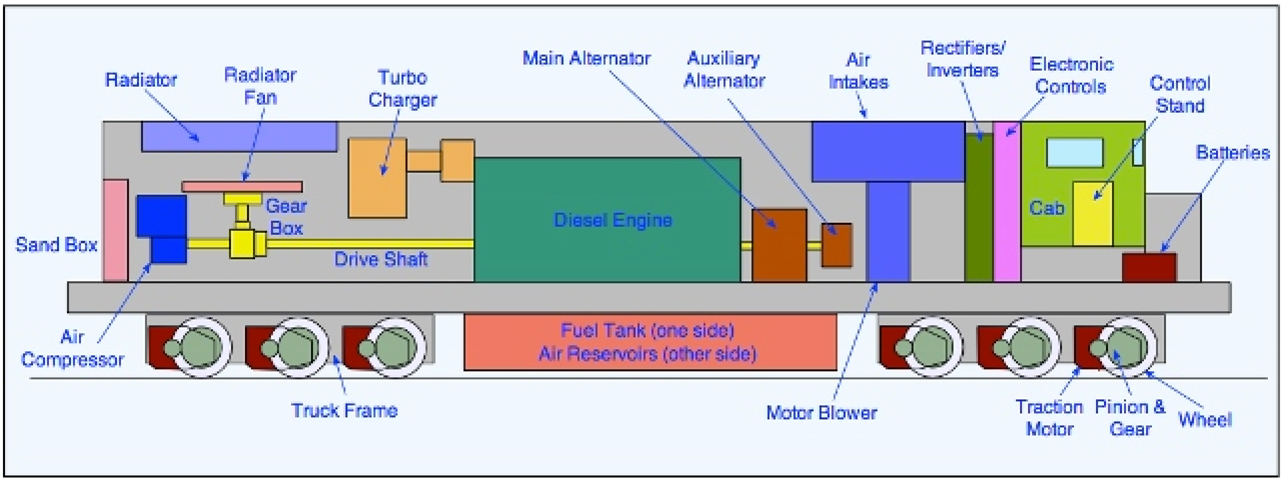
A Steam Locomotive needs high service and maintenance capacity before and after each run. Roughly 65 % of the lifespan can not be utilised for traction. Every 200 to 300 miles the locomotive has to be serviced, filled with water and coal, the burner prepared, the moving parts creased and lubricated. Service and Maintenance is personnel intensive, the energy costs are high.

In the 1920-ties Railway Companies in USA and Europe experimented with Petrol-powered Rail Cars. It took nearly another 20 years, until more powerful and reliable Diesel Engines had been at disposal. The development for reliable powerful Diesel Engines with over 1000 hps had been mainly pushed by the engineering of ship-, submarine- and war-tank engines. In the 30-ties one litre Diesel-fuel cost only 2 US $ Cent, far less than coal. A Petrol- or Diesel-Engine have an energy efficiency of 30 to 40%.

The pistons of a steam-cylinder can work directly by means of a rod on the wheel. No gear or momentum-transformer is needed. The cylinder develops on from the start, from zero motion or rotation, its full power. A combustion engine, petrol or Diesel, works only from a minimum rotation onward. In the 1920-ties a reliable mechanical gear-box for the power range of over 500 hps had not been available. Together with the Diesel Engine the power-transmission had to be developed.

Sulzer in Switzerland experimented with a direct drive without a transmission from the Diesel-engine crank-shaft to the wheels. Since a Diesel-Engine can not develop its power from zero rotation onward like a steam cylinder, the locomotive had to be started by compressed air. But this system failed.

The American Locomotive builders opted for Electric Transmission; this means, the Diesel-Engine drives a Dynamo or Generator (Main Alternator), and the produced electricity is fed to the electric traction motors connected by pinion gears mechanically with the axles. The direct drive by electric motors over a pinion gear to the axle had been in use by electric city-trams (see **Pict. No. 2; 3 in the attached Picture Gallery):**



Schematic Presentation of Diesel-electric Traction

In 1925 **ALCO, American Locomotive Company** – created 1902, when eight companies merged in USA in order to better compete in the expanding market, – joint with General Electric and Ingersoll Rand for the pioneer construction of the Diesel Locomotive CNJ 1000, a 300 hps switcher (shunter). 1937 appeared the 1000 hps turbo engine and 1950 after World War II a 1600 hps Diesel. The ALCO Diesels where more successful than Baldwin's or Lima's, but they could not jeopardise the General Motors Electric Motive's (GM-EMD) products.

In 1975 the sturdy Canada (Bombardier, Montreal Workshop) build and 1975 introduced SLR Class M4 is based on **ALCO** Technology. One can find even today those Bombardier Locomotives running in Africa on Meter-Gauge (Tanzania). The Indian WDG2 or WDM2 (in SL Class M8/M10) Locomotives are based on the same **ALCO** Technology. But the engines are fuel wasters and produce a lot of smoke with a typical sound; see **Pict. No. 4**).

The end of the Locomotive production under the **ALCO** trade mark came to end in 1969. Bombardier took over the Montreal workshop.

For a lengthy period **GENERAL ELECTRIC (GE)** was a supplier of electrical equipments to several other locomotive manufacturers. From 1925 to 1929 **GE** was partner in a consortium with Ingersoll Rand and **ALCO. GE`s** own production started in the 1930-ties with industrial shunting switchers and continued later with heavier models. Perhaps the most successful design was the U25B, introduced 1960. GE needed only three years to capture rank two between **ALCO** and **EMD** on the American market. Purchasing in 1989 the Bombardier production facility in Quebec, **GE** entered the Canadian Market. In 1933 **GE** introduced three-phase asynchrony AC traction and installed for each electric traction motor one inverter, together 6 on one AC 4000 CW. Until than DC current had been used. The three-phase AC technology had been further developed 1971 in Europe by **BBC and Henschel** with the 2500 hps DE 2500. Today most of the Diesel-Electric Locomotive around the globe use AC-technology. **SIEMENS** is nowadays the AC traction technology-leader for Locomotive manufacturers.

General Motors with its Electric Motive Corporation Division **(GM EMD**) gained in the 1930-ties the leadership. **GM EMD** is now firming as **ELECTRO MOTIVE DIESEL** under the umbrella of **CATERPILAR** and is nowadays still the world-technology leader in heavy-haul Diesel-Locomotives.

The origins of the company are in the **Electro-Motive Corporation**, which was engineering petrol-electric Rail Cars in the 1920-ties manufactured by subsidiaries. General Motor purchased it 1930 along with the Winton Engine Co. EMS, the chief industrial petrol motor supplier. **GM** developed together with Winton reliable light weight Diesel Motors. The first **GM** Diesel locomotives were market in 1935 through subsidiaries. The first mass production model was the **FT**, introduced in 1939. But to compete with the haulage power ort tractive effort of Steam Locomotives, several Diesel Unites (so-called ***"A-Unites"*** with a front driver-cab and **"B-Unites"** without driver-cab) had to be coupled together in one Unit to yield the 5000 hps range of one Steam Locomotive (see **Pict. No. 5, 6; Picture Gallery**):

GM-EMD F-3 A-B-B-A Unite

The biggest ever build Steam locomotive had been the **ALCO** build ***"BIG BOY"*** for Union Pacific, a Mallet-type 2`D`+D`2`in the 1940-ties; see **Pict. No. 7**. With an output of over 7000 hps and its tractive effort never reached by a single Diesel-Locomotive Unite of over 610 kN (Kilo-Newton), 40.51 meter in length, 32 tonnes axle load, total weight 540 tonnes, max. speed of 120 kmph the ***"BIG BOY"*** puts everything before into shade. Without a ***"helper"*** or **"banking-locomotive"** it could convey 3600 tonnes freight trains over the steep ascents with inclines of up to 1 in 56 on the route between OGDEN (UTHA) and CHEYENNE (WYOMING). Between 1941 and 1945 14 items had been build. But very soon, 1947, the area of the development of Steam Locomotive ended in America. 2 are left in museums in USA. A ***"BIG-BOY"*** is the dream of every Model Rail Roader. In April/May 2014 No. 4014 had been hauled from California to Cheyenne in Wyoming fo reconditioning. Railroaders hope to see this Locomotive again in working condition 2019.

By Diesel Traction with synchronised computerised Multi-Traction of up to 7 or 8 Locomotives and by distributing extra Locomotives in the freight train sets longer trains can be send on the journey, increasing the route capacity; see **Pict. No. 8 to 11; Picture Gallery.** 3000 metre long trains can be spotted in USA. The longest mining trains run on meter gauge in Brazil with over 300 hoppers.

An advantage of Diesel-Electric traction on down gradient runs is the **"Dynamic Retarder Brake"**. The traction motors are shunted as Dynamos or Generators and the produced electricity is discharged over a resistant, cooled by air blowers.

When you travel in SL upcountry with an M6 engine, which is based on **GM-EMD** technology, you can make out the typical sound of the dynamic brake blower. Thus on long down gradient runs wear and waste of wheels and brake shoe blocks of the friction brake can be saved.

The radiators for the dynamic brake resistant one can make out on the front nose of the upcountry B0`B0`Class **M2C No. 726 and 729**; see **Pict. No.13**.The Canadian build **M2 Class** Locomotives of Sri Lanka Railways are based on the GM EMD General Purpose Locomotives of the series GP9/GP12, sold in USA over 4000 times; see **Pict. No. 14; Picture Gallery**. This sturdy export Locomotive of the 1960- and 70-ties is running even nowadays in many countries around the globe; see **Pict. No. 15/43; Picture Gallery**. But there are no manufacturers any more on the globe selling such a simple and sturdy 4-axle Diesel-Electric Locomotive.

Although Diesel-Engines can nowadays been build in he 6000 hps range, the 4000 hps range provides an optimum in regard of cost-yield range. By computerised synchronisation several locos can be combined for multi-traction. In case one engine breaks down the train-set has enough redundancy to continue its voyage. In1969 GM put two GP 40 Locomotives on one frame to a D0`D0`"Super" Locomotive DDA40 X; 30 m long and upto 6600 hp; **see Pict. 10; Pict. Gallery.** 1980 came the end for the D0`D0`Locomotives.

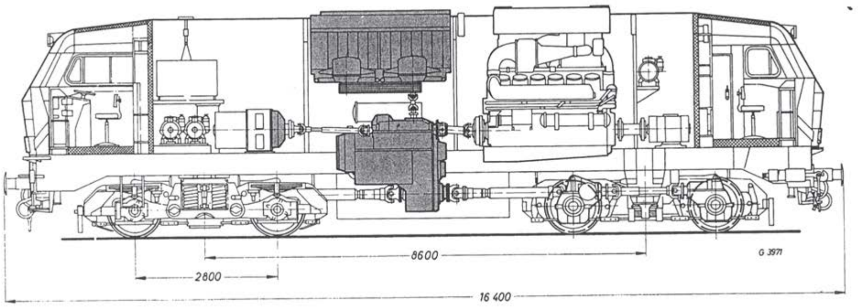
In the 1950 60-ties Union Pacific experimented with Steam and Gas Turbin ***"Giant"*** Locomotive; see **Pict. 12; Picture Gallery.** The maintenance of the ***"GIANTS OF THE WEST"*** or the ***"SUPER TURBINES"*** with up to 8500 hp had been too costly. In 1971 the last "giants" had been scrapped.

Whereas in the United States the switch from Steam to Diesel Traction had been dominated by the competitive race for stakes of the huge market by private enterprises, on the European Continent the technology shift had been steered by the State-Railways.

Britain followed the American GM Diesel-Electric Technology. The first SLR Main-Line Diesel Locomotive Class M1 from the 1950-ties is based on American GM Technology; see the Technical Paper “***THE OLD WARRIOR”*** (in progress)***.***

In order to reduce weight, in the 1930-ties the German Government Railway experimented with hydraulic transmission, with torque-converters, utilising oil between a combined oil-pumping turbine and an oil receiving turbine: Alternator (Generator) and Traction Motors are heavy parts. The hydraulic torque converter is connected with the axles by a cardan-shaft over pinion gears; see **Pict. and Figures No. 16a/b, 17; Picture Gallery**. The unsprung mass of the bogie is less and hence the bogie friendlier to the track.

On the European continent the tracks were ready to carry 16, maximum 20 tonnes axle load, whereas in USA the tracks could tolerate 32 tonnes axle loads. With the “hydraulic” transmission it was possible to build the Multi-Purpose 2000 hps Diesel Locomotive with a total weight of 80 tonnes; see **Pict. No. 18, 19; Picture Gallery**:



Flow Diagram ofGerman Diesel-hydraulic Locomotive, BR 218   Fluid Torque-Converter

With locomotive-series DB 218/19 the end of Steam-traction on Main Lines came in West-Germany end of the 1960-ties, begin of the 1970-ties at a time, when in Sri Lanka the Steam Locomotives had already disappeared from the tracks.

In Sri Lanka the ***DIESELISATION*** of the motive power fleet started in the early 1950-ties. On the Main Broad Gauge Network the Steam Locomotives disappeared 1969. On the Kelani Valley narrow Gauge section Steam Locomotives survived until the mid 1990-ties.

Steam Locomotives have still found a niche around the globe: For **nostalgic Steam-Excursion Trips, Tourist, Scenic Railways and Museum Railways and on Mountain/Alpine Cock or Pinion Railways**, which are not electrified; see **Pict. Series No. 20 to No. 36; Picture Gallery.**

Steam-Traction for freight and passenger trains has long survived in North-East China until recently with the 1`E Class QJ Locos on the ***"JINGPENG-PASS"*** = a ***"Mecca for Railway-Enthusiasts around the globe"***:

Steam Traction on "*"JINGPENG-PASS*", China; 2004

In Poland there is a small Standard-Gauge network using still today steam traction; but the days of survival are counted.

In Germany some Narrow-Gauge Lines in tourist areas are run even nowadays scheduled trains with steam on Meter or 2 ½ feet Narrow Gauge. Germany has approx. 60 standard gauge Steam Locomotives in running conditions used regularly by Railway Enthusiast. And a heritage of East-Germany is the Steam-Locomotive Workshop in Meiningen, which even nowadays build new Steam Locomotives. Famous in Germany is the yearly "**Steam-Express Train Race"** up gradient on the double Mountain Line in the Black Forest. The worldwide fastest Steam-Locomotive in working condition is the **1802**, assembled in East Germany from the frame and 2.30 meter wheels of a "***High-Speed Steam Locomotive"*** from 1939 and parts from a boiler from a Freight Steam Engine. It has a private ownership, runs up to 180 kmph and is used nowadays for chartered nostalgic Steam Trains; see **Pict. No. 23; Picture Gallery.**

In Sri Lanka Tourist Groups can charter the Steam "***VICEROY SPECIAL"*** for an up-country nostalgic train ride; see **Pict. No. 24 to 27; Picture Gallery.**

Railway Enthusiasts have rebuilt in Switzerland the alpine **FURKA-PASS** meter gauge pinion railway. Four Swiss-build and nearly 100 years old pinion Steam Locomotives have been rescued from a Mountain Railway in Vietnam under adventure conditions and rebuild in Germany and Switzerland to a new glory. They can last now for the next 100 years; see **Pict. No. 29, 30; Picture Gallery**.

In South India the famous meter gauge pinion **OOTY RAILWAY** and the UNESCO Word Heritage 2-feet narrow gauge **DARJEELING RAILWAY** in Benga/Indial using reconditioned Steam Locomotives for scheduled train services; see **Pict. No. 31 to 34; Picture Gallery.**

The 100 years old Swiss build **OOTY** Locomotives burn nowadays instead of coal a mixture of recycled Engine Oil with Kerosene or Light Oil. INR has enough waste engine oil to be used up by combustion in **OOTY** Steam Locomotives.

The Steam Train on Indians 2 ½ feet Narrow Gauge **SHIMLA Hill Railway** can be hired by Railway Enthusiast; see **Pict. No. 33; Picture Gallery.**

On the Indian **MATHERAN LIGHT HILL RAILWAY** with gradients of 1 in 25 near Mumbai the reintroduction of a reconditioned Steam Locomotive build 1905 by Örenstein&Koppel Berlin, Germany, failed due to the lack of skilled stockers, experienced to keep the right fire. Much money had been spent for reconditioning. Now the Locomotive is at Neral on a presentation plinth exposed to the corrosion by the climate; see **Pict. No. 36; Picture Gallery**.

The Steam Locomotive has the advantage, that it can start from zero on an incline; Diesel powered Locomotives have their problems.

A Steam Locomotive can always be reconditioned, since it consists only of mechanical parts. There is no electronics, which gets obsolete within few decades. Steam Locomotives have lived over 100 years, and with good service and repair they can live another 100 years.

The **LIFE SPAN** of a Diesel-Electric Locomotive is 20 to 30 years. After the expiry date it will become difficult to get spare parts. Electronics and electric equipment get very fast obsolete – a general problem with modern Diesel-Electric or Electric Locomotives. The sturdy and simple GM/ALCO Technology Diesel Locomotives Class M2 and M4 might live a little bit longer. 6 out of 10 modern **ALSTOM build M9** with a lot of electronic parts got out of order within only one decade.

Since sturdy Locomotives of the M2 and M4 type are not any more available, the question is

WHAT IS AN ADVISABLE DIESEL LOCOMOTIVE FOR SRILANKAN CONDITIONS?

1968 CGR received from Germany the Henschel-Thyssen tailor made 4 axles Middle-Mono-Cab Locomotive Class W1 with Hydraulic Torque Converter

Transmission engineered by **VOITH**; see **Pict. No. 38**. After reconditioning with a Caterpillar Diesel Engine the B'B' locomotive had been classified as W3. This Henschel locomotive had been the prototype of a new Mono-Middle Cab series continuously build in Germany for local and export market, now firming under **VOSSLOH.** The latest multi purpose version is the Vossloh 1206; see **Pict. No. 39 to 41; Picture Gallery.**

The success of this type of Locomotive has prompted **VOITH** to build its own Diesel-hydraulic versions for the German Federal Railway, the **GRAVITA-Family**; see **Pict. No. 42; Picture Gallery:**

VOITH "GRAVITA" 10 B'B'

The **VOSSLOH** and **VOITH** B'B' locomotives can be ordered with **MTU** or Caterpillar Diesel-Engines with a power rating between 1200 to 2400 hps according the wish of the customer. There is no electric transmission vulnerable to dust, water, salt-spray. The locomotive can run through stagnant water without damage to the traction system. It has a reliable Dynamic Retarder-Brake for down-gradient runs at 35 kmph. The oil in the transmission gets squeezed through nozzles and the heat dissipated by means of the cooling cycle of the Diesel-Engine. No extra radiator with an extra blower is needed.

The sturdy W3 is doing now since 1969 for 45 years its duty. When it came to Sri Lanka it had been equipped with the Westinghouse Vacuum Brake system and in addition with the **KNORR-BREMSEN** two pipe (Feed- and Brake Pipe) gradually releasable **Compressed Air Brake** system for the train. The in East Germany build Diesel hydraulic Class W 2 Locomotive had been recently rehabilitated in SL.

The 1991 introduced **HITACHI-HYUNDAI**, Korea build, Power-Set or DMU Class **S8** has a reliable 12 cylinder **MTU** Diesel-Engine and a **VOITH hydraulic transmission**. The Rail-Cars are equipped with the reliable **KNORR-BREMSEN** two-pipe, gradually releasable Compressed Air Brake system. Problems prepare the corrosion of the

Car-body, but this can be addressed. This Power-Ser is easy to handle, to service and to repair. It is now 23 years on the track. Experts predicted, that this Rail-Vehicle will run, when the later introduced Diesel-Electric DMUs, Class S9, S10 and S 12, build in China and S11 build in India will be out of service.

The that time Transport Minister FOWZIE told: ***"We have to take, what is offered to us. We can not choose, what is most suitable and advisable for us"***.

The Chinese Compressed Air Brake system with a 10 bar feed pipe is not directly compatible with the Knorr-Bremsen-System of the S5, S8, S11 and W3, used around the globe with its 5 bar feet pipe. The new imported Chinese Coaches, most of them now idling, are equipped with the Chinese Compressed Air Brake system, but SLR has no suitable Locomotive with enough compressed air feed for a trouble-free train run.

The MTU or Caterpillar powered Diesel-Hydraulic Middle-Mono-Cab B`B` 4-axles Locomotives of the W3-type are nowadays available in a higher power range of 1600 to 2000 hps with higher tractive efforts from **VOSSLOH or VOITH.** Such type of Locomotives would be the best option for an advisable and track friendly solution for flat land as well for up-county runs. This type of Diesel-Locomotive suits best the SLR track conditions.

1979 Henschel-Thyssen delivered 16 tailor made 87 tonnes 1650 hp Diesel-electric Locomotives is based on a GM-EMD licence, Class M6. In order to lower the axle-load to 16.5 tonnes an idling axle had been inserted in the 2.80 m long bogie between the traction axles. The loco has to be denoted as A1A'A1A'. Although this locomotive has not been designed for the upcountry track conditions, SLR uses the M6 up-to Badulla in shortage of more track friendly locos. The idling axle causes track curve distortions; see **Pict. No. 37**; Picture Gallery.

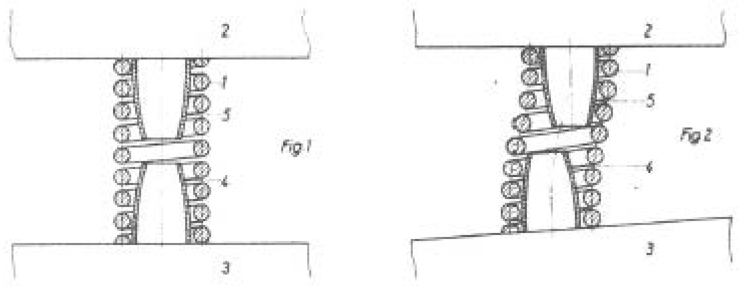
Heavy 6 axle locomotives with a wheel base longer than 2.65 metre are ***"Point-Killers"*** and unsuitable for the tight curvatures of the ailing Broad-Gauge Upcountry track.

The new Indian **Class M10**, build on basis of the Indian WDM3D with its high adhesion bogies, is too heavy for the ailing SLR Rail Tracks; and it is a **"SLR POINT-CRUSHER".** (The SLR Points have short straight tongue rails and are mostly in a deplorable condition; see Galle Railway, Fort and Maradana Stations). The M10 Locomotive is only suitable for the renewed and upgraded **IRCON**-Tracks with the Indian-Standard Points with long curved tongue rails and Manganese-Steel V-Crossings. It does not suit the ailing SWLR track conditions.

MODERN TRENTS FOR DIESEL LOCOMOTIVES

As already mentioned, although Diesel-Engines can nowadays been build in the 6000 hps range, the 4000 hps range provides an optimum in regard of cost-yield range. The world market is dominated by **EMD** and **GE**. They sell only heavy standard Locomotives. **National Railway Equipment Company of USA** found a niche for selling round the globe smaller customer adjusted Diesel Locomotives based on reconditioned parts. Reconditioning can be sometimes more economical than the purchase of brand new locomotives. Croatia has demonstrated this by reconditioning the ***"KENEDY"***, identically with the Srilankan Class M2; see **Pict. No. 43; Picture Gallery**.

HENSCHEL, which is now in the hands of BOMBARDIER, introduced in the 1970-ties a revolution in the Locomotive technology with the so-called **"FLEXI-COIL"** bogie. The bogie is not any more connected with the Locomotive frame by a **Centre Pin or PIVOT** but by so-called ***"Flexi –Coils"***. There is now more room in the bogie for other technical arrangements:

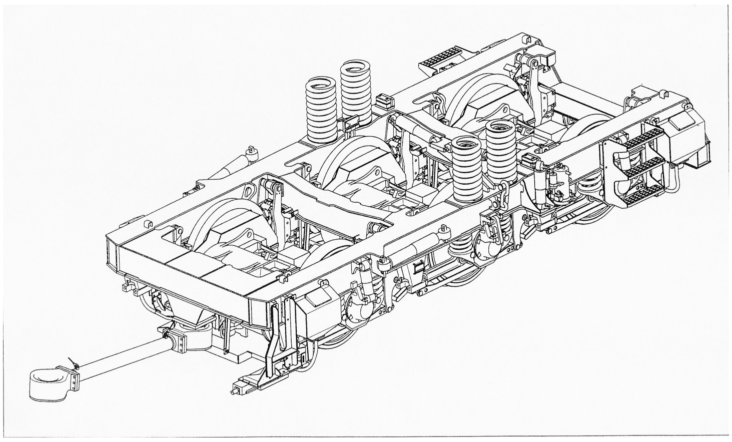


Flexi-Coil Suspension

The secondary suspension coils twist with the bogie movements. Nowadays all Electric or Diesel-Electric manufactures worldwide use this technology; see **Pict. and Fig. No. 44 to 47, 49; Picture Gallery.**

If you look in Sri Lanka on the bogies of the Chinese build Power sets or DMUs (Diesel Multiple Unites) you will find that the car bodies are resting on such flexible suspension coils and that there is no centre-pin or pivot any more; see **Pict.** of the S12 coach bogie, **No. 46; Picture Gallery**.

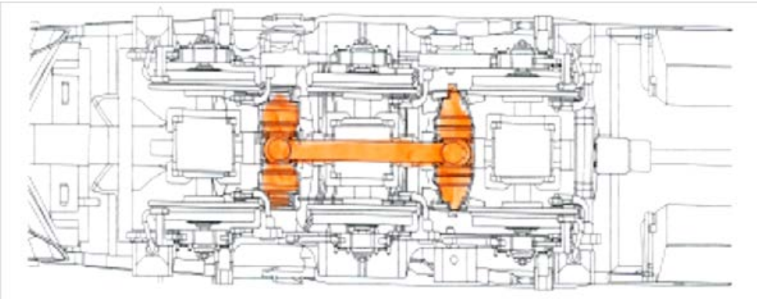
Henschel introduced a **"Push-Pull-Bar"** between Locomotive frame and the bogie to guide the traction or braking efforts from Bogie frame to the Locomotive frame in order to prevent that the front axle gets de-loaded during traction and that the front wheels might mount up and the wheel flanges might climb over the rails; **see Pict. No. 47a/b; Picture Gallery.** At the French Alstom build M9 this bar is missing, there had been not enough room. The PRIMA DE32 for Sri Lanka is a misconception; see **Pict. No. 53/54a; Picture Gallery**. The causation why the M9 has the tendency to derail by flange climbing at low speed, when the Train Driver opens the throttle, is the de-loading of the front wheels. The front-axle gets de-loaded and rides up. At higher speed, it does not derail, because the gyroscopic effect of the fast spinning wheel keeps the wheel in direction.



Henschel Flexi-Float Bogie with Flexi-Coil Suspension and Push-Pull-Bar

The same system is used for Indian Railways fasted running electric Locomotive WAP-5.

VOITH-Turbo demonstrated with its **MAXIMA**, that nowadays Hydraulic Transmission is possible up to 5000 hps. Instead of a Push-Pull-Bar the traction bogies with flexi-coils have an inbuilt stool to bridge the effort-flow from bogy to the locomotive frame. Since there are no electric traction motors in the bogie frame, there is more room; see **Pict. No. 48, 50, 51; Picture Gallery**):

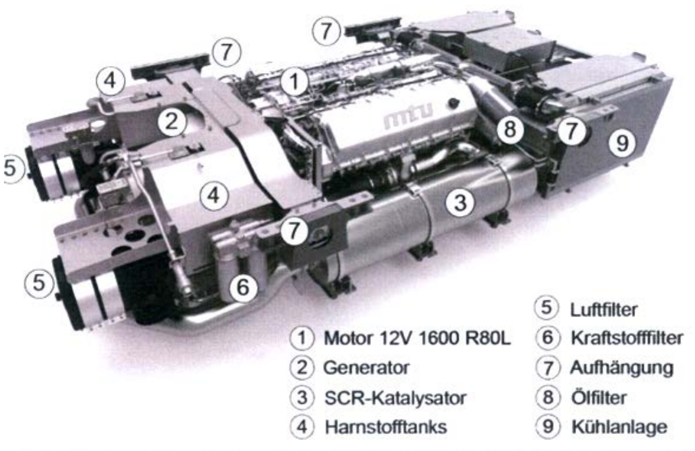


C` Traction-bogie of MAXIMA with in-build Push-Pull-Stool

The Diesel-Hydraulic **MAXIMA** competes on the European Market with a **VOSSLOH** build 4000 hps Diesel-Electric **EURO 4000** series, build in Valencia, Spain, in the former ALSTOM workshop. Vossloh took over the Alstom workshop for heavy haul Diesel locomotives in 2004. Although the outer body-shell design resembles the Syrian-Srilankan **ALSTOM DE 32** (Class M9), the interior is quite different. The Diesel parts are based on EMD 12 cylinder, two-stroke technology, and the electric traction parts are based on Siemens Technology. Vossloh build also a lighter version of its **EURO 4000** with four axles (B0'B0') and a power rating of 2400 hps, the **EURO LIGHT** with a total weight of 75.5 tonnes for the European market; see **Pict. No. 52, 54b; Picture Gallery .**

In USA and Russia tests are under trial to combust Liquid Gas instead of Diesel-Fuel.

The latest trend is to use 3 or 4 smaller Diesel Unites instead of one heavy Diesel engine in one Locomotive. Nowadays there are so-called ***"POWER PACKS"*** available for fast running Light Weight Rail Cars based on Diesel Engines developed for heavy road vehicles;see also **Pict. No. 55/56; Picture Gallery**:



MTU 900 hps POWER-PACK

The width of this pack with all needed auxiliary equipments is only 84.5 cm, less than 3 feet. It can be assembled under floor, inside the Rail Vehicle or even on the roof of a Rail Vehicle. **HITACHI** equips the new Rail-Car-Trains for the British Intercity Express Programme with MTU 12V 1400 700 kW or 900 hps power packs:

HITACHI Intercity Rail-Car with under-Floor Power-Packs for British Rail

Four 900 hps **"Power-Packs"** with all together 3600 hps instead of one heavy conventional 3600hps Diesel are more fuel efficient and make less pollution. If not the full power-output is needed, selected power-packs can be shut down to safe fuel. For repair, service and maintenance the individual power-pack mounted on a frame can be taken out and replaced by a spare pack. The Locomotive does not need to idle in Sheds for services. **BOMBARDIER** has installed in its **TRAXX F160 DE ME** B0'B0' Locomotive four **CATERPILLAR C18** Diesel-Engines, which are used also for heavy-road-vehicles, with alternators each on a frame, each rating 900 hps. The Locomotive is designed for 160 kmph; **see Picture 56; Picture Gallery**.

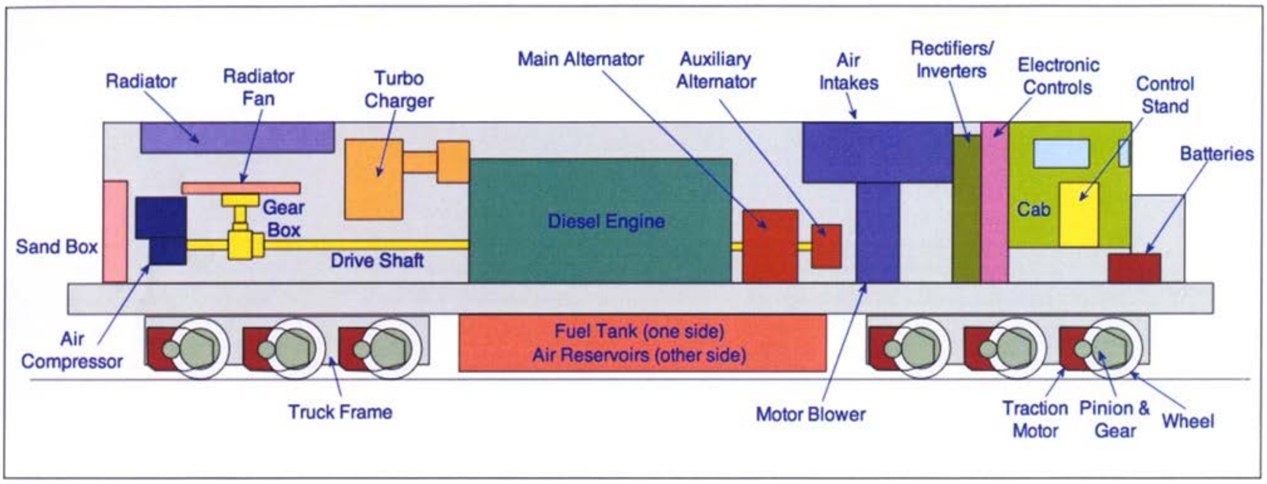
In an extra paper of this series we reveal the principles and features for the ***"LANKA ECONO RAIL"*** project initiated by Dr. L. Perera, the entrepreneur of Micro Cars in Sri Lanka, which is based on power-packs arranged in a middle traction unite with a free 100 cm wide gangway between the power-packs, based on Swiss **STADLER** technology. **STADLER** is the world leader for tailor designed Mountain Railways.

1 in 87 Scale Model for a Light Weight Rail Car with Modul Middle Traction, System Stadler for the *"LANKA ECONO RAIL PROJECT"*, designed by F.A. Wingler

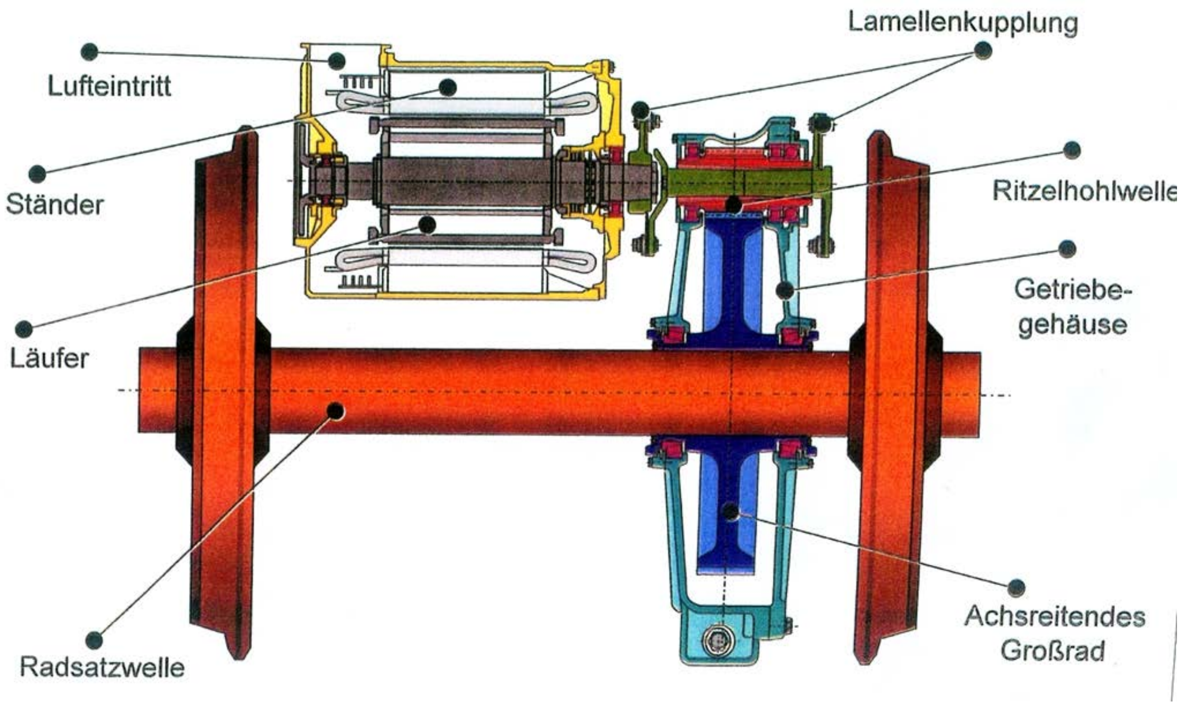
LANKA ECONO RAIL

PICTURE GALLERY

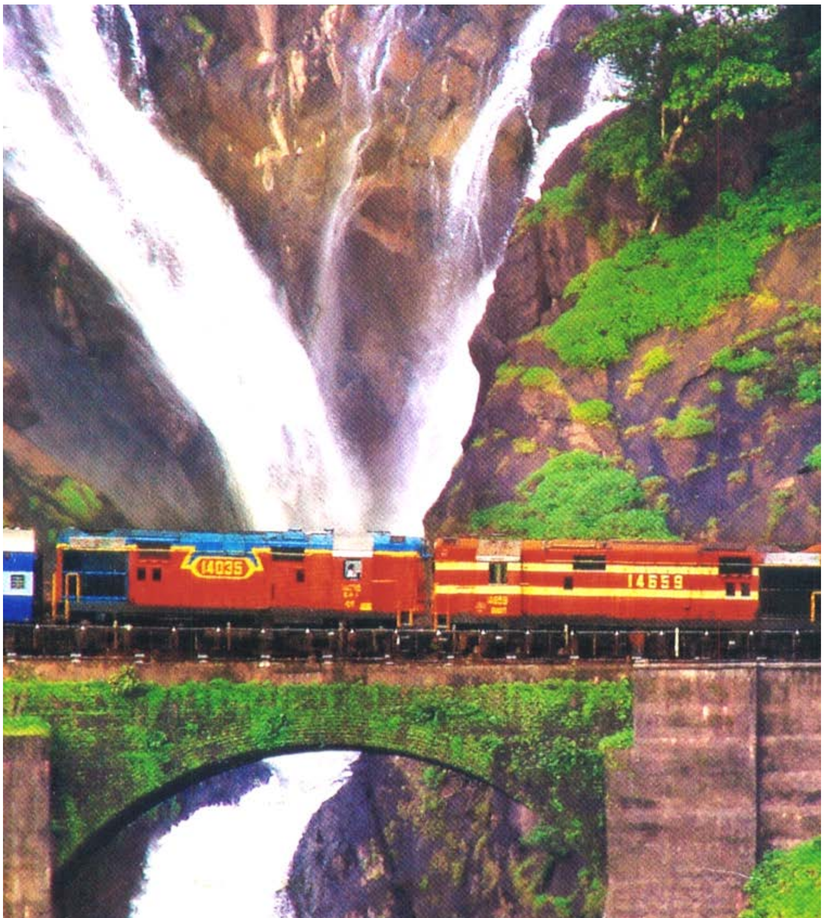
Pict. 1: Replica of G. Stephenson build *"Locomotion"* from 1925
National Railway Museum, York, UK



Pict.2: Flow Diagram of a **C0`C0`** Diesel-electric Locomotive

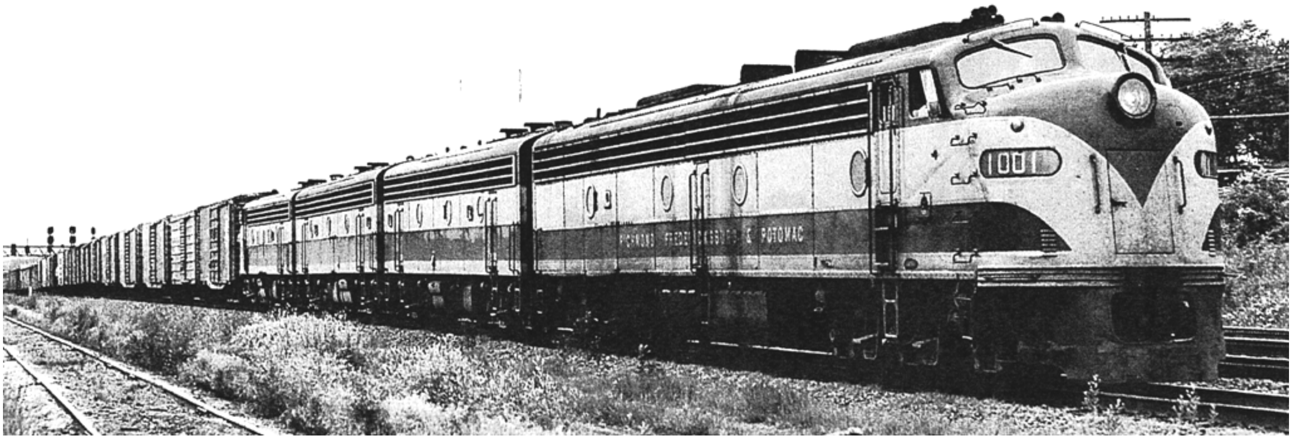


Pict. 3: Pinion Gear Transmission of Diesel-electric and electric Locomotives



Pict. 4: Indian WDP-2 Diesel-electric Locomotive**s**
based on ALCO Technology, Breganza Incline, Goa

Pict. 5: GM-EDM F3 A-B-B-A Unites



Pict. 6: GM-EDM F3 A-B-B-A Unites

Pict.: 7: Union Pacific2`D`D`2`"*BIG BOY"* **, USA**

Pict. 8: Multi Traction; Fraser Canyon, Canada

Pict. 9: Multi Traction with four GE Dash, Canada

Pict 10: **Triple** Traction with G**M EMD, D0`D0`, DDA40X,** USA **; together with over 20.000 hp; August 1975 at Cajon Pass**

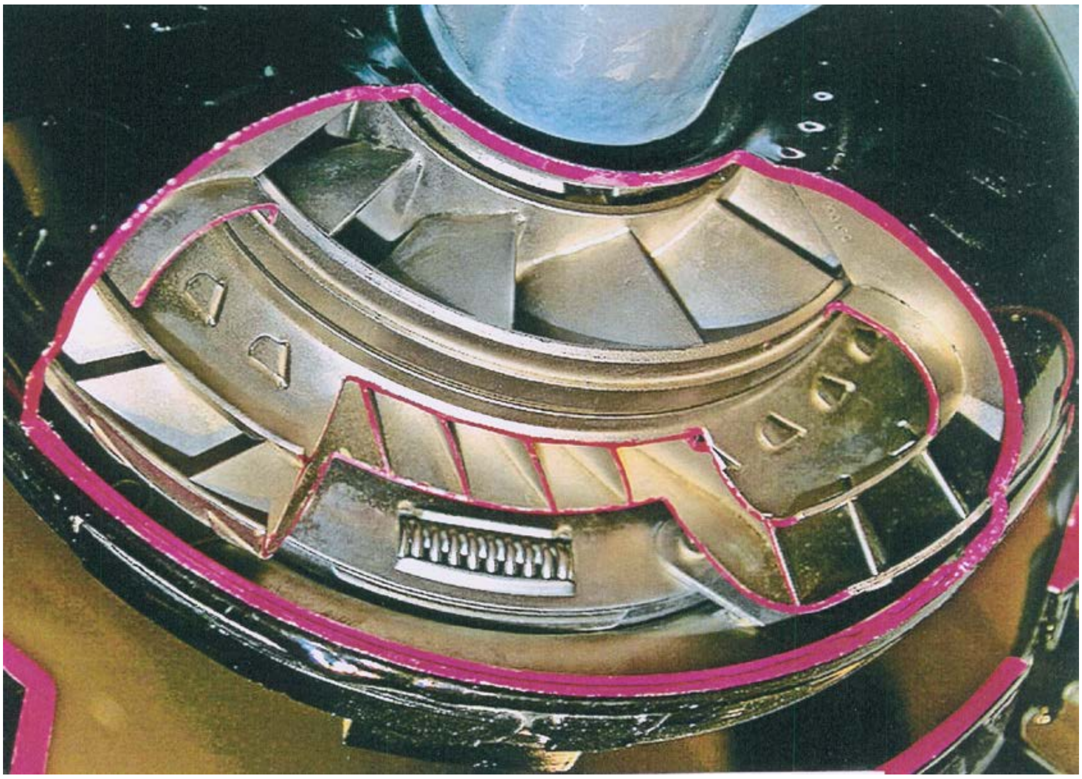
Pict. 11: Multi Traction with 6 GM EMD C41-8W; USA

Pict. 12: GE 8500 hp Gas-Turbine ***"SUPER TURBINE"*** Locomotive 1962

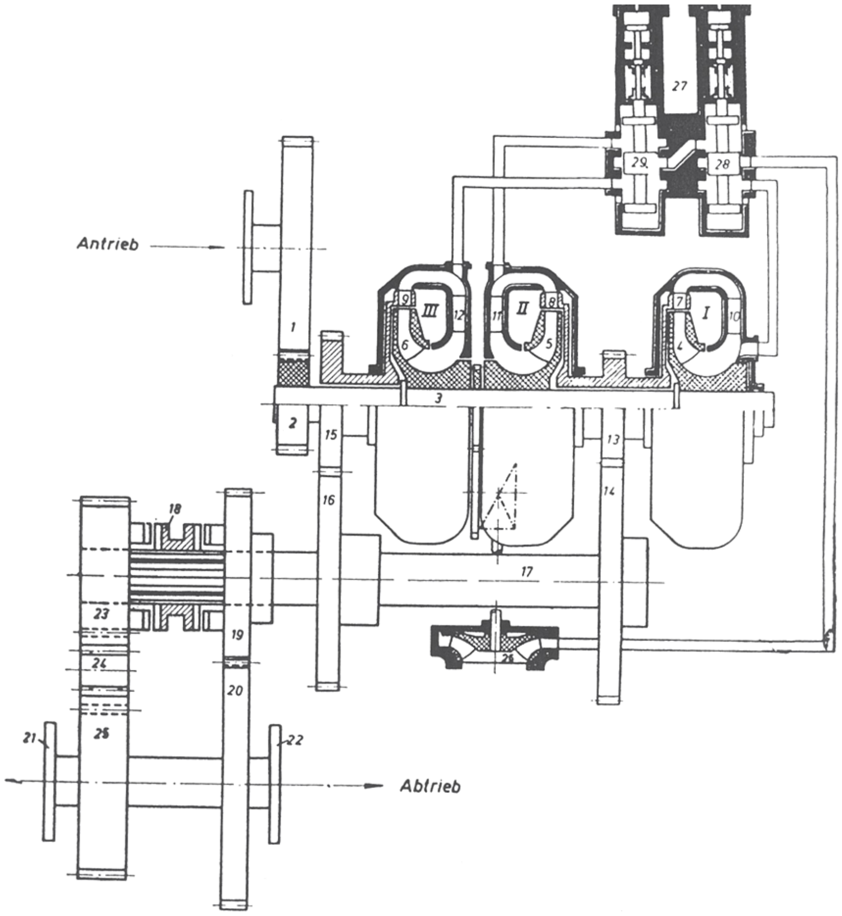
Pict. 13: Sri Lanka Railways ClassM2C, No. 626 “Montreal” with Dynamic Retarder Brake

Pict. 14: GM EDM Multi Purpose Diesel-electric Locomotive **GP 9**, the Father of one of the most successfully Export LGM Locomotives

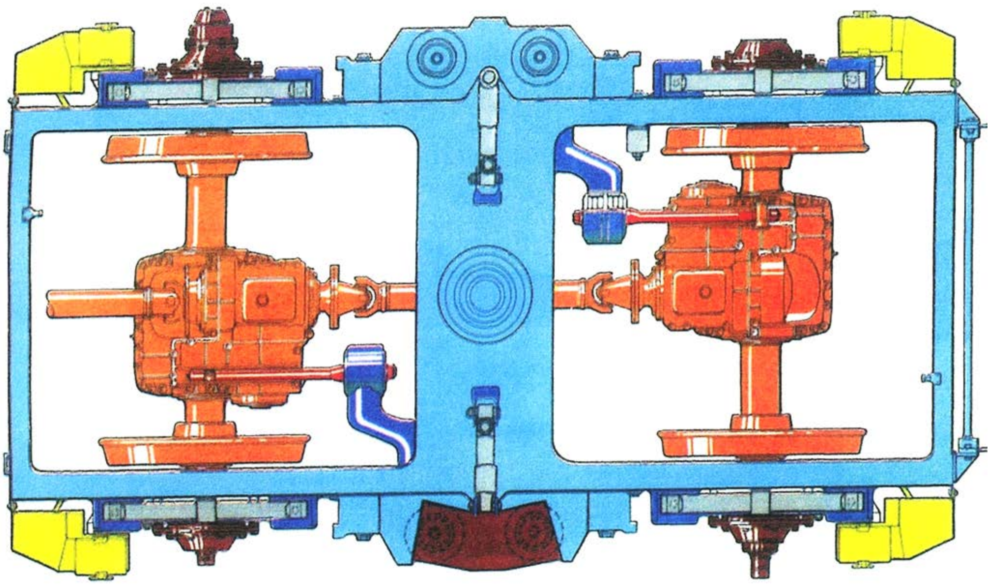
Pict. 15: EMD Export Locomotive in Argentina



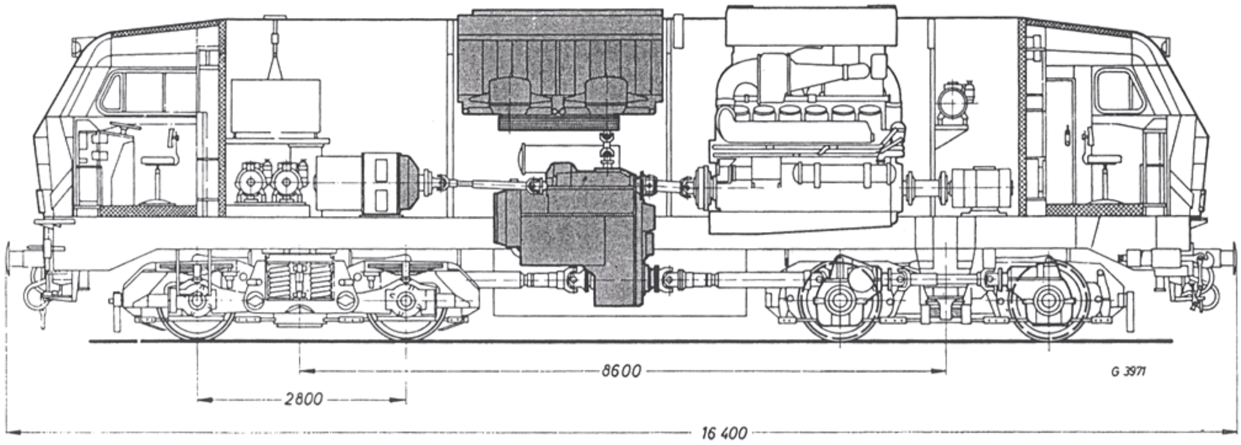
Pict. 16**a**: Hydrodynamic Torque Converter for Diesel-hydraulic Locomotives



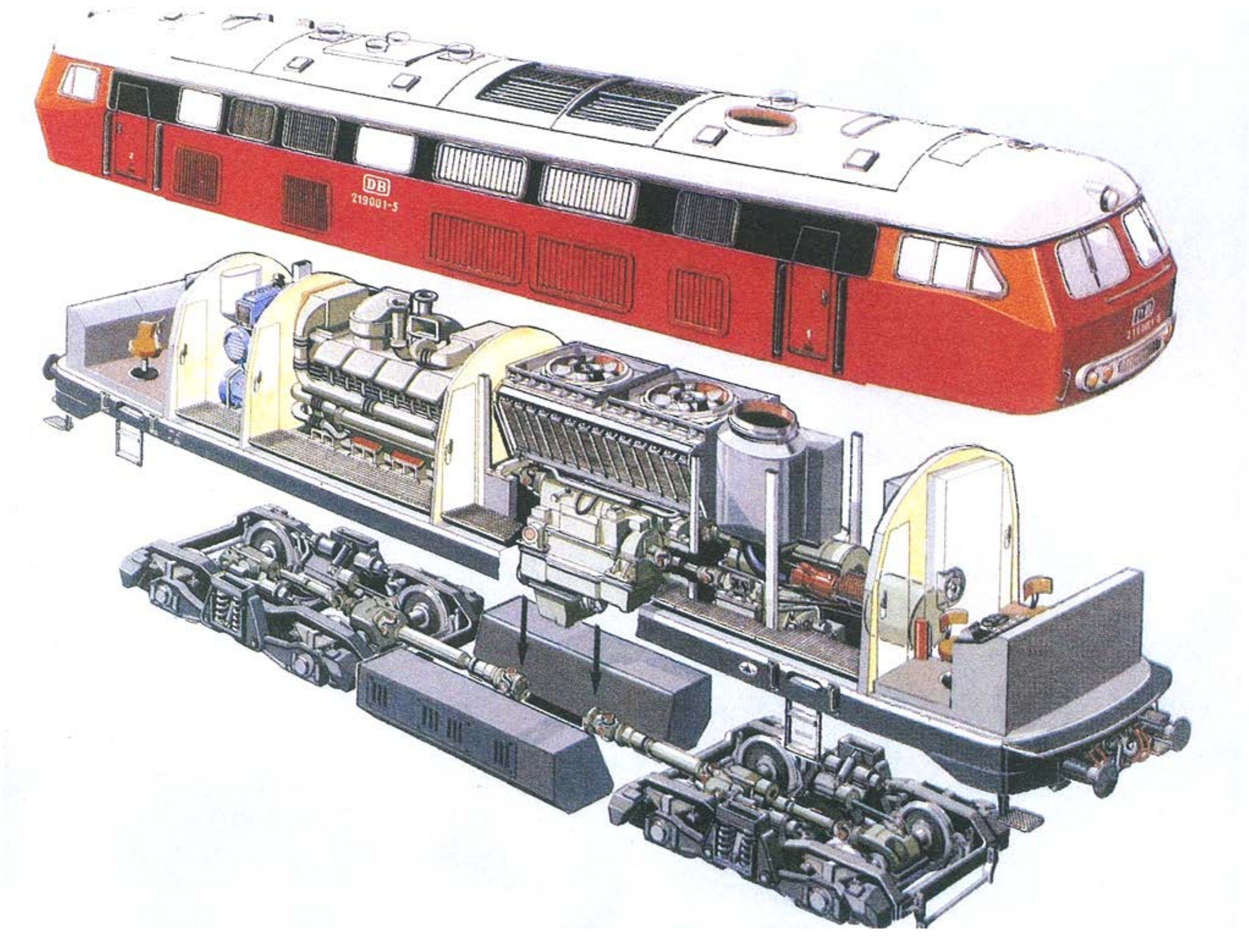
Pict. 16**b**: Flow Scheme of Voith Hydro-dynamic Torque-Converter Transmission



Pict. 17: Computer Animation of Traction Bogie for Diesel-hydraulic Locomotives with Cardan-Shaft and Pinion-Gears



Pict. 18: Flow Diagram of German Multi Purpose Diesel-hydraulic**, 2000 hps** Locomotive DB 218/219



Pict. 19: Schematic Presentation of German Multi Purpose Diesel-hydraulic**, 2000 hps** Locomotive DB 218/219

Pict. 20: Northern No. 611, build 1941 by ALCO, Norfolk Western,
on nostalgic Steam-Excursion Trip, 1998, in Virginia, USA,
now resting in Virginia Museum of Transportation, Ronake, VA, USA

Pict. 21: 3ft Gauge ***"DURANGO SILVERTON"*** Scenic Railway (Denver & Rio Grande Western), Rocky Mountains, Colerado, USA

Pict. 22**a**: 1`D1`Mikado 3 ft Steam Locomotive, ***"DURANGO SILVERTON"*** Scenic Railway

Pict. 2**2b**: *“CUMBRES & TOLTEC”* Scenic Rail Road (Denver & Rio Grande Western) Colorado/New Mexico, Rocky Mountains, USA

Pict. 22**c**: *“Nevada Nothern Railway”*, East-Ely, USA

Pict. 22d: **GM F7 A Unit on** Scenic Railroad through *"ROYAL GORGE"* (Denver & Rio Grande Western) Arkansas River, Colorado, USA

Pict. 22e: **View into the** *"ROYAL GORGE"* (Denver & Rio Grande Western) Arkansas River, Colorado, USA

Pict. 23: 180 kmph BR 18 201 German Steam Locomotive; worldwide the fastest Steam Locomotive presently in running Condition

Pict. 24: ***"VICEROY SPECIAL"*** leaving Maradana Station, Sri Lanka, with Class B1D, No. 340 ***"Frederick North"*** and B2B, No. 213; 19th Nov. 1999

Pict. 25: Sri Lanka Railways Class B2B, No 213 with *"VICERY SPECIAL"* passing "Lions Head" on Balana Incline, Nov. 1999

Pict. 26: Sri Lanka: *"VICEROY SPECIAL"* at Rozella Curvature, old 20 Degree Alignment, Class B1D , No 340 "Frederick North"

Pict. 27: 1 in 87 Scale Model of Class B1A, No. 251 *"Sir Thomas Maitland"* in old Livery

Pict. 28: Steam on Glenfinnan 12 Arch Bridge, Scottland

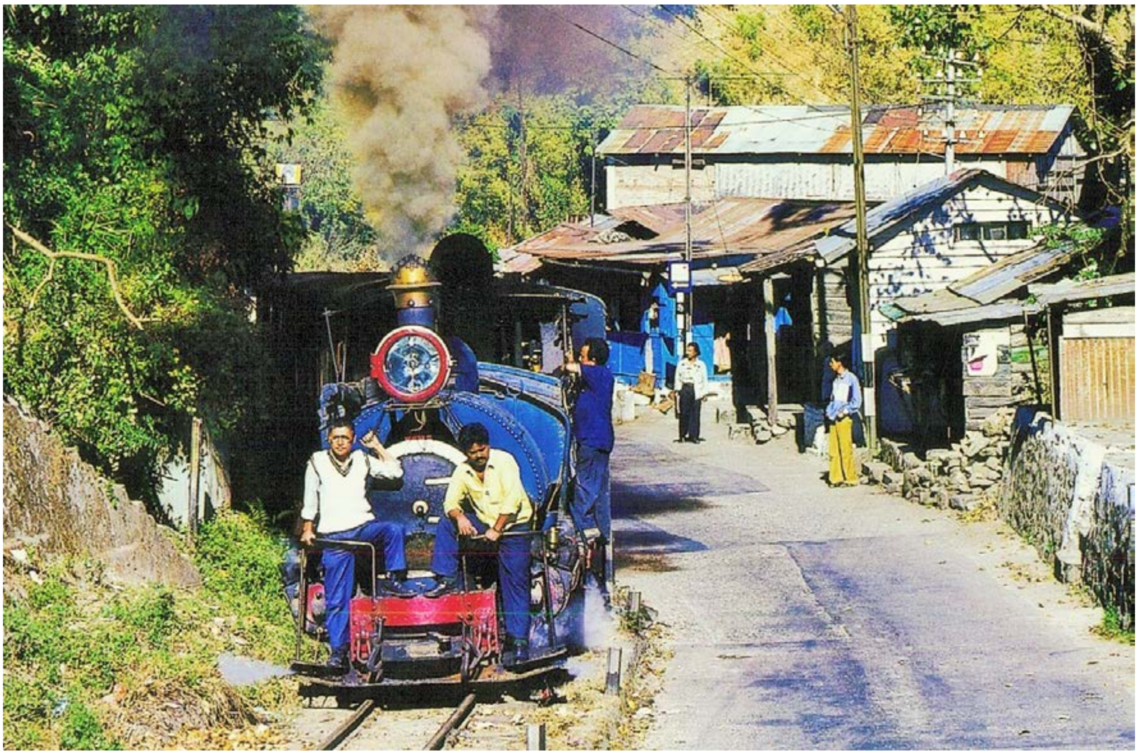
Pict. 2**9**: Rebuild Pinion 1`C Steam Locomotive on rebuild scenic *“FURKA PASS”* Railway, Switzerland

Pict. 30: Rebuild Pinion (System Abt) Steam Railway *"FURKA PASS"* near Glacier du Rhone, Switzerland

Pict. 31: Pinion (System Abt) *"NILGIRI MOUNTAIN RAILWAY"*, Tamilnadu, India

Pict: 32: Pinion (System Abt) *"NILGIRI MOUNTAIN RAILWAY"*, Tamilnadu, India

Pict. 33: Steam on Kalka-Schimla Railway**, 2009**, Himachal Pradesh, India



Pict. 34*: “DARJEELING HIMALAYAN RAILWAY”;* on 2 ft Gauge along the old Cart Road; India

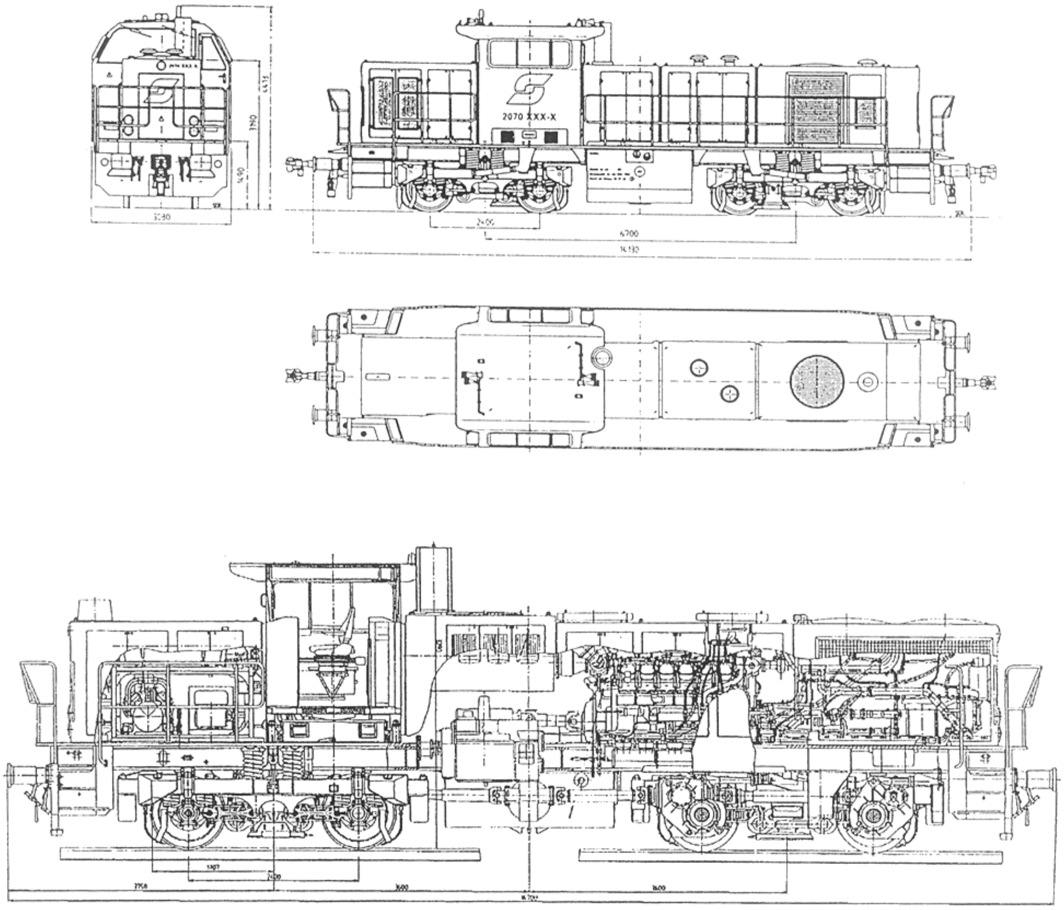
Pict. 36: Oerenstein & Koppel, Berlin, build Steam Locomotive for *“Matheran Light Railway”*, Maharastra, India; with self-steering Axles for tight 70 Degree Curves, refurbished 2012

Pict. 36a: Steam on “SETTLE CARLISE“ scenic Railway, UK; 24 Arch Ribble Head Viaduct

Pict. 36b: Sri Lanka Railways 2 ½ ft Narrow Gauge Sentinel Steam Rail Car, refurbished 1999

Pict. 37: Henschel tailor build A1A`A1A`1650 hps, 87 t Diesel-electric Locomotive for Sri Lanka Railways with GM EMD Technology, Class M4, 1979, with idling Axles, Wheel-Base: 2.80 m

Pict. **38**: Henschel 1968 build B`B`Diesel-hydraulic Locomotive Class W1, later refurbished as Class W3; a track-friendly advisable 61 t Locomotive for Sri Lanka Railways to negotiade tight Curvatures



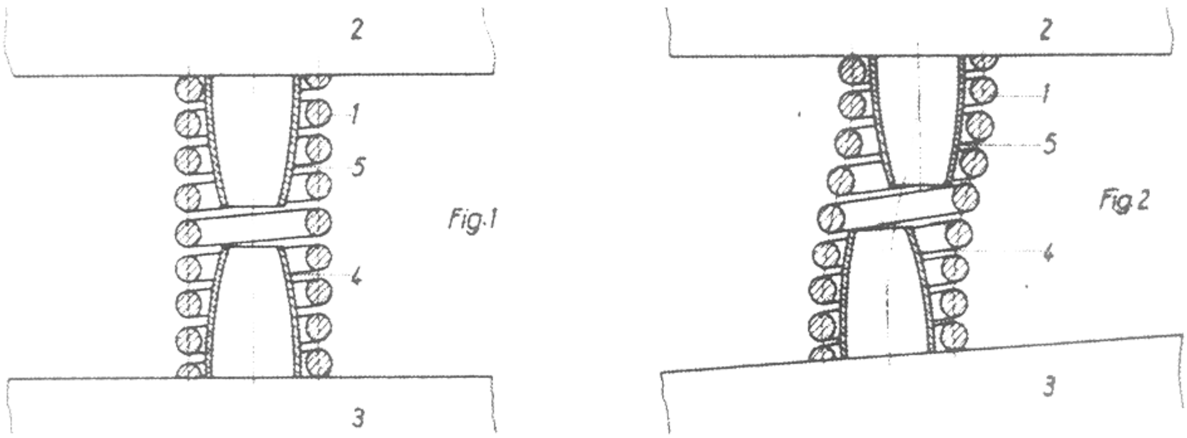
Pict. 39: Scheme for MAK Diesel-hydraulic B`B`Locomotives in Power Range from 1500 to 2400 hp with Caterpillar or MTU Engines, based on the Henschel-ThyssenKrupp Locomotive DHG 1200 for Sri Lanka Railways

Pict. 40: MAK/Vossloh Diesel-hydraulic B`B` Locomotive G 1208; an advisable Locomotive for Sri Lanka Railways

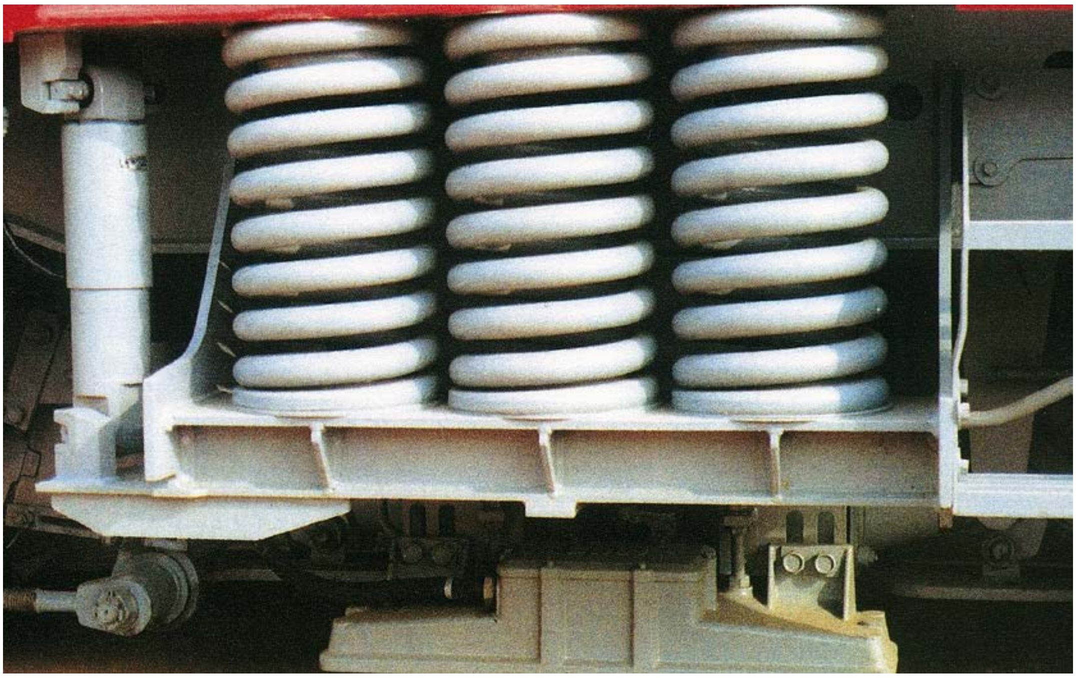
Pict. 41: Advisable B`B`Diesel-hydraulic Locomotive Types based on MAK/Vossloh Am 843/G1000-1700/1208-Series, derived from the Henschel/ThyssenKrupp designed DHG 1200 for Sri Lanka Railways

Pict. 42: VOITH-TURBO build B`B`Diesel-hydraulic Multi-Purpose Locomotive, "GRAVITA FAMILY" in the Power Range from 1360 to 2400 hps; advisable for Sri Lanka Railways

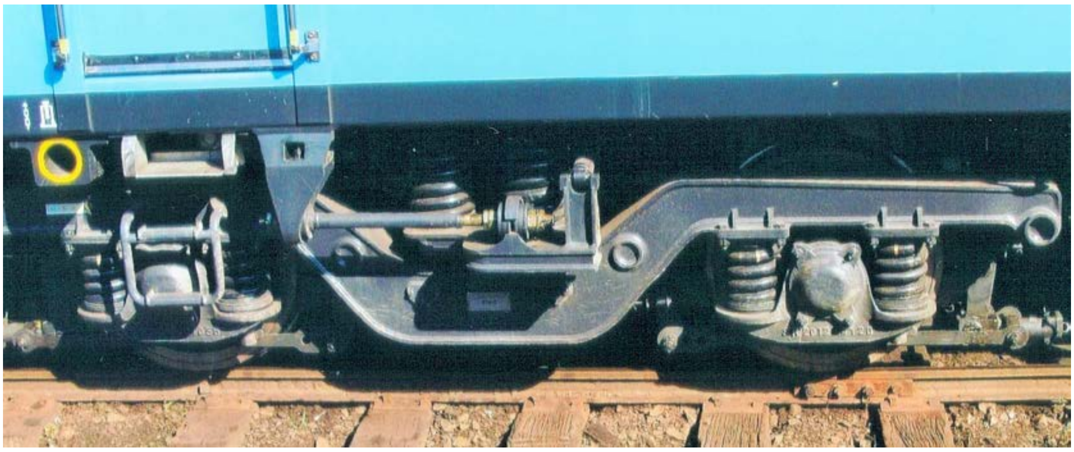
Pict. 43: GM-EMD on GP9/12 Platform build Diesel-electric Export Locomotive, refurbished in Croatia **called *"THE KENNEDY"***



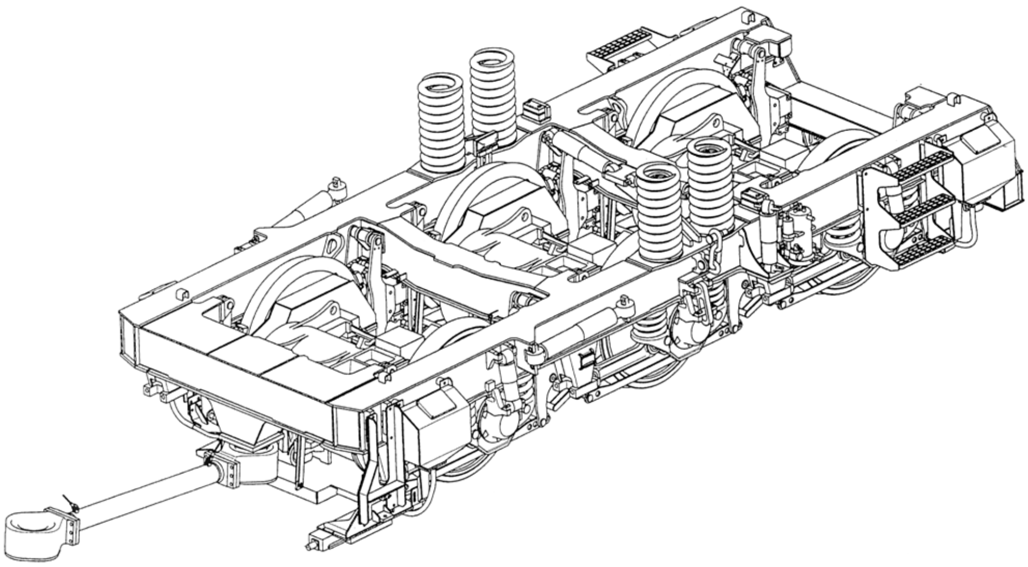
Pict. 44: Illustration of the Working Principle of the Henschel “FLEXI-COIL” secondary Suspension in straight and radially deformed Position



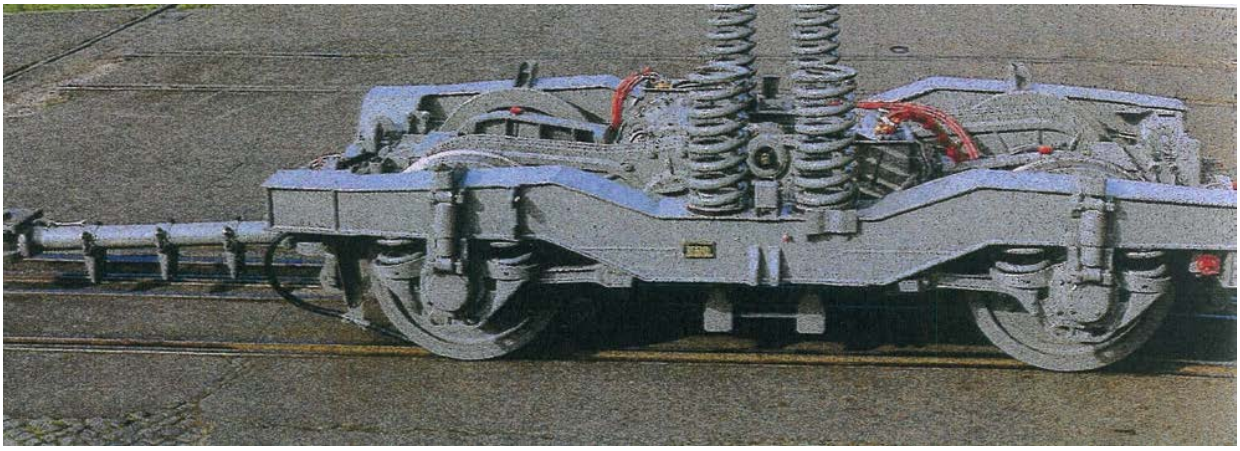
Pict. 45: Flexi-Coil Suspension of heavy Locomotive



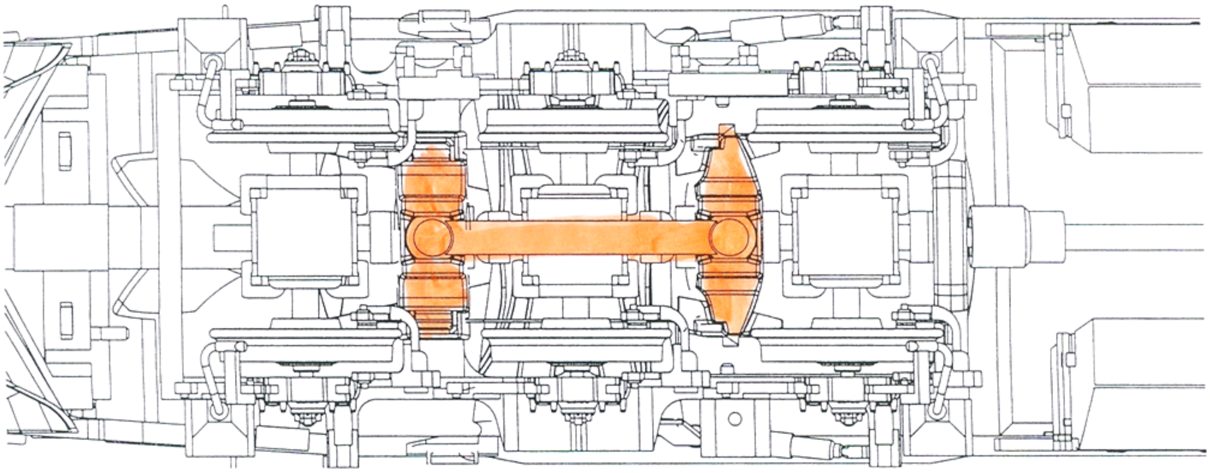
Pict. 46: Flexi-Coil secondary Suspension of China build S 12 DMU; Sri Lanka Railways



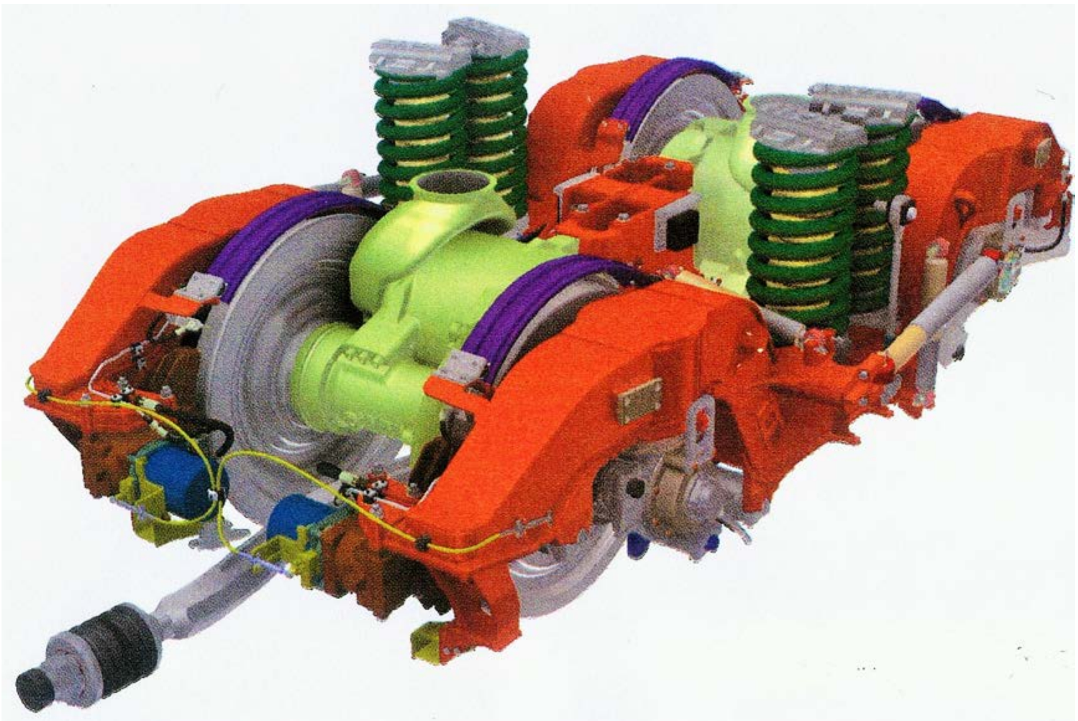
Pict. 47**a**: Illustration of Pivot-less Henschel *"FLEXI-FLOAT"* Bogie with *"Flexi-Coils"* and Push-Pull-Bar



Pict. 47b: Pivot-less Henschel *"FLEXI-FLOAT"* B0`B0` Bogie with *"Flexi-Coils"* and Push-Pull-Bar; similar Bogie is in use for the Indian WAP-5 Locomotive

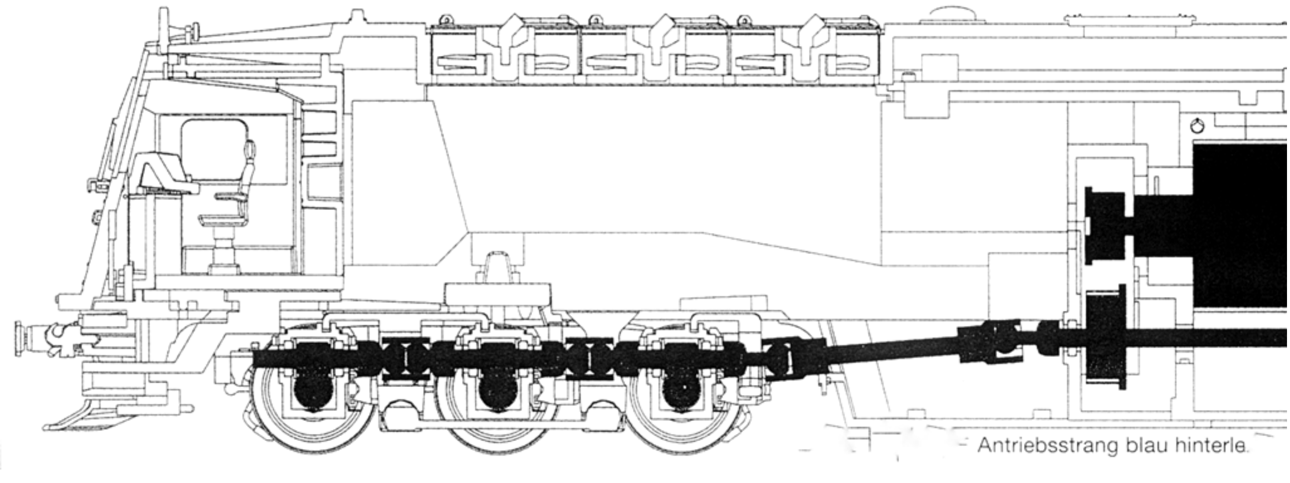


Pict. 48: **Scheme of** Voith Cardan**-**Shaft C0`C0`Bogie with in-build Push-Pull-Stool **(marked in Amber)** for Diesel-hy**d**raulic Locomotive *"MAXIMA"*; see Pict. 50



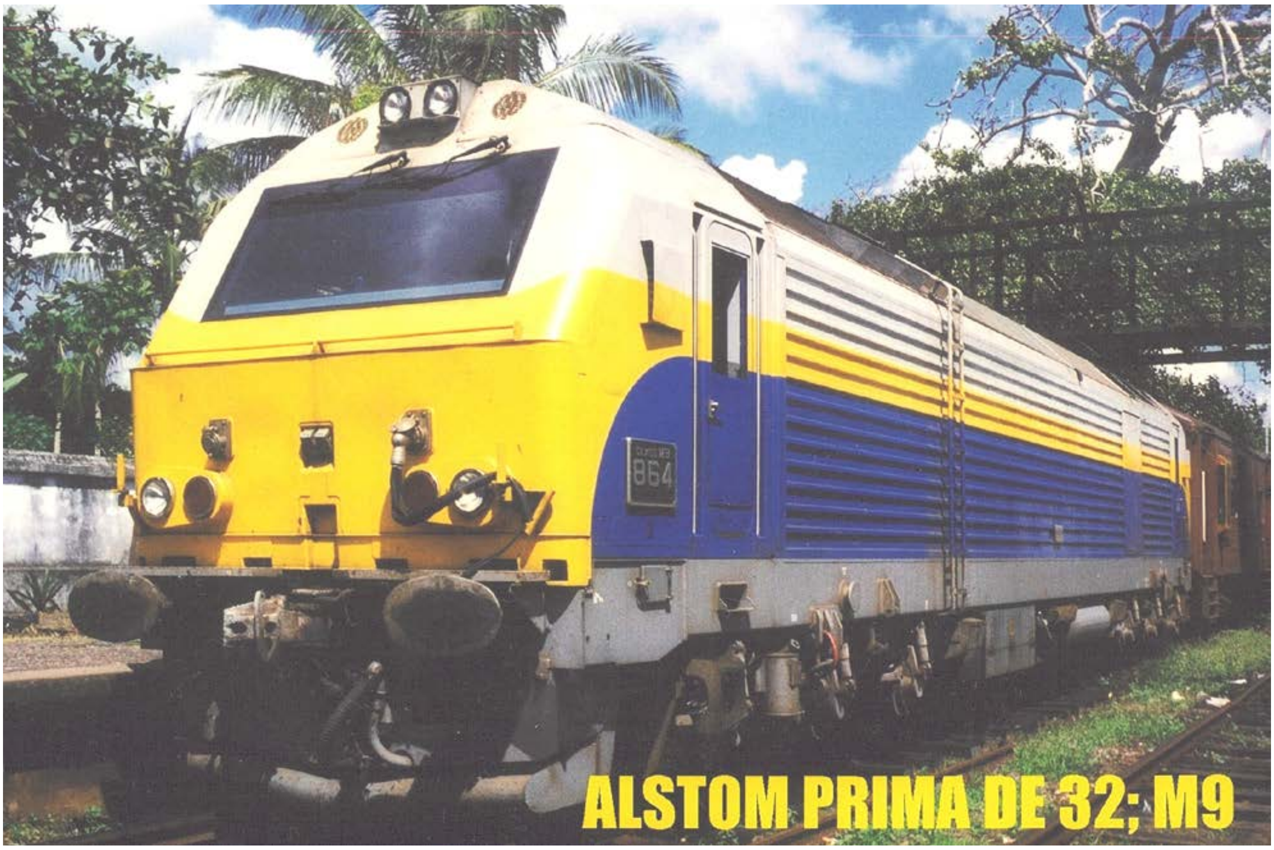
Pict. 49: GEMEINDER build B0` electric Traction Bogie with Push-Pull-Bar for a 2000 hp, 65 t Metre Gauge Swiss Mountain Locomotive; 2104

Pict. 50: VOITH-TURBO C`C`Diesel-hydraulic Locomotive *"MAXIMA"* in the Power Range from 4000 to 5000 hp; the most powerful Diesel-hydraulic Locomotive in the World



Pict. 51: Illustraion of the Traction-Shaft of "*MAXIMA*"

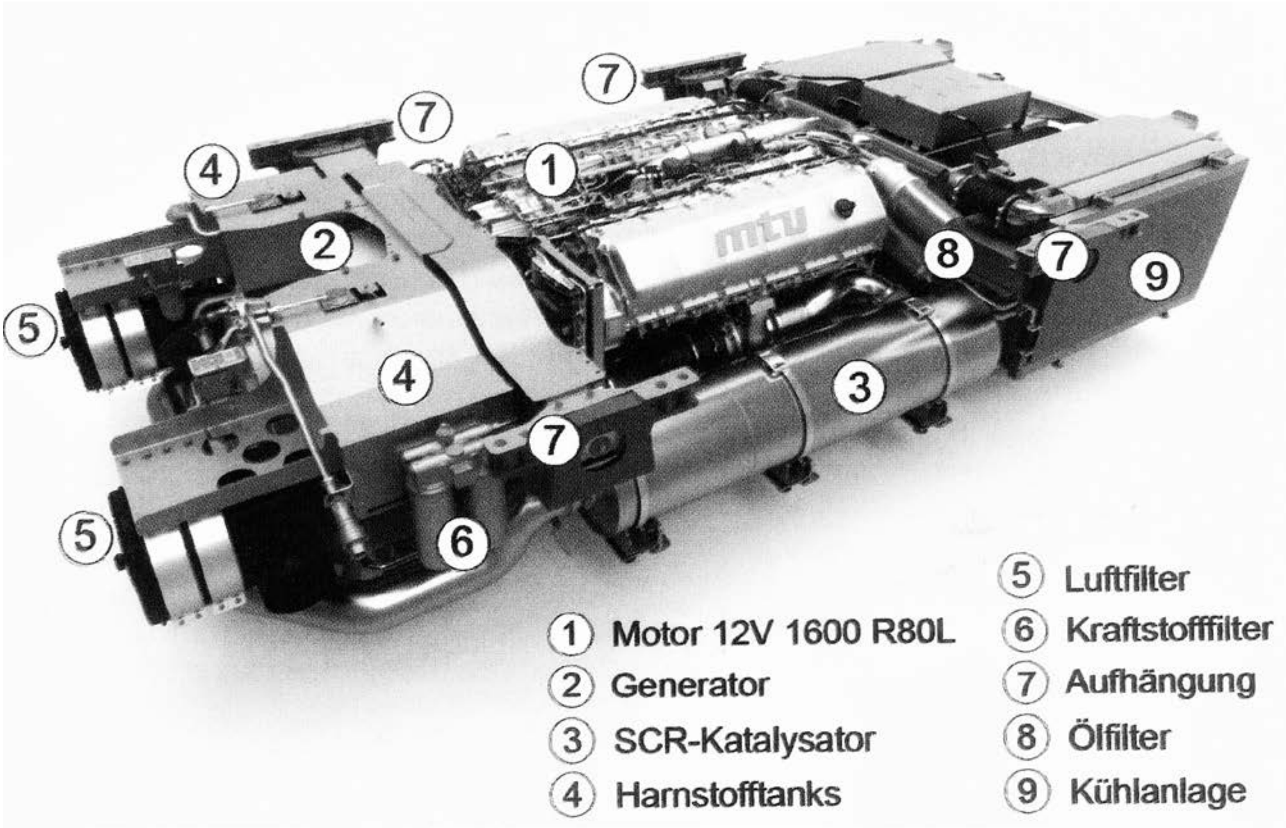
Pict. 52: VOSSLOH 333.3/**"EURO 4000"** Diesel-electric C0`C0` Locomotive with EMD Engine and SIEMENS Traction Technology



Pict. 53: ALSTOM build Diesel-electric C0`C0`*"PRIMA DE 32"* , primarily designed and build for **in Standard Gauge for** Syria and **later** adjusted for Broad-Gauge **for** Sri Lanka **Railways**, Class M9**. The livery is a Modification of the Syrian Livery with Red altered for *"SAREE-BLUE"*; see Pict. 54**

Pict. 54a: Left “Syrian“ Standard Gauge Design**;** right Sri Lanka Broad Gauge Modification
on Broad-Gauge Rolling-Stools

Pict. 54b: VOSSLOH 2400 hp B0`B0` “EURO LIGHT” Diesel-electric Locomotive for Axle-Load $\leq$ 20 t from Valencia-Workshop, former Alstom owned



Pict. 55: MTU 900 hp “POWER-PACK“ for Rail-Cars and Locomotives; with 12 Cylinder V Engine, Generator/Alternator, Cooling System and Exhaust Cleaning with Urea

Pict. 56: Animation of Bombardier *“TRAX”* Diesel-electric Multi-Engine Locomotive **with 4 Caterpillar Power-Packs instead of one Engine**