

Furrer + Frey's converted diesel locomotive Gmf 4/4 90

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Introduction

The Bern-based company Furrer + Frey AG (F+F) has been planning and building overhead contact line installations for standard- and narrow-gauge railways, mountain railways, trams and trolley buses in Switzerland and other countries for more than 90 years. The family-owned business, now in the third and fourth generation, is run by Beat und Rico Furrer, and has about 220 employees, some 80 or so of whom are installation engineers. In addition to overhead catenaries, F+F has also been successfully installing overhead conductor rail systems for 25 years. These offer utmost reliability under restricted clearance conditions where space is at a premium. There is also a swivel version available for use in maintenance facilities or on bridges. Overhead conductor rail power supply today can be used at speeds of over 200 km/h. There are more than 500 systems installed to date in service in 15 countries. A measurement container developed in-house also enables the height and lateral position of contact wires and the contact force on the pantograph contact strips to be measured in order to verify correct and complete installation.

Starting situation and task setting

About 17 years ago, Furrer + Frey acquired two two-axle, diesel hydraulic locomotives Tm 50 and 75, delivering a rated output of about 130 kW at the shaft. Originally built in 1968 by Gmeinder for the Munich U-Bahn (metro), their gauge was modified from 1435 to 1000 mm at the time of the acquisition. These two diesel locomotives were pur-

chased in 1997/1998 for carrying out work on the overhead line during construction of the Vereina tunnel on the Swiss Rhaetian Railway (Rhätische Bahn, RhB). Today, F+F also deploys a number of Holder road-rail vehicles as small tractor units at work sites on meter-gauge lines as well as various self-propelled road-rail vehicles with work platforms, some equipped additionally with a crane, and two powered trolley ladders. F+F's meter-gauge traction unit fleet today comprises a total of 14 company-owned rail vehicles.

Over the next few years, the renovation and safety-enhancing measures due to be implemented for several tunnels on Swiss meter-gauge railways will lead to a general increase in demand for metre-gauge thermally-powered service traction units. In view of the renovation and new construction of catenaries that these measures will entail, F+F therefore decided in autumn 2013 to procure a more powerful class Gmf 4/4 diesel locomotive. Extensive market research revealed that within the required period of less than one year, the only cost-effective and viable solution would be to purchase a second-hand engine and convert it to meet F+F's needs.

In autumn 2013, Tecsol GmbH in Anger (Steiermark / Styria, Austria) was able to offer a modified four-axle diesel locomotive of Romanian origin that fulfilled the basic requirements and was available at short notice. The L45H locomotive, factory number 20867, dating from 1969 is one of a total 334 engines of this type manufactured by Faur in Bucharest. In 2014 it underwent a major overhaul in Krieglach (Steiermark), was fitted with a new engine and converted from Bosnian

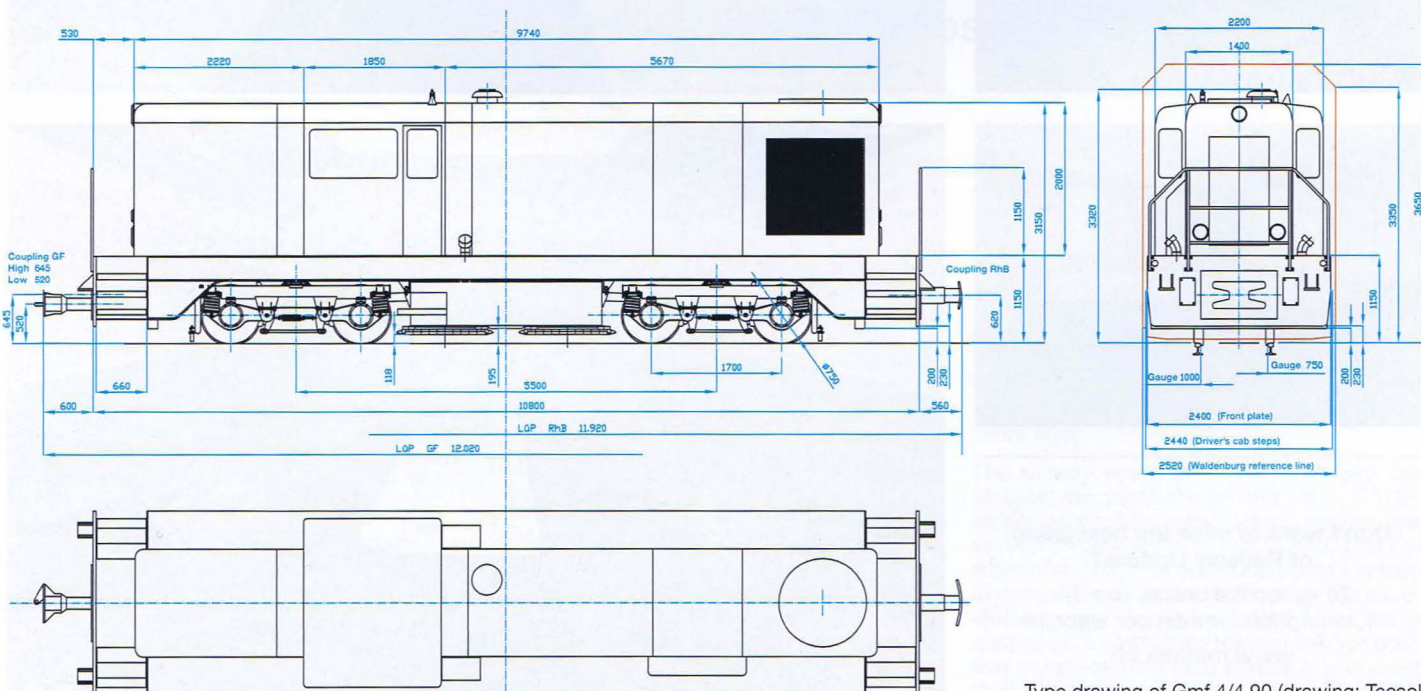
(760 mm) to metre gauge. The frame, the front-end installations, the central driver's cab, the distribution gear and the two cardan-drive bogies were retained from the original locomotive. The other components were installed new, including the diesel engine with particle filter and generators, cooling system with cooler fan, oil and water pumps, auxiliary diesel engine / generator group with particle filter, diesel oil tank, on-board converter, compressor, vacuum pump, compressed air rack, electro-magnetic rail brakes, and vehicle control system.

Mechanical section

The chassis is a welded structure consisting of rolled profiles, folded sections and metal sheets. The frame is made up of two outer and two inner longitudinal beams, several diagonally and transversely arranged reinforcing beams as well as two box-shaped end platform attachments at the front and rear. It was reinforced and designed for a longitudinal compressive strength of 800 kN. The central driver's cab is mounted on the frame between a long front section and a short rear section.

To allow deployment on various metre-gauge railways, four different types of Swiss-manufactured combined draw and buffing gear can be fitted optionally:

- Zp1, 500/750 mm above top of rail (TOR), for deployments including the Montreux – Berner Oberland-Bahn (MOB);
- Zp2, 620 mm above TOR, for deployments including the Matterhorn – Gotthard-Bahn (MGB) and Rhätische Bahn (RhB);



Type drawing of Gmf 4/4 90 (drawing: Tecsol)

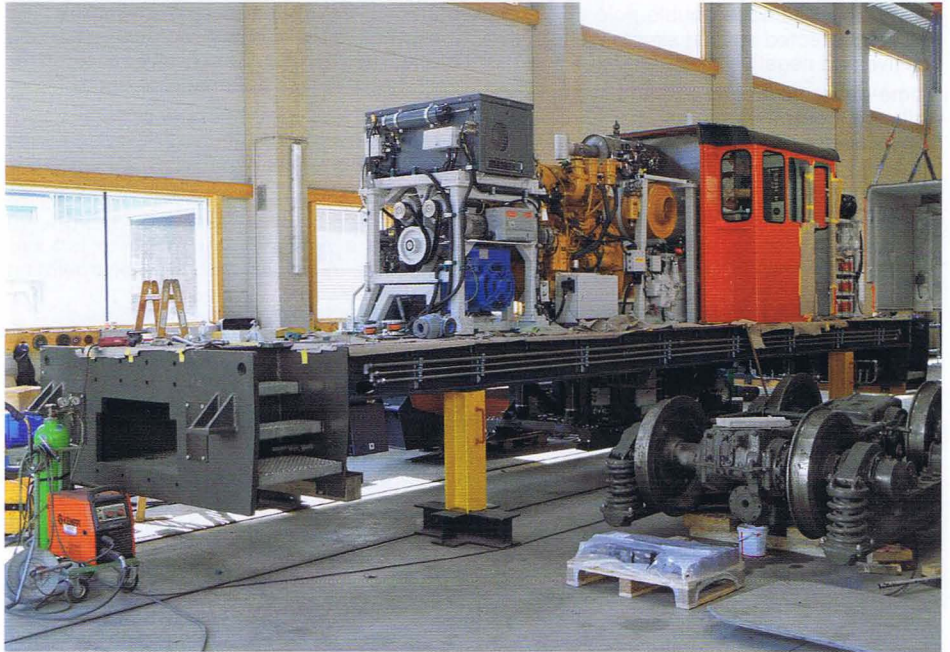
Above: Starting point for the conversion was an L45H locomotive built for the Bosnian 760 mm narrow gauge like the L45H-091 seen here on the CFI company site in Criscior/Rumania (photo: J. Blaser, 12 November 2013).

Centre: Gmf 4/4 90 during conversion on 24 July 2014 in the works hall in Krieglach (photo: P. Gerber).



- GFN "high", 620/650 mm above TOR, for deployments including the Bière – Apples – Morges-Bahn (MBC-BAM), Berner Oberland-Bahnen (BOB), and on the MGB and
- GFN "low", 500 mm above TOR, for deployments including Bern – Solothurn (RBS) regional transport and on Aare – Seeland mobil (ASm).

These are mounted as modules on bolt-on adapter change plates, and can be exchanged easily using a crane or fork-lift truck. The diesel engine torque for each bogie is transmitted via a cardan shaft to the similarly cardan-coupled wheelsets in the bogies via a hydraulic turbo transmission (selectable running direction and wearfree brake). This is supported in the frame, with the secondary transmission (with selectable mainline or shunting operation) installed underneath. Thanks to separate converters for each direction of travel, the turbo transmission facilitates wear-free braking, allowing the locomotive to negotiate steep inclines (steep gradient capability). Each bogie has two brake cylinders acting on the brake blocks arranged one on side of each wheel. A spring-loaded brake cylinder on each bogie acts as parking braking.

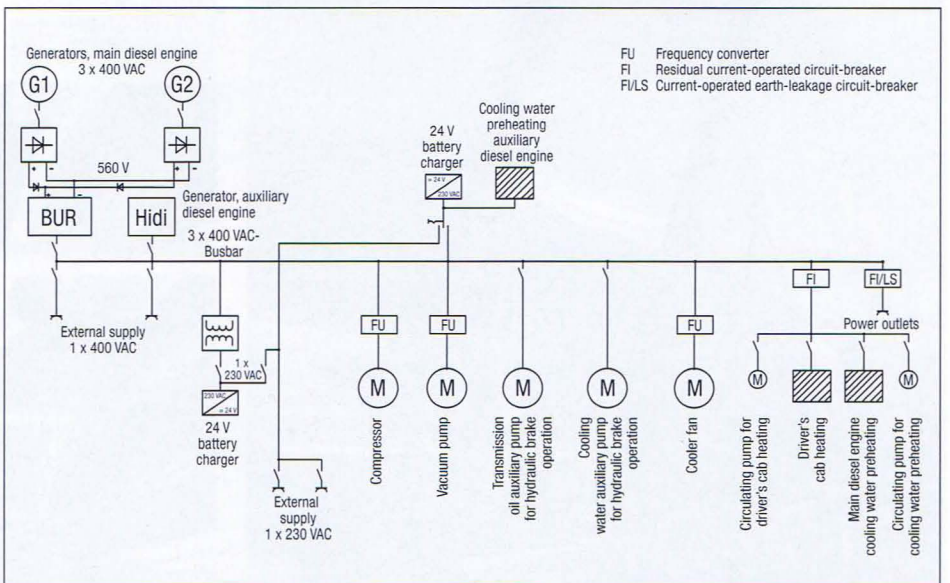


Thermal section

The locomotive is equipped with a frame-mounted Caterpillar C18 six-cylinder main diesel engine, delivering 500 kW of power to the shaft, and with a diesel particle filter system. An auxiliary diesel engine generator set with 50 kVA power rating equipped with particle filter is also installed. This ensures the 3 x 400 V AC power supply even when the main diesel engine is shut down, enabling significant fuel savings to be made on downhill deployments. The locomotive complies with the regulations in force in Switzerland relating to health protection at underground construction sites. This means that the locomotive also meets the requirements for use in all railway tunnels.

Electrical section

The locomotive has a 24 V DC control current system and a supplementary 12 V battery for the auxiliary diesel engine. In addition, a DC/DC converter generates a 110 V supply from the 24 V network for controlling the compressor. Due to lack of space, two smaller generators driven by V-belt from the main diesel engine feed the intermediate circuit of the on-board system converter directly via a rectifier bridge. The converter generates a 3 x 400 V AC on-board supply at its output. The compressor, vacuum pump and cooler fan are each operated with variable frequency



The 3 x 400 V power circuits of the diesel locomotive (drawing: Tecsol).

by a separate frequency converter. The on-board system provides a power supply at a constant frequency of 50 Hz for the two supplementary oil and supplementary cooling water pumps for hydraulic brake operation, the cooling water preheating for the main diesel engine, and the supplementary heating for the driver's cab. It also supplies the two circulating pumps for the main diesel engine cooling water preheating, as well as the circulating pump for the driver's cab heating. Alternatively, the 3 x 400 V on-board system is fed from the auxiliary diesel engine or via the stationary external feed connectors. The 24 V battery is charged either from the generator of the main diesel engine, from the 3 x 400 V busbar via a 400 V / 230 V transformer, or with 230 V AC via the single-phase external feed. The 12 V battery is charged from the generator of the auxiliary diesel engine or via the 230-V external feed. Since the auxiliary diesel engine has a 12 V starter, the locomotive can also be restarted with a jump lead from any car if its batteries are flat. The locomotive is equipped with a Selectron vehicle controller CPU type 831 and a bus architecture based on CAN-open, Ethernet, J1979 and RS485 interfaces. All safety-relevant circuits have double pole operation and are protected against simple faults in the positive and negative path.

A time-dependent safety control system with vigilance control monitors the locomotive driver's alertness. Cameras are installed at the front and rear for better observation of the track, and transmit the images to a monitor on each driver's desk in the cab.

The built-in remote control system "LocControl 100" allows the driver to operate the loco-

motive from outside the cab. Two roof-mounted yellow lights flash when remote control mode is activated. Before the locomotive starts moving, reversing alarms on both sides in the track axis sound three short notes to warn people in the track area. Blue lights on the roof also indicate faults or urgent measures to be taken by the locomotive driver before starting.

Pneumatic equipment and brakes

The locomotive itself has compressed air brakes, but it can haul rolling stock equipped with either vacuum or compressed air braking. By means of a pilot valve, the locomotive's air brake also acts as an automatic brake under vacuum control from the main vacuum pipe.

The locomotive has shoe brakes with two brake cylinders on each bogie and a Samson brake block with 3% phosphorous content per wheel. These are activated via the automatic air brake (optionally with 5 or 4 bar control pressure), via the electrically controlled direct brake (shunting brake), via the vacuum brake with a control pressure of -52 cm Hg, or via the spring-loaded parking brake. Two spring-loaded cylinders are integrated in the two end sections as parking brake. There is one control valve provided for each bogie for the automatic air brake.

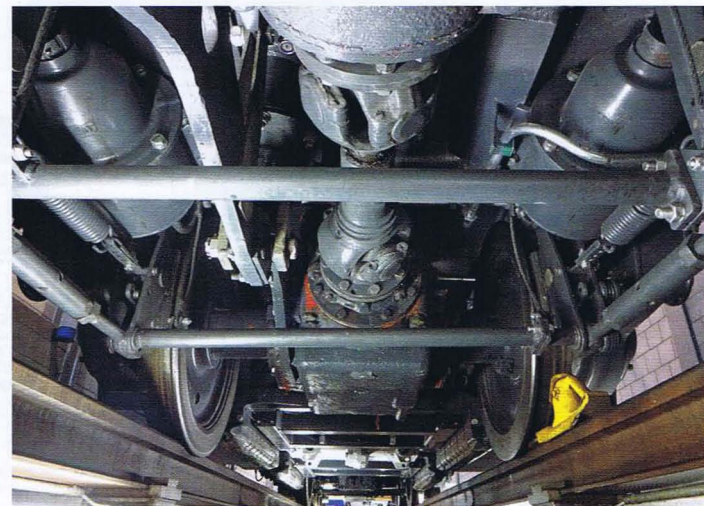
Additional vehicle braking is provided by a wear-free hydraulic retarder brake which gives it its steep gradient capability.

The implementation provisions of the Swiss Railway Regulations (Eisenbahnverordnung) mandate a safety brake which is not dependent on rail/wheel friction when operating



Left: Transferring Gmf 4/4 90 from the railway wagon onto the low-loader semitrailer with two truck-mounted cranes in loading/unloading siding H25 at Brig station (photo: P. Gerber, 29 September 2014).

Below: View from the work pit of the underside of Gmf 4/4 90. The four electromagnetic rail brakes mounted on the main frame can be seen behind axle 2 (photo: P. Gerber, 1 October 2014).



Technical data

Axle arrangement	B' B'
Service weight	40 t
Maximum axle load	10 t
Drive	diesel-hydraulic
Main diesel engine rating at 2100 rpm; due to permissible turbo transmission output	520 kW
restricted to 1800 rpm	490 kW
Auxiliary diesel engine rating at 1500 rpm	50 kW
Starting tractive effort up to 10 km/h	90 kN
Maximum speed:	
Self-propelled/high gear	50 km/h
Self-propelled/low gear	22 km/h
Towed	55 km/h
Length over buffers	12 000 mm
Length over frame	2440 mm
Width over body	2200 mm
Height	3320 mm
Distance between pivots	5500 mm
Bogie wheelbase	1700 mm
Gauge	1000 mm
Wheel diameter, new	750 mm
Wheel diameter, worn	710 mm
Smallest negotiable curve radius	45 m
Fuel tank	970 litres

on lines with independent track beds and more than 60% incline (which includes the MOB, and RhB's Berninabahn).

Construction and commissioning

The project kicked off at the beginning of November 2013 with the delivery of a non-refurbished locomotive of type L45H by the Rumanian company CFI in Criscior and the partial reconditioning of mechanical components in Rumania. The major overhaul and conversion work started in the Tecsol plant in Krieglach at the beginning of 2014. An approximately 30-metre long metre-gauge track panel laid on the hall floor enabled initial start-up tests to be carried out.

The locomotive left Steiermark by rail at the end of September 2014, loaded on a former Swiss military tank transport wagon, for the journey via Wien Zentralverschiebehnhof -

Buchs SG to Brig. On 29 September 2014, it was transferred onto a low-loader semitrailer in loading/unloading siding H25 by means of two truck-mounted cranes for the short road transport to the Glisergrund workshop of the Matterhorn – Gotthard-Bahn (MGB). At Glisergrund, the low-loader semitrailer was lowered at one end to allow the locomotive to travel under its own power over a temporary track directly onto the rails of the MGB. This was followed by two intensive weeks of dynamic commissioning runs on the MGB network between Ackersand, Visp, Brig and Grenchols and on the Nättschen below the 2033-metre high Oberalppass station. These runs verified the fault-free functioning of the locomotive, and the necessary fine adjustments were made. Braking distance measurements and trial runs under load with 50 t hauled loads on the steep sections of the MGB (up to 70%) were also carried out successfully at the beginning of October.

On 10 October 2014, the Swiss Federal Office of Transport (BAV) verified the locomotive on a technical/operational safety test run between Brig and Ackersand. A few days after the successful approval by the BAV and after 2 days of driver training, the locomotive was transferred by road to Transports Publics du Chablais (TPC) in Aigle. It has been deployed here productively since 20 October 2014 for work on the contact line system of the line to Le Sépey (– Les Diablerets) with inclines of up to 60%.

Outlook

The locomotive was returned to MGB's Glisergrund depot workshop in Brig at the end of November 2014 to undergo follow-up work. Then, starting at the beginning of February 2015, the locomotive will be deployed for several months working on the Furka Base Tunnel on the MGB line between Oberwald und Realp.

Summary

In October 2014, Furrer + Frey, the Bern-based maker of overhead contact line systems successfully put into operation a four-axle diesel locomotive from Rumania with a shaft power rating of about 500 kW following conversion and a major overhaul. The Krieglach workshop of Tecsol GmbH in Steiermark (Austria) completed the work in less than ten months. The work involved converting the locomotive from the Bosnian gauge (760 mm) to metre-gauge and fitting a modern diesel engine. After successful dynamic commissioning at MGB, Gmf 4/4 90 has been ready since mid-October 2014 for deployment on metre-gauge adhesion railway networks in Switzerland.



Above: Load test of adhesion diesel locomotive Gmf 4/4 90 hauling the MGB 50 t rack motor car Deh 4/4 23 in 70% grade up from Nättschen to Oberalppass (photo: J. Blaser, 7 October 2014).

Centre: Vehicle gauge test between track and transmissions of loco Gmf 4/4 90 in 70% grade in the beginning of the rack and pinion track section near Ackersand (photo P. Gerber, 3 October 2014).

Below: First test ride on the TPC line Aigle – Le Sépey with 60% grades on 16 October 2014: loco Gmf 4/4 90, hauling the 25 t heavy historic EMU BDe 4/4 2, is passing EMU Be 4/4 404 in Exergillod (photo: Th. Stolz).