The electrohydraulic brake

The electrohydraulic brake corresponds to an architecture for which:

- Brake control is ensured in a purely electric way
- Actuation energy (providing brake force or ensuring brake release) is hydraulic

Thus there is no more pneumatic pipe, even, on most of vehicles using this type pf brake (essentially tramcars), no more compressed air production (some tramcars still being equipped with a small compressed air production for sanding and, eventually, for pneumatic secondary suspension).

The electrohydraulic brake has been developed in the years 1960/1970 to dramatically improve the performances of tramcars, associating the almost immediate response times of the electric control to the very short ones of hydraulic.

Indeed, the hydraulic fluid being uncompressible (on the contrary to air), pressure transmission is performed in an almost static way in the circuit (the fluid having almost no movement), which in turn leads to response times reduced to some hundreds of milliseconds. For tramcars, this improvement in response time has revealed of very high importance in order to enable reactions that are has fast as for road vehicles.

The present page describes the main aspects of this type of architecture.

Service braking control

<u>Braking control at train level</u>

Service braking control is most of time associated to traction control: both are using the same master controller, which has a traction range when pushed forwards and a braking range when pulled backwards.

The master controller includes electric potentiometers which deliver a voltage that is proportional to the position of the handle in each range, as well as contacts indicating if it’s the traction or braking range.

The voltage delivered by the potentiometers and the status of contacts are supplied to an electronic device (encoder), which has in charge to encode the force demand (traction or braking) in form of a signal which is:

- Either of the analogic type (PWM most of time): distinction between traction and braking is performed by means of the sign of the PWM signal (+ for traction, - for braking), or by different ranges for traction and braking (e.g. 52% to 95% = traction, 52% to 48% = coasting, 48% to 10% = braking), or coding in parallel binary train lines (supplied from battery voltage, and being either powered or switched off) and indicating whether the required brake force shall be a traction or braking one.
- Or of the digital type: a digital bus is substituted to PWM and traction/braking train lines mentioned above, all traction, braking and demand information being then transferred in a purely digital way by means of the main processor unit.

<u>Braking control at bogie level</u>

For each motor bogie, a traction/braking electronic control unit receives traction and braking orders (analogic signals or/and digital information). These orders are decoded by this electronic unit, and transformed into a traction or brake force to be applied.

Internal algorithms then decide, in case of braking, to require first the dynamic brake, then the mechanical brake as a complement. This mechanical brake complement can be determined locally for the bogie itself (local blending), or being determined from a demand calculated by a central management unit (main processor unit of the digital bus, global blending). If a mechanical brake complement is required on the concerned motor bogie, the demand is transferred to an electronic unit dedicated to mechanical brake control.

For each trailer bogie, an electronic brake control unit also receives traction and braking orders (analogic signals or/and digital information). These signals are decoded by this electronic unit and transformed into a brake force to be applied (in this case: no action in traction phase). In case of local blending, internal algorithms decide to apply or not a brake force according to predefined blending strategies; in case of global blending, the brake demand to apply is received for the central management unit and applied as it is.

Brake force correction according to the vehicle load can be performed:

- Either by measuring the load by means of potentiometric sensors, installed between the car body and a bogie, and measuring the deflection of the car body; these sensors are interfaced with one of the electronic units of the vehicle or with the digital bus, which makes it possible to calculate the global load and, in the case of a local blending strategy, to transfer it back to the other electronic units.
- Or by means of a deceleration control: brake demands issued by the traction/braking master controller are transformed into a deceleration, which shall be obtained for any load of the vehicle; Control units (central management unit or local electronic control units) then increase the brake forces until the required deceleration is reached, the latter being permanently calculated by derivation of the speed value vs time.

Brake demand is the eventually corrected by the wheel slide protection function (adaptation to available wheel-rail adhesion).

Each local electronic control unit will then controls an electrohydraulic transducer, in order to transform the brake demand into a hydraulic pressure.

The control pressure issued by the transducer is directly delivered to the brake calipers. These are in general:

- Of the spring applied type on motor bogies: the brake force is produced by springs, and the force level is adjusted by modulation of a hydraulic counter-pressure on the piston.
- Of the direct type on trailer bogies: the hydraulic pressure directly produces a force, in the same way as for an automobile caliper.

Emergency braking control

Braking control at train level

Emergency braking control is totally distinct from the service braking control, in order to guarantee higher safety and availability levels. Control is performed by means of an emergency loop which runs all along the train, and is looped at the level of the last bogie and runs back towards train front end. In case of multiple unit operation, the loop is:

- Either automatically reconfigured to be looped at the level of the last bogie of the rear trainset.
- Or formed by coupling both loops of each trainset by means of a specific device (relays).

The emergency loop is permanently powered, being supplied either directly from the batteries or by means of a floating potential power supply (making it possible to highly reduce risks of unintended supply of the loop). Initiation of emergency braking is done by opening of one of the contacts installed in series on the loop, so that the latter is at potential zero, meaning that emergency braking has been required.

Each of the contacts in the loop is actuated by a specific device: emergency position of the traction/braking master controller or safety equipment (dead man’s device, speed control, etc.).

Braking control at bogie level

Emergency braking relays are directly connected to the emergency loop. When the latter is powered, each emergency braking relay is kept energized, and performs no action. When the emergency braking loop is switched off, each emergency braking relay is de-energized, and provides logic information to electronic control units indicating an emergency braking.

In case of local blending strategy, information means, for each electronic unit, that it shall require a brake force corresponding to emergency braking.

In case of global blending strategy, emergency braking information is also supplied to the central management unit, which in turn forces brake demands to levels corresponding to emergency braking. Emergency braking information also supplied locally to brake control units is then only used as a redundancy to endure a minimum force in case the brake demand received from the central management unit is wrong.

Each control unit then controls all brakes (dynamic and/or mechanical) that it has in charge, the mechanical brake being controlled by means of the electrohydraulic transducer.

Load correction remains active in this braking mode, as well as wheel slide protection.

Emergency braking relays also require application of magnetic track brakes if the vehicle is equipped with. These generally remain applied until the vehicle stops (or almost).

Safety braking control

Braking control at train level

Safety braking control, when existing, is totally distinct from the service and emergency braking controls, in order to guarantee a maximum safety level. Control is performed by means of a safety loop which is distinct from the emergency loop and runs all along the train, and is looped at the level of the last bogie and runs back towards train front end. In case of multiple unit operation, the loop is:

- Either automatically reconfigured to be looped at the level of the last bogie of the rear trainset.
- Or formed by coupling both loops of each trainset by means of a specific device (relays).

The safety loop is permanently powered, being supplied either directly from the batteries or by means of a floating potential power supply (making it possible to highly reduce risks of unintended supply of the loop). Initiation of safety braking is done by opening of one of the contacts installed in series on the loop, so that the latter is at potential zero, meaning that safety braking has been required.

Generally the safety loop can be switched off only by means of the mushroom type push-button. Moreover, action on the mushroom type push-button also switches off the emergency loop, in order to guarantee that at least on of both loops will be switched off.

Braking control at bogie level

Safety braking relays are directly connected to the safety loop. When the latter is powered, each safety braking relay is kept energized, and performs no action. When the safety braking loop is switched off, each safety braking relay is de-energized, and:

- At the level of each motor bogie: leads to complete venting of calipers (fluid sent back to the hydraulic tank of the hydraulic power unit), thus application of the maximum brake force of the spring applied calipers; this venting is performed either by direct or indirect) switching off of the power supply to the electrohydraulic transducer controlling the pressure in the calipers, or by switching off power to a safety braking magnet valve.

- At the level of each trailer bogie: switches off the power supply to a safety braking magnet valve, which in turn supplies the direct brake calipers with a hydraulic pressure directly issued from the accumulator through a preset pressure limiting valve.

In parallel, each safety braking relay also provides logic information to the control electronic units, so that the latter requires a brake force corresponding to safety braking (redundancy).

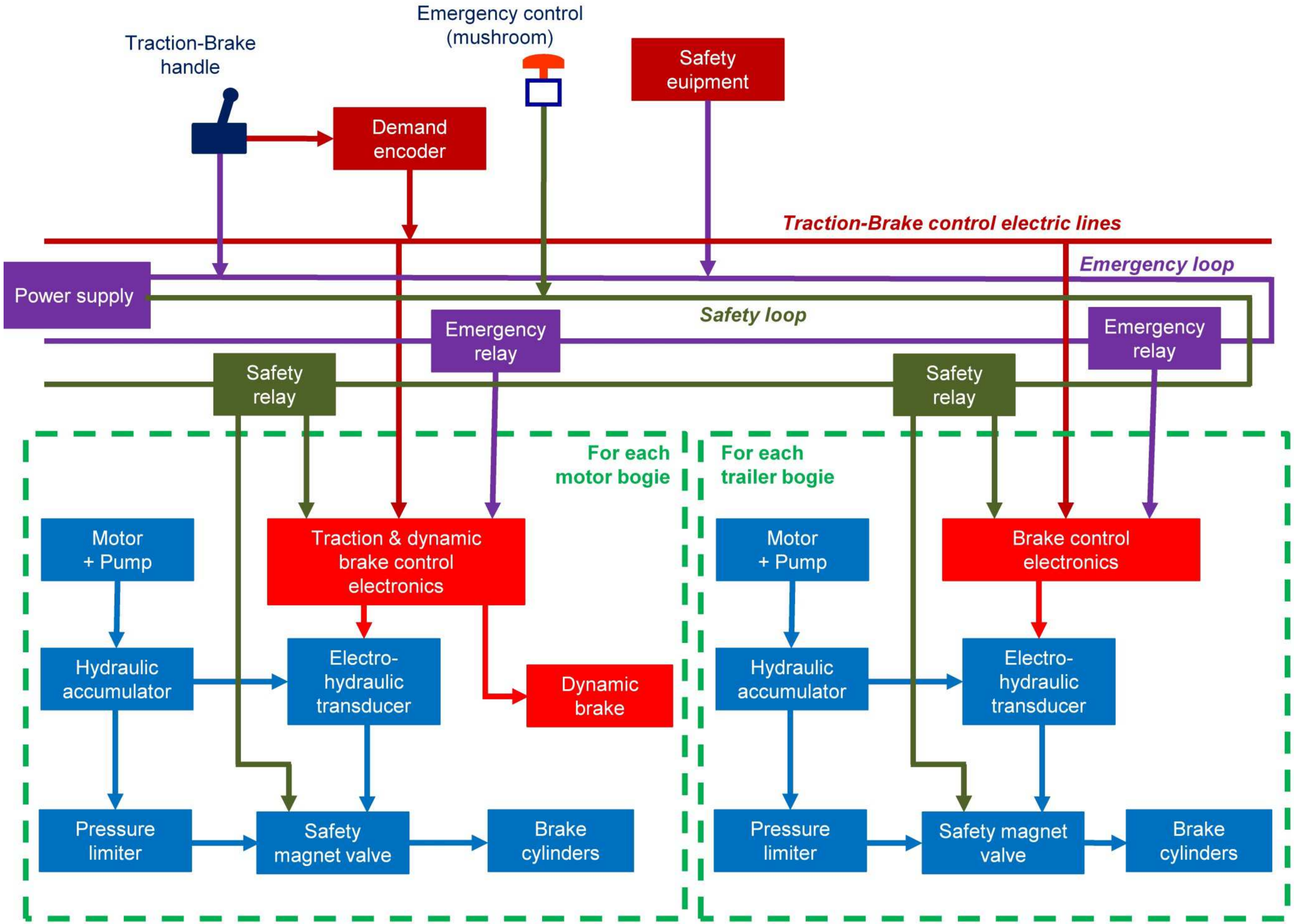
The dynamic brake is inhibited for this braking mode, generally by opening the main circuit breaker (which also guarantees a safe traction inhibition).

Load correction is inhibited for this braking mode, as well as wheel slide protection.

As the emergency loop is also switched off, emergency braking relays also require application of magnetic track brakes if the vehicle is equipped with. These generally remain applied until the vehicle stops (or almost). It shall be noted that switching off of the emergency loop enables to guarantee that at least emergency braking will be applied on each bogie in case of failure on a safety braking relay, provided that the emergency braking corresponds to a brake force equivalent or even higher than the safety braking.

Generic synoptic diagram of an electrohydraulic brake

As most of the applications for this type of brake system are the tramcars, we propose under the generic synoptic diagram for this type of vehicle.



Traction-Brake handle
Emergency control (mushroom)
Safety euipment
Demand encoder
Traction-Brake control electric lines
Emergency loop
Power supply
Safety loop
Emergency relay
Emergency relay
Safety relay
Safety relay
For each motor bogie
For each trailer bogie
Motor + Pump
Traction & dynamic brake control electronics
Hydraulic accumulator
Electro-hydraulic transducer
Dynamic brake
Pressure limiter
Safety magnet valve
Brake cylinders
Motor + Pump
Brake control electronics
Hydraulic accumulator
Electro-hydraulic transducer
Pressure limiter
Safety magnet valve
Brake cylinders