

Redundant Compressed Air Supply for Trams and Railcars

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Abstract

A sensible combination of an efficient part load operation and redundancy of the air supply is possible. Such a combination was already successfully applied to air conditioning systems. For new projects, a redundant stationary compressed air supply was developed. The compressor as a core module is derived from the medical technology. The plant is described in this contribution, its parameters are given in a table.

1 General Information Regarding the Redundant System Design in Railway Vehicle Construction

Technical systems with changing requirements must be designed to satisfy the most extreme needs, even with very infrequent boundary conditions in terms of temperature, humidity, rain and sunlight. This can be explained based on the air conditioning of railway vehicles. The combination of the maximum thermal load (heat from people, solar radiation, heat transmission) with the external temperatures and air humidity set in the relevant standards will actually occur only in a fractional part of the vehicle's operating time.

It is also important that the relevant technical engineering objectives are fulfilled, even in partial load operation which comprises the largest portion of the operational spectrum; some of these are:

- energy efficient operation,
- less wear and tear,
- noise and vibration dampening,
- high availability and reliability, and

- lower maintenance costs.

One way to achieve efficient partial load operation is to use two smaller aggregates, rather than one large aggregate. If this is the chosen approach, the widest possible spectrum of partial load operations should be covered by one aggregate, so that in these cases, a high degree of redundancy is also provided in addition to efficient operation. Continuing with the example of air conditioning, the expected temperature control of the interior space with a system can also simultaneously occur in a wide operational spectrum. The comfort reduction would be limited by the second system in the case of a fault in extremely inclement weather conditions and/or for fully loaded railcars.

The cooling load for mass transit is determined mainly by body heat and solar radiation. For some rolling stock, the air conditioning norm DIN 14750 recommends designing with the assumed occupation of all seats and two standing places/m² as well as 100% solar radiation. A small reserve for pre-cooling is considered when designing so that the desired indoor climate is still created by reduced air conditioning on one of two

cooling circuits when all seats are filled and for 50% solar radiation.

The Tango tram for Basel Area Transport (BLT) (*Figure 1*) [1] and for the city of Geneva have four air conditioning systems (*Figure 2*) which each have two independent cooling circuits. The concept of redundancy has also been used for quite a few years here, as has been the case for certain other Stadler Group trams. This also applies for the prototype of the 853 Metelica low floor tram which has been developed by Stadler Minsk for the market to the East of the EU. It was introduced to the public at Innotrans 2014 and is currently being tested in various Russian cities (*Figure 3*). However, at least in the prototype, any equipment using pneumatics was omitted.

The possible availability of cheaper, tested systems plays a role when considering the transfer of the redundancy concept to other systems. Smaller devices of this kind can often be adapted from other industries, as shown in the following area of the compressed air supply.



Figure 1: BLT Tango Tram in Basel's Inner City

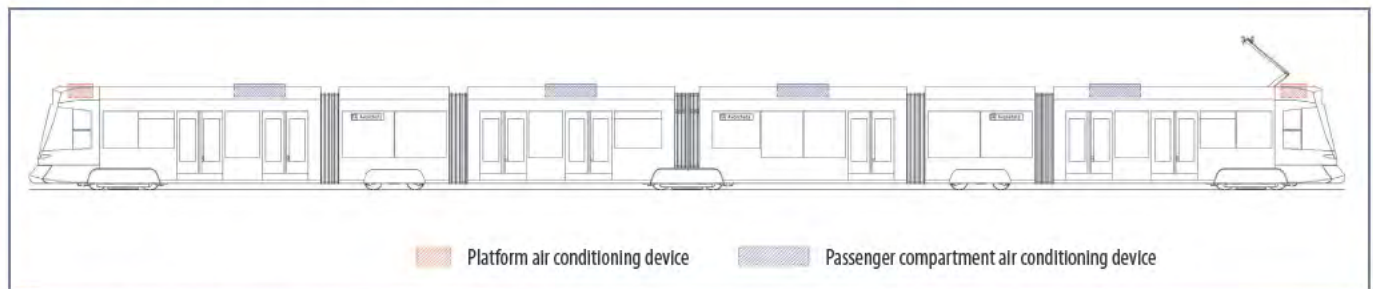


Figure 2: Type plan of the Genfer Verkehrsgesellschaft TPG tram with air conditioning devices

The Tango tram uses the air suspension in the secondary suspension level in order to

- ensure a high level of in-travel comfort,
- be able to travel in the Basel city suburbs at the maximum speed of 80 km/h at this comfort level,
- keep the height difference between the platform and the entrance doors of the rolling stock for different passenger loads as low as possible.

There is a trend for future tram sector projects of measuring the pressure in the air spring and using the signal as the input variable for brake control. Figure 4 shows the block diagram to illustrate this. The wheel/rail adhesion power can be used better with this load-dependent brake. Likewise, the signal can be used as the input variable for the air conditioning systems used for climate control, e.g. those in [2]; they have consistently shown that the passenger-dependent regulation of the quantity of fresh air

provides very great potential, for heating in particular, but also for cooling. In comparative calculations for a normal passenger car, the savings was 25%; it is

expected to be even higher for mass transit due to the lower average occupancy rate [2]. The air suspension pressure is nearly proportional to the number of passengers and is thus suitable as an input signal for regulating the quantity of fresh air. As a result, the reliability of pneumatics and especially of the compressed air supply system will grow in importance within this arrangement. The search for redundancy and thus for high-value small compressors is a current one. Reliability should reach levels of availability that are as close to 100% as possible.



Figure 3: Metelica 853 Low Floor Tram in Winter Use in Moscow

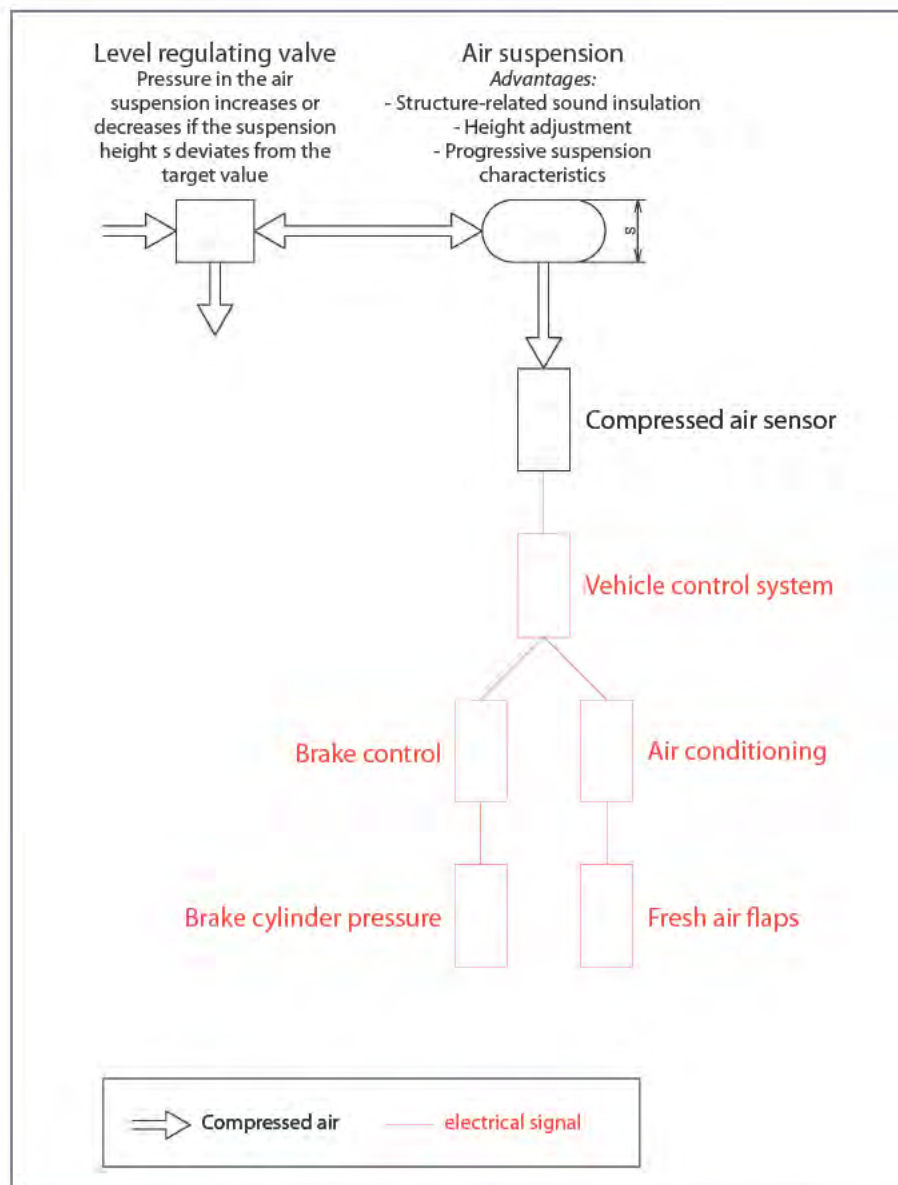


Figure 4: Air Suspension with Peripherals and Further Signal Utilization Block Diagram



Figure 5: 2 Cylinder Compressor with V-shaped Arrangement (Core of this type of Compressed Air Supply System)

2 Compressors for the Medical Field

It is likely that most readers do not know that compressed air is used in a variety of ways in dental practice. Clean, dry compressed air is used for the blowing and drying of the oral cavity and for vacuuming out saliva and dust from drilling. Furthermore, most drills (the medical term is "dental handpiece") have a compressed air turbine motor. The electrically driven device requires compressed air for cooling.

It is obvious that the compressors used (Figure 5) are required to have peak values in terms of purity of the air supplied and in terms of the reliability. A defective compressor would lead to the temporary closure of the affected dental practice. Since dental offices are often housed in older, inner city residential homes, issues such as low vibration and quiet operation are a challenge for the manufacturers. Important parameters of the compressors used in this segment of the EKOM spol. s r. o. company in Piestany (Slovakia) are displayed in Table 1.

The requirements for medical compressors are even higher compared to dental compressors. They are required for patient ventilation and for the anaesthesia sector.

The Medical Devices Regulation [3] requires double redundancy for these kinds of systems. The system illustrated in Figure 6 is divided into three groups. Each group comprises one compressor and an air conditioning system and is dimensioned in such a way that it is sufficient for primary care. Because all three groups run in base load change operation, the patient's compressed air supply is always guaranteed.

In another design, the third redundancy level is implemented thanks to compressed air tanks. This makes sense if the failure of the electrical network in the medical device cannot be completely excluded.

Since compressed air that is used for respiratory purposes is classified as a medical product, the compressed air quality must correspond to the European Pharmacopoeia [4]. A costly compressed air conditioning system is required as a result. In addition to air drying in the PSA process, a catalytic after-treatment of

I Table 1: Parameters of EKOM Compressors

Model	Type Description	Supply	Supplied Quantity (without Dryer)	Pressure Increase
1 Cylinder	AJX 70	0.5 kW	70 l/min	8 bar (optional 10 bar)
2 V-cylinders	AVX 140	1.1 kW	140 l/min	8 bar (optional 10 bar)
4 V-cylinders	AVX 280	2.2 kW	280 l/min.	8 bar (optional 10 bar)

compressed air is required in order to eliminate residual contaminants. PSA stands for Pressure Swing Adsorption (2 chamber adsorption dryer).

3 EKOM Slovakia

EKOM is one of the market leaders in the field of dental and medical compressors. It has an acoustic echo chamber and air chamber that maintains temperatures of 35 to +40°C and within which high humidities can be realized. These good test capabilities were used in the development of the aggregate described under section 5.

4 The Path from Medical Compressors to Industry Compressors: Synergies of Characteristics

With the founding of EKOM-AIR GmbH in Ahrensburg in the vicinity of Hamburg in 2006, EKOM spol. s.r.o. Piestany considerably strengthened its presence in Western European countries and stretched this further through applications in the industrial and vehicle sectors. Changes in medical compressors were necessary; only the most important ones are mentioned here:

- Increase of the maximum pressure from 7 bar that is typically used in the medical field to 8 bar and optionally, 10 bar,
- Design for continuous operation with the corresponding adjustments and tests,
- Drive motors in a large requirement segment for direct current (12 to 110 V),
- Adjustment to external use that concerns rail vehicles, especially compliance with EN 50125, and

- Construction of the compressed air refurbishment system according to structural and climatic conditions (in rail vehicles, this is with regards to constructing the flattest possible device mould for underfloor or roof assembly).

The focus is especially directed towards the automated work (sample preparation, rheometer, and spectrometer), rolling stock/construction machinery and packing machine sectors.

Many medical practices have automated analysers (Figure 7), for blood samples, for example. The gripping and transportation processes optionally also use the centrifuge drive, implemented here pneumatically in many cases. Packing technology also uses this technology in the same way as gripping and transport processes.

In the railway vehicle sector, there are applications for pantograph lifting systems, vacuum toilets in passenger cars, and uric acid (AdBlue) dosing systems for large diesel engines. AdBlue is the brand name of a synthetically manufactured, highly pure urea that massively reduces nitrogen oxide's emissions through selective catalytic reduction. This urea is supplied from the storage tank to the exhaust system either through a metering pump or based on an injection principle. Compressed air again plays a role when using the injection principle.

5 Redundant Compressor Systems for Trams and Railcars

A redundant compressor system for trams and other smaller railway vehicles was designed, constructed, and manufactured on the basis of the oil-free compressor described here through the cooperation of EKOM-AIR Ahrensburg, EKOM Piestany and Stadler Altenrhein AG. The core is two four-cylinder compressors with V-shaped arrangement, with each



I Figure 6: Triplex Compressor System for the Medical Sector (a Line is Provided for Maintenance; the Other Two Lines are Provided for Redundant Operation)



Figure 7: Work Analysis Instrument with its Pneumatic Components

having a compressor volume of 170 l/min at 8 bar. They are supplied with 400 V AC current by the electrical wiring system. Downstream from the compressors are heat exchangers and two-stage dust separators, each strand having a drying system. In a vehicle-side intermediate tank, the compressors transport a volume

of 190 l which was used in the first application example. In order to minimize the pressure fluctuations of the oscillating compressors, pressure detection is carried out with pressure sensors on the compressed air tank. Both compressors are turned on at an air pressure < 6.5 bar. This limit is determined by the maximum

air pressure in the air springs for a fully loaded vehicle. One compressor will be shut off at 7 bar and both compressors will be shut off at 8.5 bar.

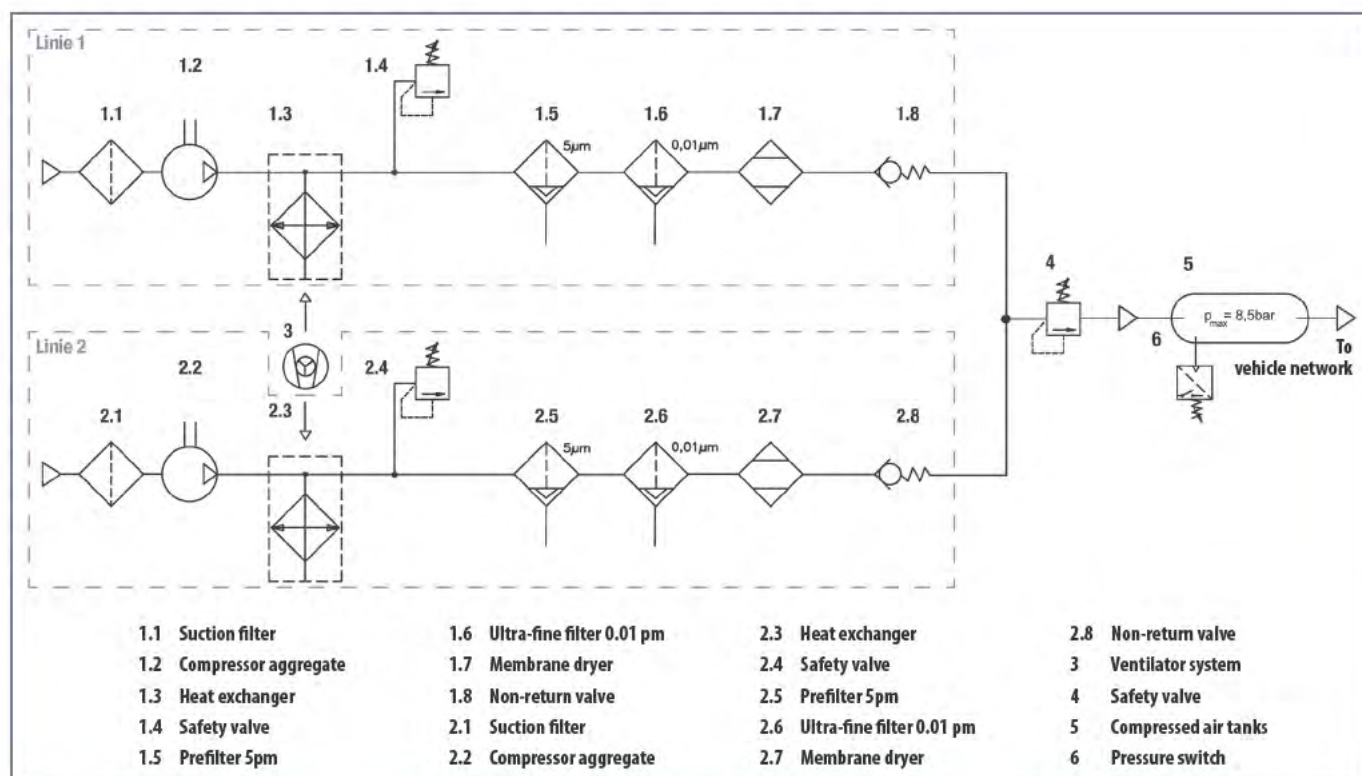


Figure 8: Tram Redundant Compressor System Compressed Air Schematic

Table 2: Tram Redundant Compressor System Technical Parameters

Pressure Increase	8.5 bar
Air volume to the dryer when switching on both compressors	2 x 170 l/min
Weight with housing	approx. 190 kg
Supply voltage	3 x 400 V AC/24 V
Sound pressure level at a distance of 1 m	
one compressor in operation	67 dB (A)
two compressors in operation	69 dB (A)

The compressed air schematic is shown in *Figure 8*.

In the first application example, the compressors are alternately controlled from the vehicle control unit. This applies as long as there is no fault or an extraordinarily high demand for compressed air;

source in such a way that the sound pressure level can be reduced to 6 dB when doubling the distance. This is based on the 6 dB law for spherical sound waves [5]. Considering the roof aperture, the external values for the standardized measurement points in rail vehicles



Figure 9: Tram Compressor System with Weather and Noise Protection Covering

this can happen at approximately 300 l/h or even somewhat higher. This extraordinarily high demand for compressed air can be required, for example, by

- extremely fast increase in the number of passengers at a station,
- leaks in the compressed air system of the vehicle, and
- the filling of the system after maintenance work.

In these special cases, both compressors will run and the system will fully drain its performance capability.

Table 2 gives an overview of the system's technical parameters. Figure 9 and Figure 10 show the system's equipment. A good representation of the spatially interleaved compressors can be seen in Figure 10. The noise level in Table 2 is measured in EKOM's reverberation chamber. The values listed, measured at the distance of 1 m, can be approximated at a point sound

normally lying at a distance of 7.5 m from the track centre must therefore be below 60 dB (A).

Another design that is considered for this solution could also utilize the frequently used auxiliary compressors that are installed for lifting a pneumatically actuated pantograph for a completely empty compressed air system. These compressors required for this special task have a battery as a single power source. It then becomes possible to operate one compressor with 400 V from the vehicle electrical wiring system and the other with battery voltage for the proposed redundant compressed air supply.

In this design, the compressors will no longer be controlled in an alternating manner but operated according to the following working principles:

- Normal operation: 400 V compressor,
- Pantograph lifting: battery-operated compressor:
- Filling of the compressed air system: 400 V and battery-operated compressor,
- Extreme requirements: 400 V and battery-operated compressor, and
- 400 V compressor fault: battery-operated compressor.

The compressor with battery power supply should only be used when either the corresponding depot outlet has been turned on or when the battery charger that makes the battery voltage available

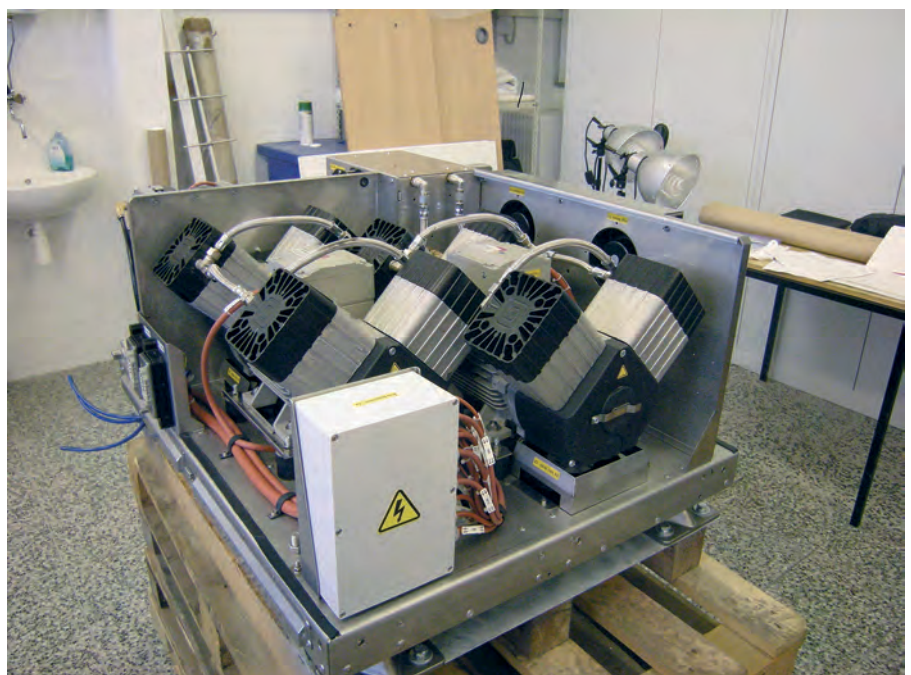


Figure 10: Compressor System after Acceptance of the Cover

to the compressor is working. Designing a battery to be large enough so that the compressor with the battery-supplied power can absorb a failure of the 400 V compressor during operation seems unreasonable because this would be relevant only if there is a double fault from the 400 V compressor and battery charger.

6 Conclusion

The realization of two independent partial aggregates which together implement the required maximum power but cover only wide partial load ranges provides a promising approach in the design of subsystems in railway vehicles, but also otherwise in railway vehicle and system construction. In most cases, sufficient partial load ranges emerge as a side effect - yet another desirable redun-

dancy. In any case, the use of two small devices has a beneficial effect on the dimensioning of the electrical wiring system because clear energy requirement data is more advantageous than the calculation with activation time probabilities for large devices. Furthermore, undesired starting currents will be halved.

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(Index keywords: mass transit, components, operation)

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