

Functions – Functional analysis

Module 02.2en


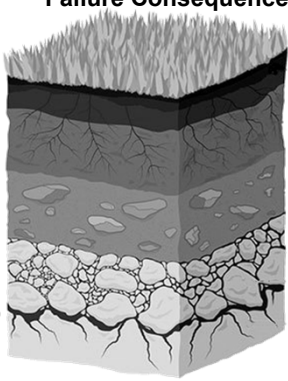
Failure Consequences

Failure Effects


Failure Mode

Failure

Function



The bedrock of RCM analysis



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RCM – 7 Question process

A process used to

determine what must be done

to ensure that a physical asset continues to do what

its users require it to do in its operating context:

What do its users require it do (Functions)?

What specific performance losses can occur (Failures)?

What event causes the failure (Failure mode)?

What happens when it fails (Effects)?

Why does it matter (Consequences)?

Can you predict, prevent or mitigate the failure consequences (Maintenance task)?

What if no mitigating task can be found (Default action)?

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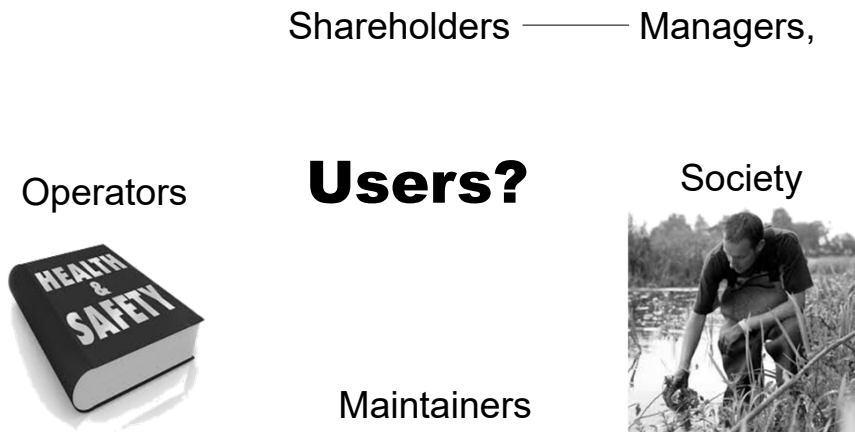
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The objective of maintenance

- The objective of maintenance is to ensure that physical assets continue to do **what their users want them to do ...**
- So the development of a maintenance program must start by **defining** what its users want the asset to do in the current **operating context**.

3

“What do the users really want?”



4

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Maintenance program must start by defining

what its users want the asset to
do in the current operating
context.

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RCM may be thought of as a
formal language that narrowly
defines various terms and
concepts that we need to
establish a maintenance plan.

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Function statements – Five attributes

1. Function statement structure
2. Performance standard(s)
3. Primary and secondary function categories
4. Types of performance standards
5. The asset's operational context

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The function statement is grammatically structured

1. Begins with the infinitive form of the verb. (In English the statement starts with "To".)
2. The verb usually has an object.
3. There should be at least one performance standard.

Example:

To pump beer at a minimum rate of 500
liters/minute

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The function statement is grammatically structured

1. Begins with the infinitive form of the verb. (In English the statement starts with "To".)

"Not to"

"Able to if"

"In the presence of"

2. The verb usually has an object.
3. There should be at least one performance standard.

Example:

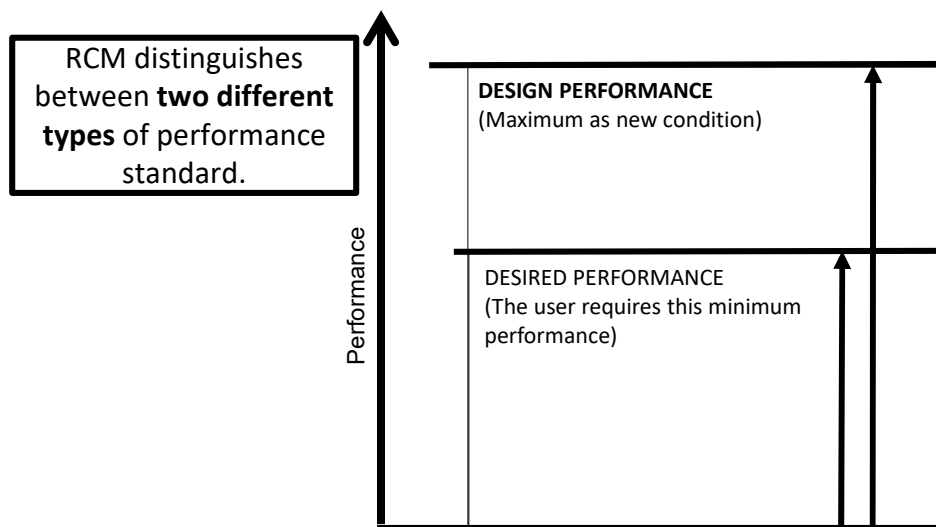
To pump beer at a minimum rate of 500
liters/minute

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Functions - Performance standards

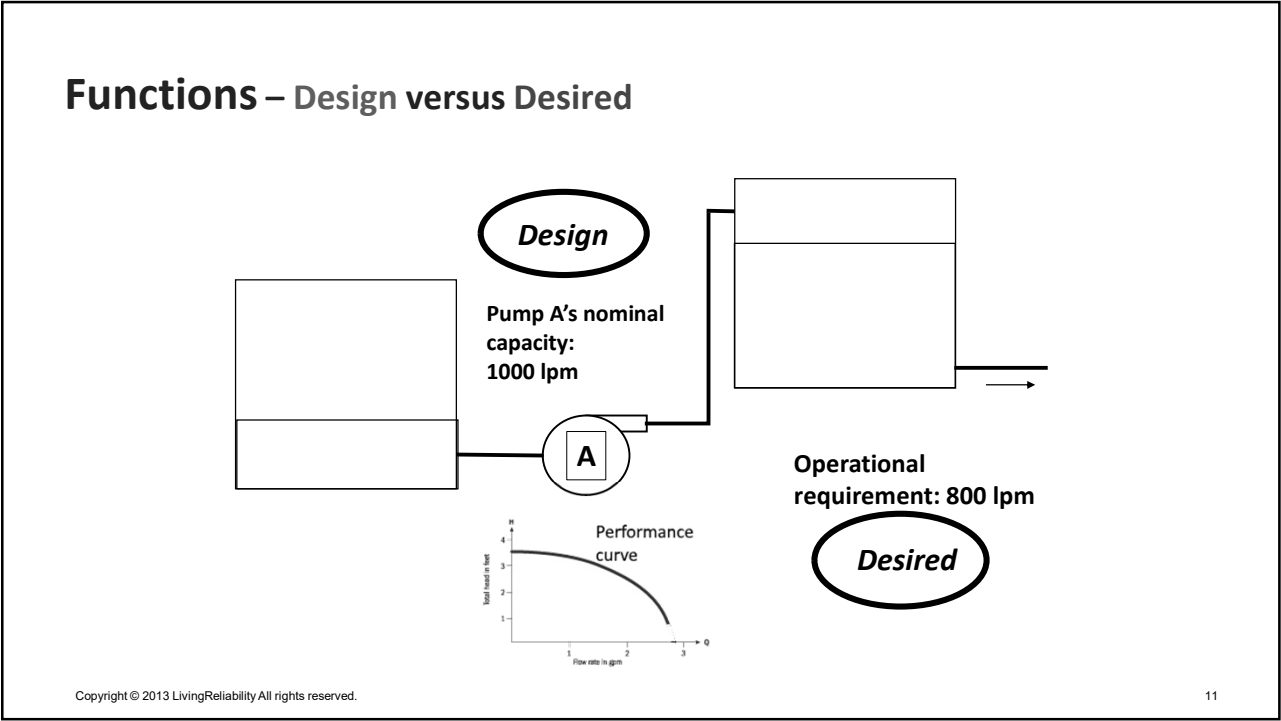


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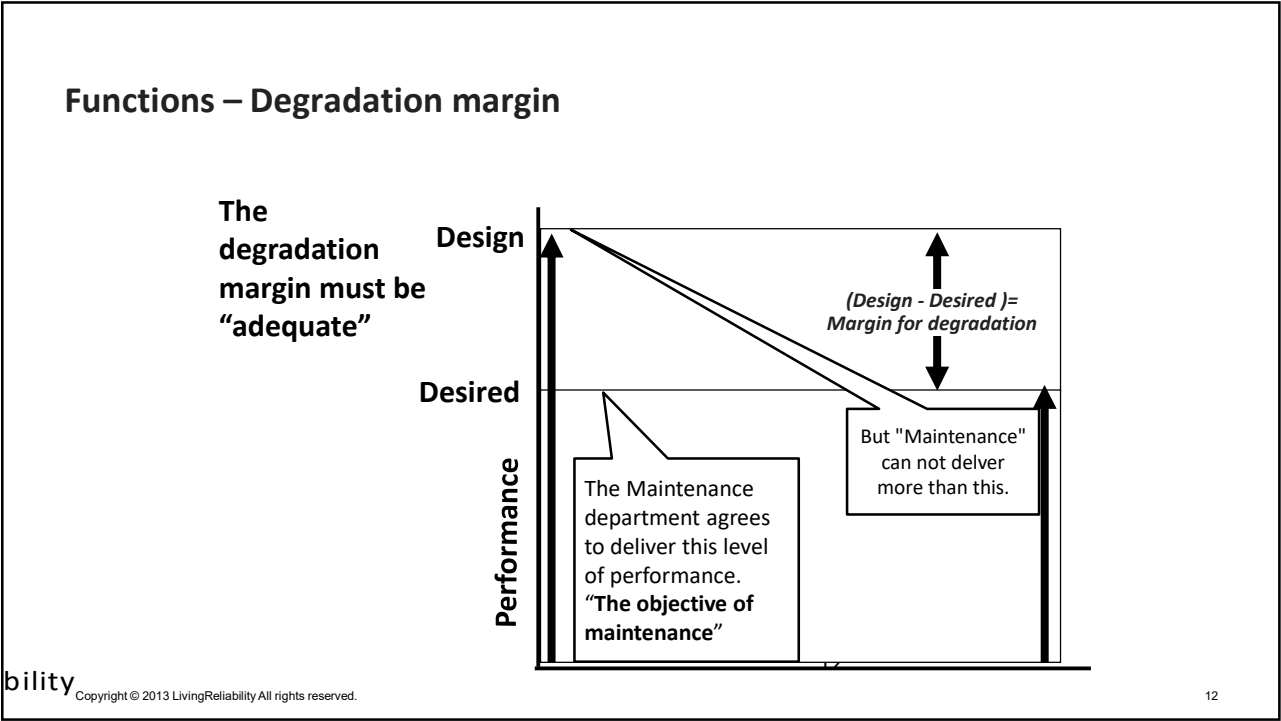
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2.2.1 QUIZ I FUNCTIONAL ANALYSIS

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1. The first challenge in RCM is to answer the question "What do users really want?" Which of the following is INCORRECT? *

1. The user's requirements are always obvious.

2. Some requirements can be surprising.

3. Some requirements can be found in the operating and maintenance manuals, drawings, and standard procedures.

4. Some requirements can be discovered during brainstorming among the operators, maintainers, and supervisory staff..

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Functions – Two categories

I. Primary


II. Secondary

"Why we purchased the asset"

"Additional requirements that the asset must fulfill"

"Secondary", in the language of RCM, **by no means implies** "less important".

Illustrative example:
The domestic automobile



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Primary function describes why you bought the car

The secondary functions are all the other necessary requirements, for example, safety standards. (Secondary does not mean “less important”.)

Domestic car v1.0

To get a driver and up to 4 passengers
~~To get~~ from A to B at speeds up to 85 mph?
while traveling along paved roads.

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Primary function describes why you bought the car

The secondary functions are all the other necessary requirements, for example, safety standards. (Secondary does not mean “less important”.)


Domestic car v1.0

To get a driver and up to 4 passengers
~~To get~~ from A to B at speeds up to 85 mph?
while traveling along paved roads.

Secondary functions mnemonic

1. Protection
2. Environmental integrity
3. Appearance
4. Control/containment/comfort
5. Health & Safety
6. Economy/efficiency
7. Structural integrity / Superfluous functions

Hazard warning lights



You can use your hazard lights only when you are a temporary obstruction or you are being towed. You can usually find the button in the centre of the dashboard and it will almost always have a red triangle.

The hazard warning lights flashes all four indicators simultaneously.

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Example: Space shuttle arm

Space shuttle arm v0.2

1. During orbit phase provide wrist

1. Partial or complete loss of v

1. Motor drive Component



Canada arm wrist and elbow view

Failure Mode

Motor drive Component in circuit fails caused by n/a

(From RCMCost):

Effects

Summary:

When wrist roll motion and torque is lost the astronaut cannot continue the FTS task and mission. There is not direct effect at the orbiter mission. The position sensor and torque sensor are displayed at DAC. There is a backup arm to put arm in safe position.

Corrective Task:

Place arm in safe position using backup hardware

Skills:

Specialist

Est. Downtime(h): 4


Consequence

Operational

Type	Description	Interval	Skills
No scheduled maintenance	Run to failure		

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A primary function describes the reason the asset exists




Office chair

To support a person up to 200 kg comfortably seated.

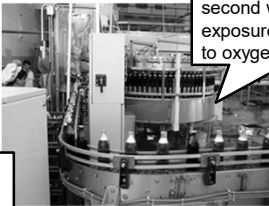
1. Support the upper floors and roof

2. Isolate the occupants from the weather




Building Envelope

Your home's exterior walls



Beer bottle filler

To fill 740 +1-0 g of beer into cans 5 times a second without exposure of the product to oxygen.



Robinsons Supermarket

Supermarket sign

To indicate to a normally sighted person from up to 30 meters the name of the business.

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Secondary functions – office chair



Examine the parts of the chair.
What functions to they suggest?

Secondary functions mnemonic

1. Protection
2. Environmental integrity
3. Appearance
4. Control/containment/comfort
5. Health & Safety
6. Economy/efficiency
7. Structural integrity / Superfluous functions

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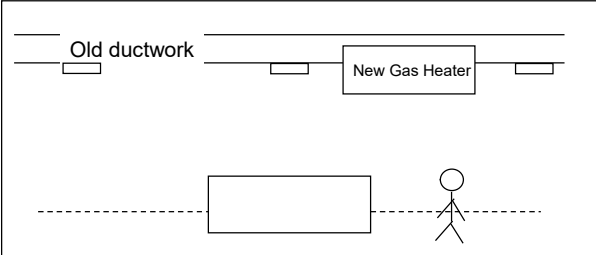
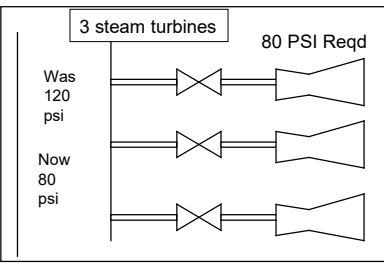
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Superfluous functions:

Secondary functions mnemonic

1. Protection
2. Environmental integrity
3. Appearance
4. Control/containment/comfort
5. Health & Safety
6. Economy/efficiency
7. Structural integrity

Superfluous functions





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Avoid superficial analysis






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What if maintenance is regulated by government agencies?



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Over stress tests.



Avoid them. Use NDT, CBM, ...

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2.2.1 QUIZ 2 FUNCTIONAL ANALYSIS

<https://forms.gle/cKqCf4oYwCWh9YbQ7>

1. A primary function is more important than a secondary function. True or false? *

1 point

☐ True

☐ False

2. A superfluous function is: *

1 point

☐ 1. A function that is not important to the users.

☐ 2. A function that once was required but today due to an operational change is no longer required.

☐ 3. A redundant equipment unit.

☐ 4. All of the above

☐ 5. None of the above.

3. Which of the following should NOT be included in a function statement? *

☐ 1. The phase of operation

☐ 2. The context

☐ 3. Quantitative standard(s) to be met

☐ 4. An infinitive verb, an object, and descriptive details.

☐ 5. Whether the function is primary or secondary.

4. Maintenance people tend to think in terms of parts and components while RCM encourages describing their functions. True or false. *

☐ True

☐ False

5. Open questions: *

☐ Can be answered by a yes or no.

☐ Discourage thinking too deeply.

☐ Are avoided by the RCM facilitator in order to save time.

☐ Require delving into facts relevant to the issue at hand.

6. The more functions in an asset, the more unreliable it is. True or false? *

☐ True

☐ False

7. RCM may be thought of as a formal language that narrowly defines various terms and concepts that will allow us to establish (and continuously improve) a maintenance plan. True or false? *

☐ True

☐ False

8. Code phrases that can be used in the function statement to draw attention to a hidden (redundant, protective, backup) function can be: *

☐ 1. "in the presence of"

☐ 2. "Able to"

☐ 3. "in the absence of"

☐ 4. Any of the above.

9. Should we perform an RCM analysis where there is already a maintenance program from a government regulatory authority? *

☐ Yes, we should seriously consider doing our own analysis.

☐ No, RCM analysis is unnecessary since the government has assumed liability.

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Functions – Performance Standards

Can encompass one or more of the following types of standards:

1. Multiple
2. Quantitative
3. Qualitative
4. Absolute
5. Variable demand
6. Upper and Lower limits

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1. Multiple performance standards

“To heat up to 4 metric tons of oil and additives while mixing at a rate of 13 rpm to a **temperature of 110C in 2 hours”**

Multiple performance standards specifying mass, speed, temperature, and time.

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2. Quantitative performance standards ...

Performance standards should be *quantified* where possible.
For instance, do not say:

~~To operate at maximum speed~~ or ~~"To meet production target"~~.

(Specify the target or what the maximum speed is.)

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3. Qualitative standards

Occasionally a quantity cannot be expressed in a practical way.
For example

To look "acceptable" to board of directors
when they visit the equipment location.

The involved parties should carefully reach an understanding of
exactly what the appearance expectations of the board are.

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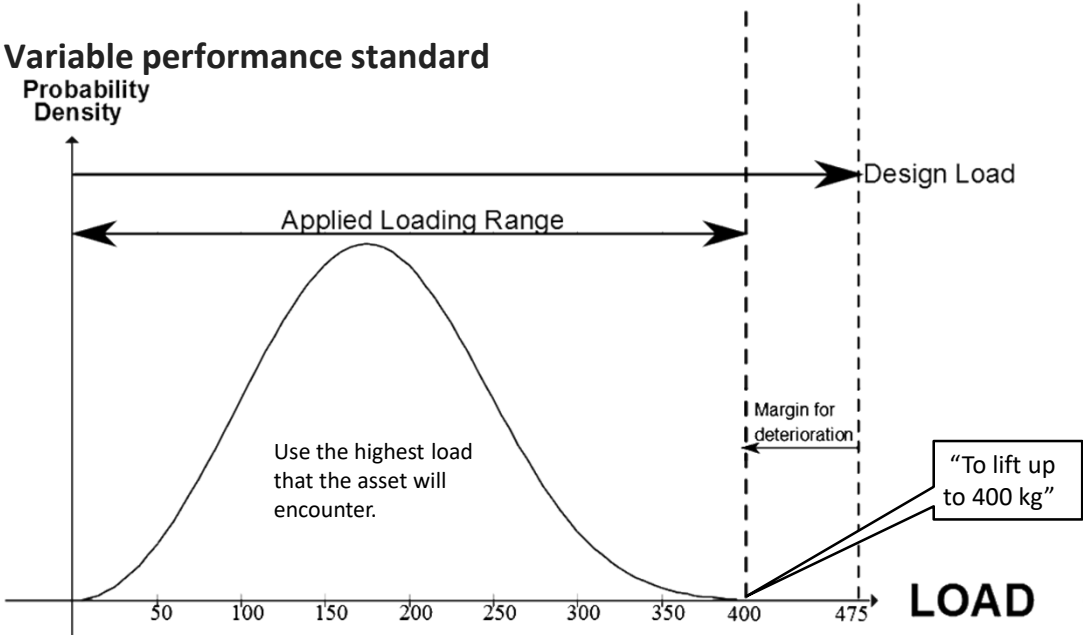
4. Absolute standard

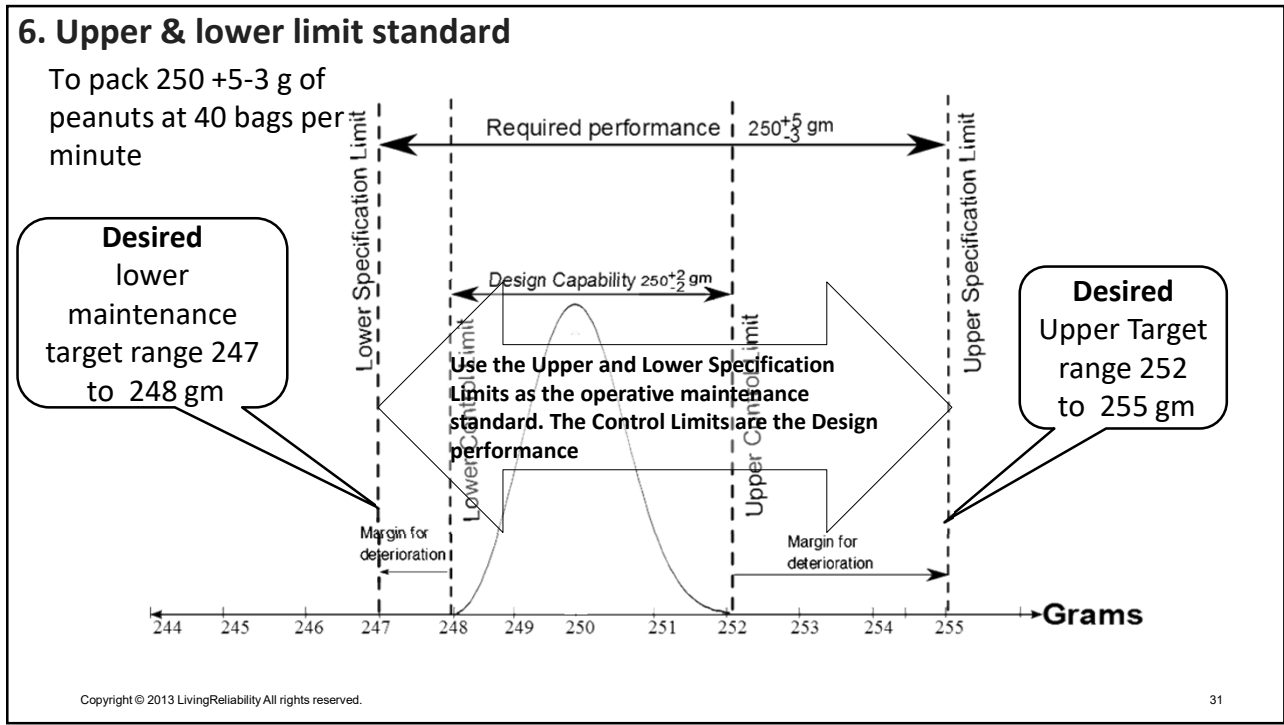
If a quantitative standard is omitted it often implies an absolute performance standard, For example

To contain hydrofluoric acid

Implies that the user in fact demands *zero* leakage.

5. Variable performance standard





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Typical Protective (Hidden) Functions

- E-stops
- interlocks
- temperature switches
- ultimate level switches

Protective devices provide five types of actions:

- Warn users of an extraordinary or dangerous situation
- Shut down equipment when a critical component has failed
- Eliminate or relieve danger resulting from a failure
- Take on the impaired role lost due to failure of the asset's principal operating components.
- Prevent a dangerous situation or occurrence.

- over-speed switches
- pressure relief valves
- fire detection, fire warning and fire fighting systems

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Function statements with Operating phases

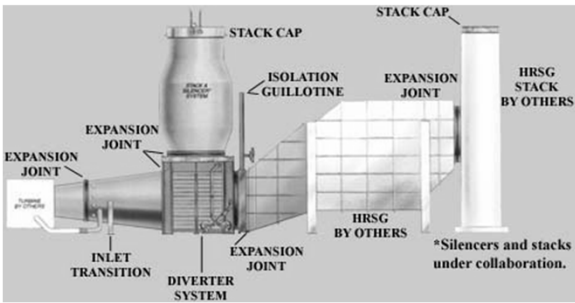
The function statement should also include all relevant operating phases.

- 1. Seasonal
- 2. Start up, running, shutdown
- 3. Etc.

Example:

To supply hot water with a temperature between 50C and 55C to all taps within 15 seconds of opening the tap in summer and in winter in the presence of a full stand-by heating capability.

Turbine exhaust system



Turbine exhaust system v6.0

- 1. To deliver all the exhaust gases to an outlet 20 meters above the building
- 2. To contain turbine discharge gases
- 3. Not to introduce flow restrictions
- 4. To attenuate sound to ISO 30 at 90 Meters with a reduction of pressure no greater than 30 bar.
- 5. To prevent duct surface temperature in turbine building from rising above 60°C
- 6. To warn operators if EGT > 475°C
- 7. To shut down turbine at EGT > 500°C
- 8. Not to distort ducting due to temperature variation

The functional analysis process

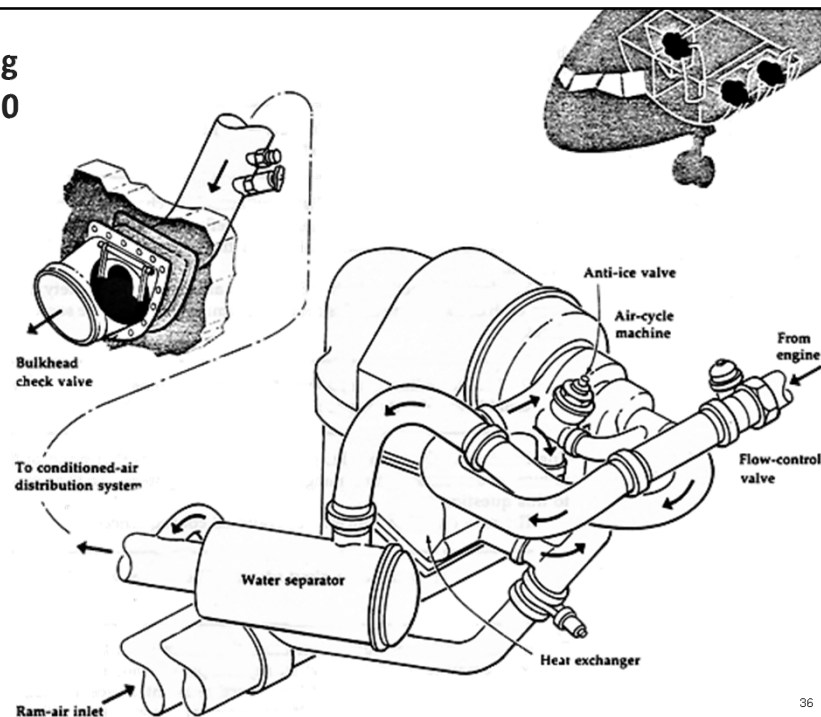
1. **Document** the asset's operating context at the start.
2. **List** the functions (suggested by components) as function statements.
3. **Refer** to all helpful documents (drawings, schematics, manuals).
4. **Recall** individual experiences while listing the item's functions.
5. **Specify** one or more quantitative performance standards. (Actual requirements, *not* design capacity.)
6. **Devote** special care to hidden functions.

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Example: Air-conditioning pack in the Douglas DC-10



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 Air-conditioning pack v7.0

- 1. To supply air to conditioned air distribution ducts at the temperature called for by pack temperature controller
- 2. Able to prevent loss of cabin pressure by backflow if the duct is fails in unpressurized nose-wheel compartment

System information worksheet – type of aircraft: Douglas DC-10			
Item No.	Number for aircraft: 3	Prepared by: F.S. Nowlan	Date: 3/6/78
Item name: air-conditioning pack	System: Air conditioning	Reviewed by: J.E. Kuhl	Date: 3/6/78
Vendor part/model number: Airesearch 927370-4	Zone(s): 110	Approved by:	Date:
Item description: Pack delivers temperature-controlled air to conditioned-air distribution ducts of airplane. Major assemblies are heat exchanger, air-cycle machine, anti-ice valve, water separator, and bulkhead check valve.		Redundancies and protective features (include instrumentation): The three packs are completely independent. Each pack has a check valve to prevent loss of cabin pressure in case of duct failure in unpressurized nose-wheel compartment. Flow to each pack is modulated by a flow-control valve which provides automatic over temperature protection back by an over temperature trip off. Full cockpit instrumentation for each pack includes indicators for pack flow, turbine inlet temperature, pack-temperature valve position, and pack discharge temperature.	
Reliability data:		Built-in test equipment (described): none	
Premature-removal rate (per 1000 units hours):		Can aircraft be dispatched with item inoperative? If so list any limitations which must be observed: Yes. No operating restrictions with one pack inoperative.	
Failure rate (per 1000 units hours)		Classification of item (check)	
Source of data:		Significant	
		Hidden function	X.
		Nonsignificant	X.

Operating context and functional analysis

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Distributed control system

 Distributed Control System (DCS) v2.0

- 1. To provide safe, secure, uninterrupted; redundant, cost effective, continuous process control and monitoring in the presence of a UPS
 - 2. To respect environmental regulations.
 - 3. To alarm on abnormal conditions in the process real time
 - 4. To allow manual intervention
 - 5. To interface with other control systems
 - 6. To graphically present the process to the operators
 - 7. To exchange data with other control systems
 - 8. To capture historical data
 - 9. To provide the means to alter control logic
 - 10. To backup restore configuration data
 - 11. To execute batch recipes within the continuous process, for example cleaning cycles
 - 12. To provide safe shutdown in the event of a hardware failure
 - 13. Able to alert the operator, in real time, when some part of the DCS hardware or a field device fails
 - 14. To be immune from physical, electromagnetic, electronic, environmental intrusion
 - 15. To be ergonomic

Item description:
Distributed control system (DCS)

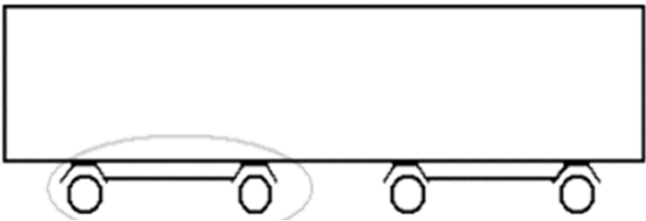
Redundancies and protective features (include instrumentation):
Built-in test equipment (describe):
Hidden functions: Yes, UPS

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Example: Passenger rail car truck (bogey)

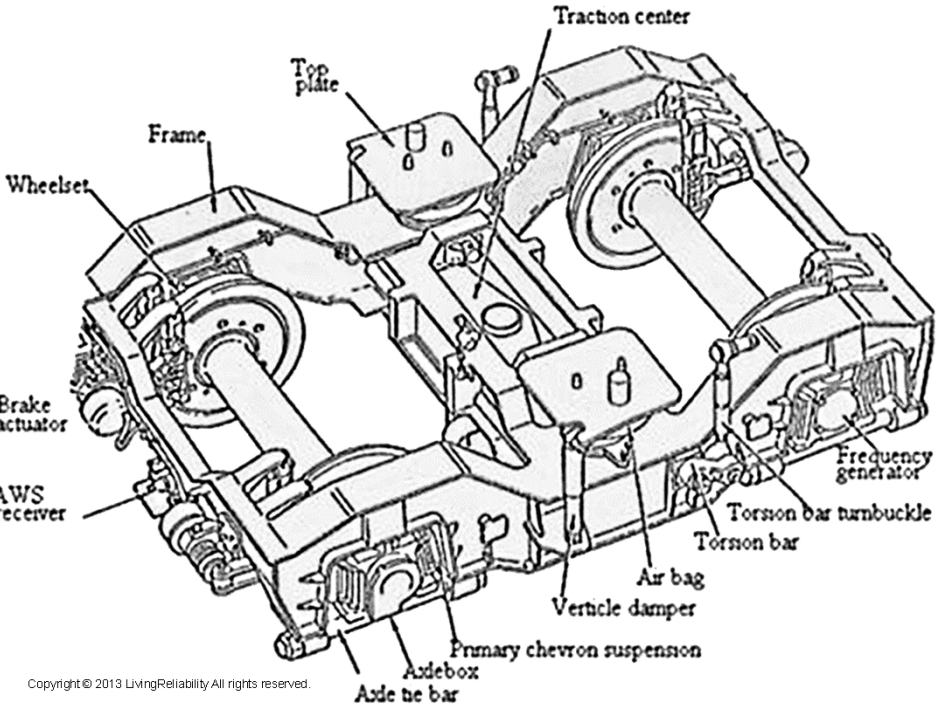


Using the following images and documentation, perform a functional analysis as a set of function statements.

Examine each component and associated text and ask: What function does this component suggest?

- 1. Include one or more quantitative specifications in your primary function statement.

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Each passenger car weighing up to 53 T is mounted on two four-wheel trucks (also called bogies). Each bogie supports 1/2 the weight of the passenger car.

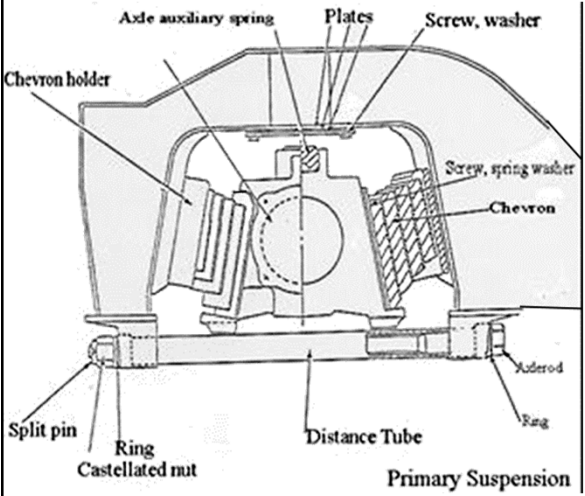
Hint: Consider the primary function “To support ...” under typical operating regimes”

- 1. The general state.
- 2. A specific (typical, high load) state: Traveling along the rails at 120 kph.

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Example: Passenger rail car truck (bogey)

Primary suspension



The primary suspension consists of rubber/steel chevrons which mount the axle box to the truck frame. The inherent damping within the chevron assemblies avoids the necessity for supplementary dampers in the primary suspension. The axle box also houses a rubber bump stop, which serves to prevent direct contact between the truck frame and the axle box under severe bounce conditions.

The arrangement of the primary suspension shows the tie bar arrangement under the axle box.. The tie bar arrangement consists of a spacer tube, tie bar, locating rings and suitable fasteners. The tie bar serves two purposes, it ensures the wheel arch structural integrity and also allows the truck to be lifted from its wheel sets. The load of the wheel sets is supported by the tie bars via the axle boxes, when a complete truck is lifted.

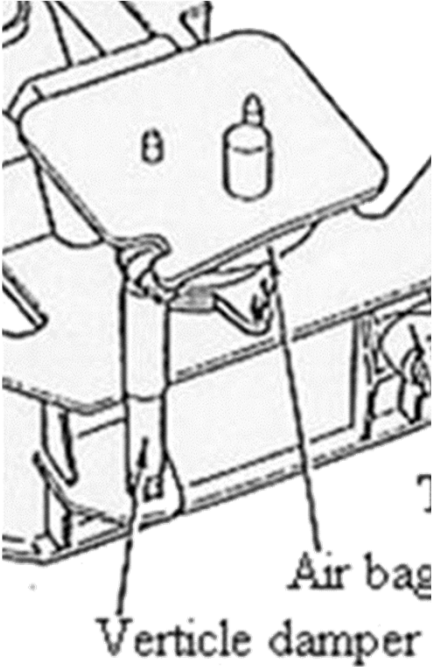
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Example: Passenger rail car truck

Secondary suspension (vertical damper)

Vertical oscillations are damped by two hydraulic shock absorbers, one each side of the truck adjacent to the secondary suspension. The dampers being mounted on brackets on the truck side frame at the one end and to the air spring top plate at the other end.



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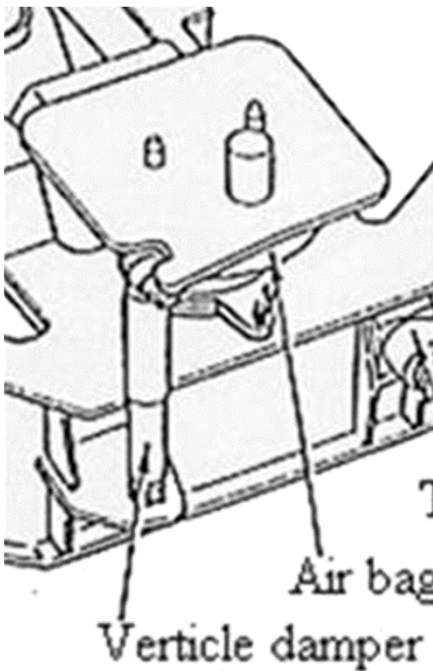
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Secondary suspension (air spring)

A leveling valve mounted on the car controls the air pressure in the air springs and maintains a constant floor height independent of passenger loading. Passengers stepping into or from the car at each station should not experience any difference in elevation between platform and car floor.

The air spring is a component of the secondary suspension insulating passengers from bumps on the rails. It is connected to the car bolster by an air spring top plate. These plates can only be fitted in a certain manner (Figure) and serve as both the mechanical and pneumatic connection to the car. The lower sealing face of the air spring seals onto the top of the layer spring assembly.

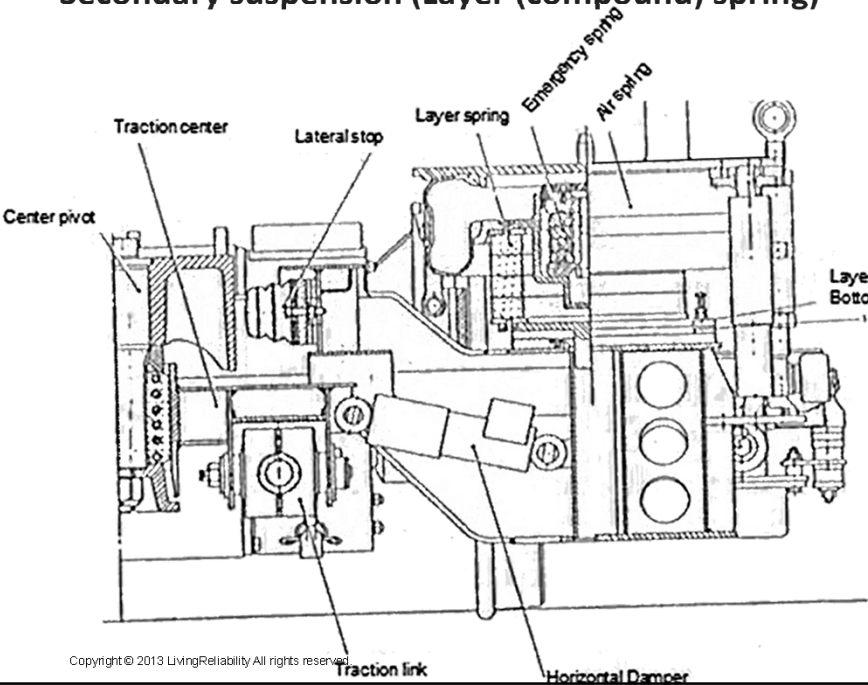


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Secondary suspension (Layer (compound) spring)



The layer spring consists of a series of rubber and metal elements bonded together. A plate on the top of the layer spring serves as the sealing face for the air spring and as a housing for the emergency spring.

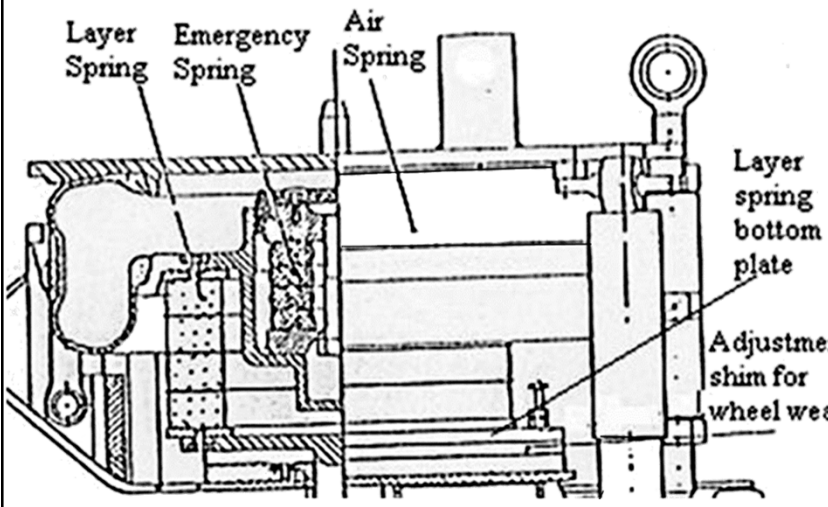
The layer spring is held in longitudinal position by a bolt with split pin protection. The layer spring keeps the top plate centered longitudinally with respect to the center pivot through which the entire forward driving force is transferred.

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Secondary suspension (Emergency spring)

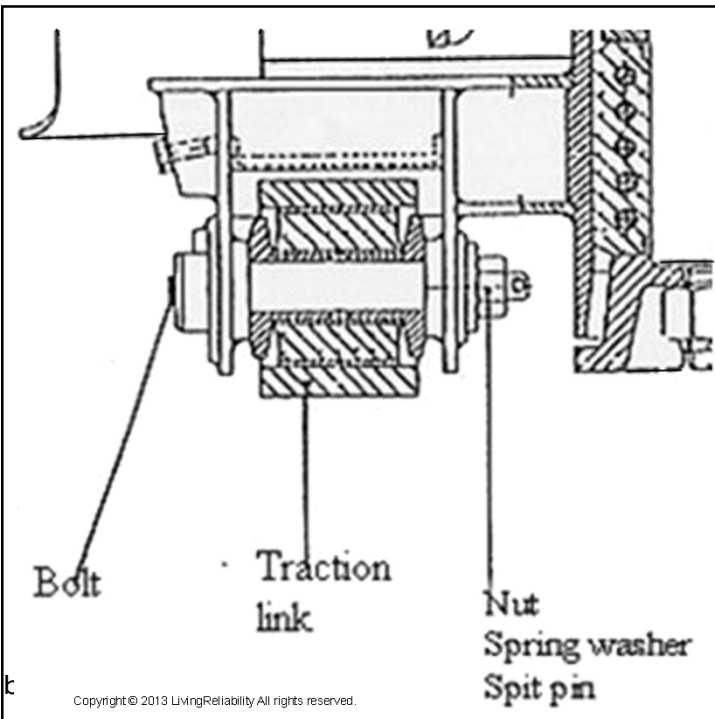


In the event of the air spring being deflated, the car will rest on emergency springs which are located on top of the layer springs. The emergency spring comprises a metal/rubber assembly and has a low friction surface fitted to its upper surface. This low friction surface allows the use of a vehicle in service with a deflated air suspension, albeit with a reduced quality of ride.

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Traction Link

Tractive and braking forces are transferred from the truck frame to the traction center by two traction links. The traction links house resiliently mounted bushes in each eye, so that the forces are transferred as smoothly as possible.

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Torsion Bar & Turnbuckle Assembly

A torsion bar passes through one of the lateral tubes mounted in the transom and through holes in the side frames, adjacent to the bearing housing brackets.

Roll of car body relative to truck is controlled by an anti-roll torsion bar, which is housed in the truck transom and connected to the car body by a turnbuckle linkage.

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Frequency generator

Torsion bar turnbuckle

Torsion bar

Air bag

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Lateral stops, Lateral dampers

The lateral bump stop assemblies limit the possible lateral body movement relative to the truck. Each bump stop assembly consists of a bounded rubber/steel bump stop and a fixed stop, such that any lateral movement is unrestricted until the center pivot comes into contact with the bump stop; further movement is then resisted by elastic deformation of the bump stop until the fixed stops are met.

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Resilient bump stop

Distance washer

Spring washer

Nut

Lateral stop

Shim

Spring washer

Nut

Bolt

Traction link

Nut

Spring washer

Split pin

Traction link

Bolt

Lateral damper

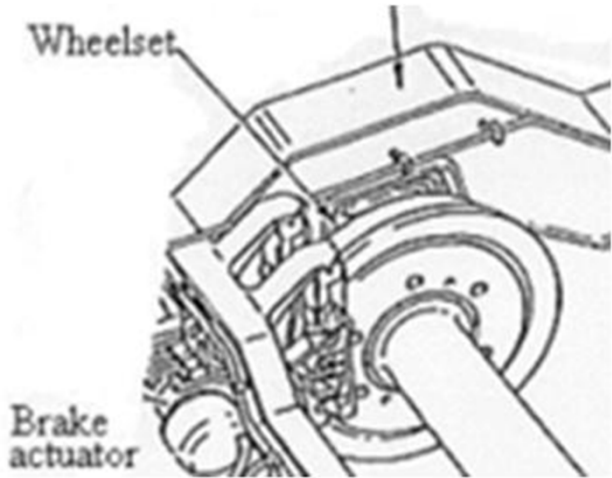
Traction Center Assembly

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Example: Passenger rail car truck

Brake actuator



All trucks are fitted with disc brake equipment.

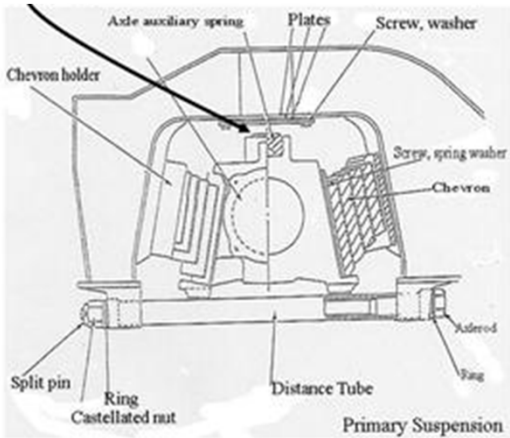
Actuators for the wheel mounted discs are mounted on each headstock. The actuators on the trailer trucks are not fitted with parking brake facility.

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Example: Passenger rail car truck

Axle auxiliary spring



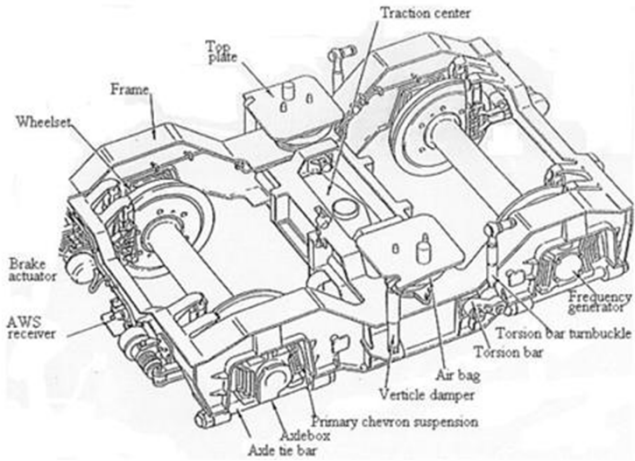
is located on each axle box and strike plates are screwed onto the wheel arches

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Example: Passenger rail car truck

Lifting lugs

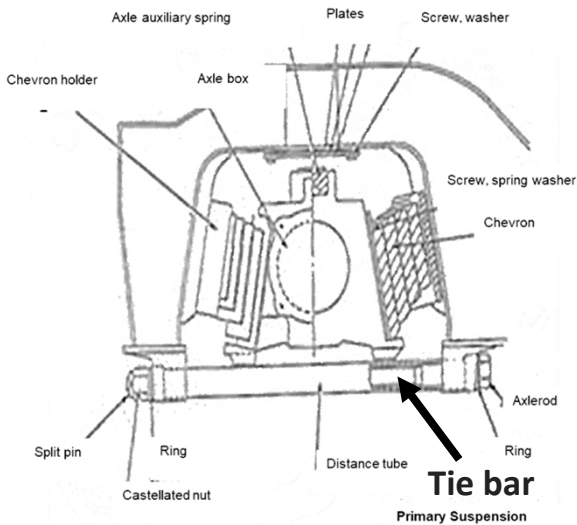


Four towing points are fitted, two to each side frame, in-board of the wheel arches. The points can also be used as lifting points, when handling individual trucks.

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Tie bar



The arrangement of the primary suspension shows the tie bar arrangement under the axle box.

The tie bar arrangement consists of a spacer tube, tie bar, locating rings and suitable fasteners. The tie bar serves two purposes, it ensures the wheel arch structural integrity and also allows the truck to be lifted from its wheel sets. The load of the wheel sets being supported by the tie bars via the axle boxes, when a complete truck is lifted.

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Lateral bump stop

The lateral bump stop assemblies limit the car's possible lateral movement relative to the truck. Each bump stop assembly consists of a bonded rubber/steel bump stop and a fixed stop such that any lateral movement is unrestricted until the center pivot comes into contact with the flexible bump stop; further movement is then resisted by elastic deformation of the bump stop until the fixed stops are met.

Traction Center Assembly

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Split pin

Prevents the traction link retaining nut from coming undone.

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Wheels, axle

Wheels of BR-PB profile of mono-block constructions, are shrunk onto solid one piece axles which run in double roller bearing axle boxes. The wheel specification being to BS 468 class D oil hardened and tempered.

The axles are manufactured from low alloy steel conforming to the BR specification 109A. The wheels are shrunk onto the axles and the wheel set is balanced in accordance with BR specification 163. To effect removal of the wheels, the hubs are drilled with two diametrically opposite oil injection holes. The gearwheel is also fitted with an oil injection hole to assist removal. The axle ends are suitably center drilled to allow wheel turning on a wheel lathe.

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Example: Passenger rail car truck

Axle box


The axle box is a forged aluminum alloy body fitted with a shell liner which provides the housing for two self aligning bearings which are directly mounted on the axle.


Machined on each side of the axle box body is a mounting to carry the primary suspension, each chevron being retained to the mounting with two bolts. At the top of the forging is a machined circular housing to accommodate the axle box rubber bump stop.


A sealing collar is abutted up to a shoulder on the axle, and open cover fitted over it. Labyrinth grooves in the collar and cover prevent leakage of grease from the rear of the axle box. The front of the axle box is sealed by either a front cover or the housing of a frequency generator via an adaptor plate. The axle box is lubricated with a lithium base grease such as Shell Alvania 3, Exxon Beacon 3, or a comparable approved grease.


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Functional analysis – Rail car bogey


▼  Passenger Rail Car Bogey v7.1


▶  1. To provide smooth rolling support for (up to 26.5 tons) speeds up to 120 kph


▶  2. To insulate passengers from shocks, Minimize transient oscillations


▶  3. To insulate passengers from jerks during acceleration and braking


▶  4. To control the roll angle of the car body relative to the bogie


▶  5. To ensure carriage floor is level with platforms at each station stop


▶  6. To assist in stopping the train at up to 0.88 m/s2


▶  7. To prevent axle box bogie frame contact under severe bounce conditions


▶  8. To permit the bogie to be lifted and/or the car to be towed easily

▶  9. To ensure wheelsets remain attached to bogie while bogie is being lifted

▶  10. To insulate the car from shocks to some extent if the air bag fails

▶  11. To limit lateral movement of car relative to bogie

▶  12. To prevent traction link retaining nut from coming undone

▶  13. To prevent compound spring retaining nut from coming undone

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2.2.1 QUIZ 3 FUNCTIONAL ANALYSIS

<https://forms.gle/QX5VCpvUbgRfvBSj7>

1. When composing the function statement, including more than one performance standard: * 1 point

☐ 1. Will make the analysis more complicated

☐ 2. Will increase the number of functions

☐ 3. Will make the analysis simpler and more easily read by others.

☐ 4. all of the above

☐ 5. none of the above

2. Often a deep component function can be included more conveniently and meaningfully when expressed as a failure mode of a failure of a "more primary" function. True or false? * 1 point

☐ True

☐ False

3. A non-quantitative (i.e qualitative standard) is used when: * 1 point

☐ 1. The analysts do not know the quantitative requirements.

☐ 2. The requirement varies over a range of values.

☐ 3. The requirement cannot easily be expressed quantitatively but the maintainer understands what the user has in mind.

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