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Engineering Procedure

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EPD 0005

REQUIREMENTS ANALYSIS, ALLOCATION AND TRACEABILITY

Version 2.0

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Document control

Revision	Date	Summary of change
1.0		First issue
1.1		Section numbering updated, Reference corrections and Document Control Page added.
1.2		Replace reference from RIC to RailCorp
1.3	31/8/05	Standardising Format.
2.0	October 2009	3 yearly review. See below for summary of changes.

Summary of changes from previous version

Summary of change	Section
Application of new Engineering Procedure format as specified in TMA 400	All
References to existing RailCorp Engineering Procedures – Design have been updated to the format specified in TMA 400 regardless of whether the document has been published in the new format at the time of publishing this procedure. Therefore ED 0019 P now reads EPD 0019 for example.	Several
Replace ‘major’ with ‘high complexity’ and ‘minor’ with ‘low complexity’	Several
Replace ‘design staff’ with ‘designers’	Several
Paragraph 2 – inserted ‘and safety’ after ‘customer’	1
Updated referenced documents	2 & 3
Reworded paragraph 2, replaced ‘references’ with ‘requirements’ in paragraph 3	2
Reworded to be consistent with other Engineering Procedures – Design	4
Paragraph 1, dot point 1, replace ‘commences’ with ‘begins’	
Minor rewording of paragraph 1, 4th dot point Removal of ‘or the award of a design contract to an external company, when final requirements have been established’ from end of penultimate sentence in paragraph 3 Paragraph 3 inserted new sentence ‘Some safety … … process.’	5.1
Paragraph 1 – inserted 6th dot point ‘opening of train doors shall be inhibited above 5kph’ Paragraph 4 beginning ‘Solutions define …’ deleted Figure redrawn, arrow from "Validation requirements & methods" box to the "Functional & performance requirements of design output" box added	5.1.1
Paragraph 1 reworded	5.2
Paragraphs 1, 3 & 4 reworded, last paragraph deleted New final paragraph ‘Safety requirements … … of RailCorp.’ inserted	5.2.1
Figure redrawn, paragraph 4 replaced ‘UPS’ with ‘uninterruptible power supply (UPS)’	5.3
Reference to DOORS included in paragraph 2 6th paragraph ‘, eg those where the design action can be recorded on the CCR documentation raised for the item’ removed	5.4
Replaced ‘Design Delivery Managers’ with ‘Project managers’	6.2
Data reduced in sample and additional image of an actual traceability record included.	Appendix

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1 Introduction

The requirements analysis, allocation and traceability process is designed to ensure that:

- all functional and performance requirements included in an engineering specification or design brief are taken into account when planning the design task
- each requirement is allocated to one or more functional systems, sub-systems or items to be met within the final design
- the fulfilment of each requirement is demonstrated as part of the design validation process.

The main focus of the methodology is to ensure that customer and safety requirements and other design inputs are properly understood before the design task begins and that compliance can be demonstrated within the final design.

The process also represents an important element in the management of risk. It helps to avoid situations where requirements are either not understood or overlooked at the start of the design task and to minimise the resultant time and cost of reworks to correct non-compliant aspects of the final design solution.

2 Scope

This procedure establishes processes to be used to ensure that the requirements of the applicable engineering specification are fully represented in the output of each design task.

To align with the scope of design development typically undertaken in Rail Corporation NSW (RailCorp) projects the process described in this procedure is scaled down from the full functional and requirements analysis process described in *ISO/IEC 26702* and similar standards such as *AS/NZS 15288:2003*. Key elements have been retained in tailored form to achieve the objectives stated in 1.

The tailoring of this procedure does not mean that full functional analysis may not be required for some projects such as the development of control systems having a major software element. The need to use more detailed techniques such as functional flow diagrams, state and transition diagrams, timelines and control and dataflow diagrams for such projects shall be determined on a case by case basis and applied in accordance with the appropriate standards and requirements.

3 Referenced documents

ISO/IEC 26702 (IEEE Std 1220-2005) Systems engineering—Application and management of the systems engineering process

AS/NZS 15288:2003 (ISO/IEC 15288:2002) Systems engineering—System life cycle processes

4 Definitions and terms

Refer to the glossary in EPD 0001 for definitions and terms used in this procedure.

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5 Requirements

5.1 Process application

The primary purposes of the requirements analysis, allocation and traceability process which are to be applied for RailCorp design tasks are to ensure that:

- design requirements are clearly identified before the task begins
- each requirement is allocated to one or more systems and sub-systems to establish specific requirements for each system and to ensure that all functions and performance requirements have been taken into account
- a framework is established for validation of the final design solution
- traceable records are produced that demonstrate that all requirements have been considered during the design process and that the final solution has been validated.

The process is normally applied in three distinct but continuous stages. The scope, level and complexity of each stage may vary considerably between high and low complexity projects. However, the principles set out in this section apply equally to all design work and must be applied for all design tasks to the extent described under individual headings.

Requirements analysis normally begins during the assessment of a design/development task to assist in preparing an estimate or quotation or as part of a task to develop a concept design brief. It involves a detailed review of the specification/s to identify all operating and performance characteristics to be met by the final design as well as initial assessment of ways of meeting the requirement and the risks associated with compliance. The process is completed as the first design activity following acceptance of a design task by design personnel. Some safety requirements will be derived through the safety change process. for projects identified as 'significant' through the SMS safety change assessment and reporting determination (SCARD) process The process is described in more detail in 5.2.

Requirements allocation represents the first stage of design synthesis and is generally completed in conjunction with initial planning of the system architecture within either the concept or preliminary design phases. It involves an assessment of the functions, physical/performance characteristics and outputs that must be delivered by individual systems, sub-systems and items to meet the requirements of the specification (design inputs). The end result is the determination of how each individual requirement of the specification will be met within the final design and allocation of each requirement to one or more systems and items. The process must continue until all relevant requirements have been identified and allocated. The process is described in more detail in 5.3.

Traceability records provide the link between specification requirements and the results of tests or other methods used to validate the final design solution. Creation of a traceability record from the outset of the design process provides the basis for system validation, test and commissioning plans and provides the main documentation to support the systems verification review conducted at the completion of high complexity projects.

Each aspect of the requirements analysis, allocation and traceability process is described in more detail in the following paragraphs. The process is shown in simplified form in Figure 1.

5.1.1 Requirements versus solutions

Clear differentiation between requirements and solutions is a key consideration in the requirements identification process.

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Requirements establish specific outputs such as level of performance or characteristics to be achieved by the new design or design change to meet the intended purpose. Examples of requirements include:

- track components shall be designed for a speed of 115 Km/hr
- safety factor for supplementary conductors and other wires shall be 2.5 (min)
- design life of the bridge shall be 100 years
- improve reliability of item X to achieve an MTBF of 25,000 hours
- all structures shall be galvanised to Specification XXX
- opening of train doors shall be inhibited above 5 kph.

Requirements are typically, but not consistently, identified in specifications by use of the term ‘shall’. Other terms such as ‘should’ or ‘may’ indicate that the specification statement is desirable but not mandatory.

The requirements identification and allocation processes must focus on requirements so that designers have a clear understanding of the outputs to be achieved by the design and are able to assess alternatives and to understand and assess implications of the change.

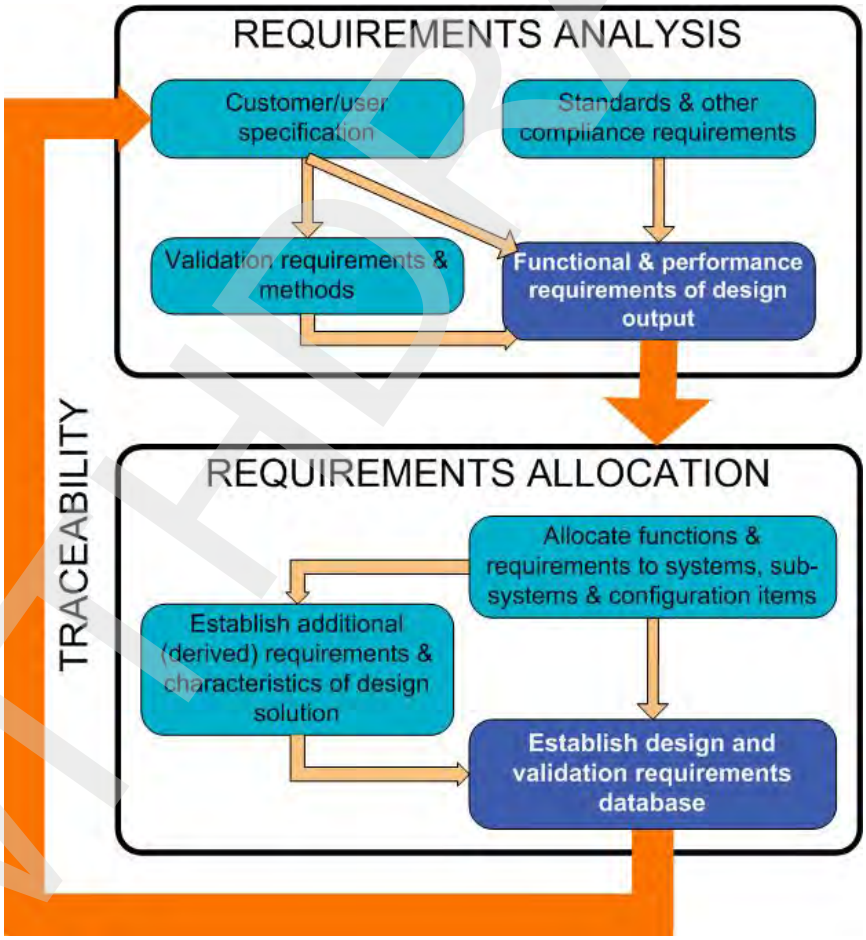

Figure 1- *Requirements analysis, allocation and traceability*

5.2 Requirements analysis

All design work performed by or on behalf of RailCorp shall be carried out to meet customer requirements. To ensure that this is achieved the first stage in any design task

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shall be to analyse the task specification and document specific operating and performance requirements for individual elements of the design.

The initial requirements analysis process should also be used to establish validation requirements and methods where these are specifically identified in the specification and where it is possible to do so.

5.2.1 Requirements analysis – high complexity projects

Requirements analysis for high complexity projects must be undertaken using a top-down approach, particularly where the project involves the design and integration of multiple infrastructure systems. This is necessary as some specifications include general sections that apply to the system as a whole, ie are not related to individual items or elements of the design, which must be flowed down to individual systems and sub-systems, examples include:

- overall system performance requirements such as transit times and maximum design speed
- reliability and maintainability requirements that are grouped in other than system terms
- design life
- environmental design criteria. Environmental design criteria generally relate to either the natural or the built environment and include aspects such as the operating temperature range, exposure to ultra-violet radiation, wind, rain, vibration, humidity, EMI/EMC under which the item or system is designed to operate.

Requirements analysis is an iterative process that must be applied to each design phase. As designs progress through each phase the initially identified requirements shall be further allocated to various major components as appropriate.

The requirements analysis may be performed manually or with the aid of computer aided systems engineering (CASE) tools. Whichever method is used the essential outcome is to ensure that design requirements are clearly identified and documented for the project being undertaken.

This is necessary even when the proposed design concept and approach is based on the application of standard designs or the use of type approved equipment.

The use of standard designs represents the preferred approach where appropriate and cost-effective. However, all designers have an obligation to ensure that the use of a standard design approach:

- is consistent with the functional and performance requirements specified by the customer/user, and
- represents a cost-effective solution. In particular it is essential that the use of standard designs does not result in solutions that are substantially in excess of user requirements and which will lead to increased construction costs or to increased support costs.

Responsibility for requirements analysis may be approached in different ways within different projects. However, it is essential for each design discipline to review the entire specification, including general sections, to establish the full set of requirements that are applicable to a particular system or item within each discipline.

Requirements should be grouped by individual systems and, where appropriate, sub-systems to ensure that all requirements applicable to each system/sub-system are taken into account in developing the design.

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Interface requirements shall also be considered and documented as part of the requirements analysis process. These interfaces may be between systems or sub-systems within the same discipline, between systems managed by different disciplines or with systems/requirements managed by external agencies. Each identified interface represents one or more design requirements to be taken into account within the final design solution and will often represent a constraint on the solution adopted. Management of interfaces is further covered in *EPD 0007*.

Safety requirements identified as part of the safety change hazard analysis process represent inputs for high complexity projects. *EPD 0008* establishes requirements for the application of hazard and risk analysis processes as part of every engineering design task undertaken by or on behalf of RailCorp.

5.2.2 Requirements analysis – low complexity projects

Developing a clear understanding of design requirements and objectives is equally essential for low complexity projects as it is for high complexity ones. In many cases it will be even more critical, particularly if a configuration change request (CCR) is expressed in terms of a solution rather than a requirement.

In most cases the process for low complexity projects and design changes will be limited to identifying those specific characteristics of the design that are to be affected by the proposed change. This includes potential changes to specific items and the effect on internal or external interfaces within the existing design in order to meet altered performance requirements and objectives for the change.

Requirements for low complexity changes must also include new validation or re-validation requirements for items affected by the change. This will be necessary in every case where the performance envelope or conditions of use are to be changed or where the performance envelope for the section of the infrastructure affected by the change is not properly documented or is uncertain.

Proper evaluation of requirements for low complexity projects and CCRs represents an essential step in creating/maintaining accurate configuration management and design records for the infrastructure system. Recording the purpose of each change or addition to the system, as well as the detailed changes made to the approved design configuration, is not only essential for documenting the current approved configuration but for assessing the impact of future changes. *EPD 0014* sets out more detailed requirements for configuration management.

5.3 Requirements allocation

The flow down of requirements from the specification to individual systems, sub-systems and items is illustrated in the simplified diagram in Figure 2.

Allocation of requirements to individual systems, sub-systems and items is a continuation of the requirements identification process. The primary objective is to ensure that all specific and common requirements, including interface definitions, are established for each sub-system and item as appropriate.

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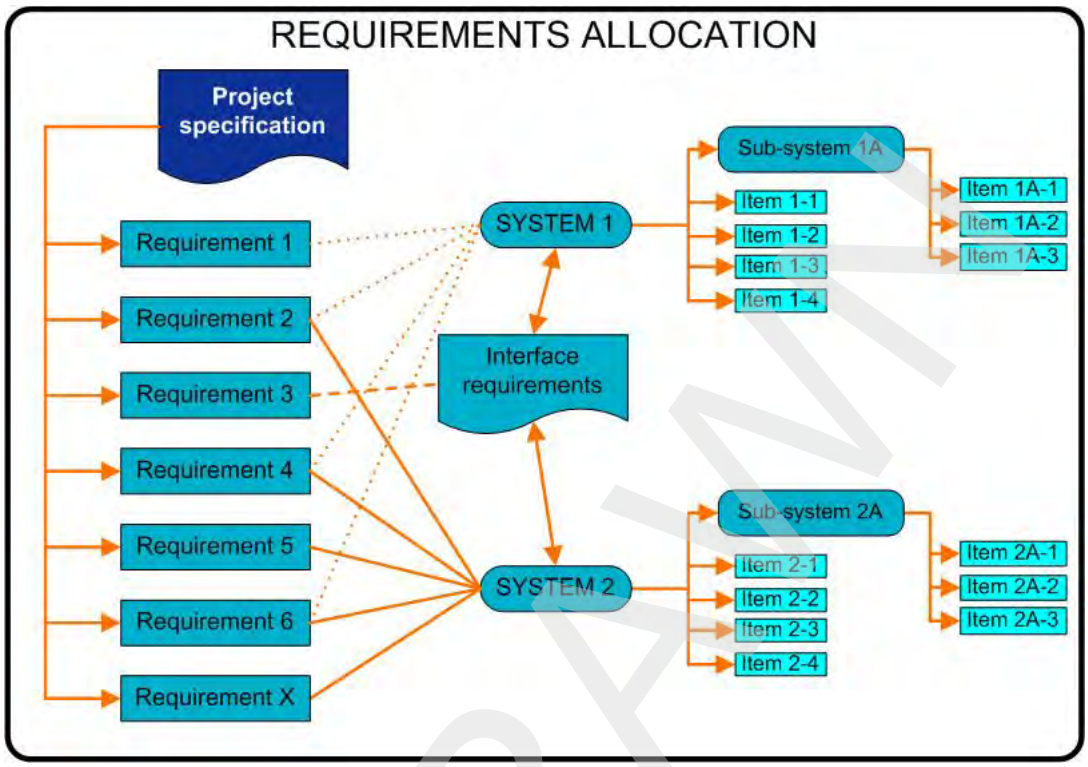

Figure 2- *Requirements allocation*

The diagram in Figure 2 shows only the first level of allocation. Functions to be met at the sub-system level will clearly need to be met by one or more items comprising that system or sub-system. The allocation process may need to be extended by one or more levels to provide a comprehensive picture of the requirements to be met by the design of each item.

Requirements allocation must take account of the application of common requirements to individual systems and items (refer to 5.2.1) and may lead to the identification of derived requirements and corresponding changes in system architecture during concept development. For example, a requirement for the system to continue operation for a period following mains power failure may lead to the requirement for an uninterruptible power supply as well as appropriate sensing and switching functions in one or more hardware/software elements.

5.4 Documentation of requirements — traceability

Documentation of requirements and the allocation of each requirement to one or more systems, sub-systems or items shall be carried out progressively as the analysis is performed.

The scope of the documentation required will be a function of the complexity of the project, the number of systems/disciplines involved and the number of requirements. Similarly, documentation methods will be influenced by the tools in use within a high complexity project, eg the possible use of CASE tools such as DOORS. *(DOORS has been adopted by RailCorp for requirements analysis, allocation and traceability and is currently being used on the ATP Project.)*

Where CASE tools are not being used a relatively simple spreadsheet may be used to establish traceability records for both high and low complexity design tasks. The spreadsheet provides a permanent record of the set of requirements to be met, the

allocation of these requirements to individual systems/sub-systems as well as a basis for tracking the status of validation requirements.

A sample requirements analysis, allocation and traceability matrix (RATM) is shown in the appendix.

A matrix in this form shall be prepared for all but very simple changes.

The completed matrix is to be maintained and filed as part of the design record for the item or system concerned.

6 Responsibilities

6.1 Design engineers and supervisors

Design engineers and supervisors responsible for planning and completing design tasks are to ensure that the requirements for the task are clearly identified and recorded using the general methodology set out in this procedure.

6.2 Project managers

Project managers are responsible for ensuring that consolidated requirements analysis and traceability records are established for all low and high complexity projects and are completed to provide documentary evidence of validation of all elements of the design.

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APPENDIX Sample requirements analysis, allocation and traceability matrix (RATM)

NOTES:
1. Requirement classes used in this example are function = F, physical = P, interface = I
2. Validation requirement refers to the method to be used. Refer to *EPD 0012*
3. Example is taken from New Southern Railway Fit-out Project
4. The following page contains an image of an actual traceability record

Req no	Spec para ref	Description	Parameter	Requirement class	Applicable standards	Standards status	Allocate to	Validation req	Compliance	Compliance reference	Test plan no	Test plan status	Test report status	Notes
C6-1	1	Signalling system	Control	F I			Signals TICS	T						
C6-2	1	Signalling system	Operation	F			Signals	T						
C6-4	1	Signalling system	Signals/TIC interface	F I			Signals TICS	DT						
C6-7	4.1	Headway	3 minutes	F	Signal design principles	C	Signals	DA						
C6-12	4.1	Signalling system	Speed boards	P	Civil?	?	Signals	DI						
C6-15	4.2	Performance	Availability /reliability	F	NSR	C	Signals	AT						
C6-18	5.1	Signal design	Control tables	F	Signal design principles	C	Signals	D						
C6-33	5.4.1	Signals operation	1300m from control	F			Signals	T						
C6-37	5.4.2	Signals	Mounting method	P			Signals	D						
C6-41	5.4.4	Tunnel signals	A lights	P	Signal design principle A9	C	Signals	DI						
C6-42	5.4.4	A lights	Construction	P	571	C	Signals	I						
C6-46	5.5	Trainstop	Operate to 1300m	P			Signals	T						
C6-124	C3 4.8.2/3	Catenary switching	Interface	I			Signals, Elec	DTC						
C6-125	C3 & C5	Station SCADA	Interface	I			Signals	DTC						
C6-126	C3 4.4.9	Airgaps	Location	I	EP 0802DM	N	Elec	I						Also Signalling Design Principle A12, plus new RAC Electrical Standard

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Requirements Matrix

Requirment No.	Pargraph ref.	Description	Parameter	Requirement Class	Applicable Standards	Standards Status	Allocated to	Verification Req.	Qualification Method	Compliance - 1	Compliance - 2	Compliance - 3	Compliance Reference	Test Plan No.	Test plan Status	Test Report Status	Notes
C6-1	1	Signalling System	Control	F I			Signals TICS	T									
C6-2	1	Signalling System	Operation	F			Signals	T		Yes			M Train, Function test				
C6-3	1	Signalling System	Outputs/Inputs	F I			Signals TICS	T									
C6-4	1	Signalling System	Signals/TIC Interface	F I			Signals TICS	DT									
C6-5	1	Signalling System	Signal Maintenance	F I			Signals TICS	DT									
C6-6	1	Signalling System	Lineside Cupboards	P	708	C	Signals	D									
C6-7	4.1	Headway	3 minutes	F	Signal Design Principles	C	Signals	DA		Yes			M Train				
C6-8	4.1	Signalling System	Failure Modes	F			Signals	D									
C6-9	4.1	Detailed Design	Maximum Speeds	F			Signals	D		Yes			M Train, Braking, Overlaps				Requires Civil Input
C6-10	4.1	Operational Requirements	M Train Simulation	F			Signals	A		Yes			M Train,				
C6-11	4.1	Signalling Plan	Submission to TBJV	P	703	C	Signals	D		Yes			Transmittal				
C6-12	4.1	Signalling System	Speed Boards	P	Civil?	?	Signals	DI		Yes			Specification / M Train				
C6-13	4.2	Performance	MTBF/MTHE	F			Signals	DA									
C6-14	4.2	Performance	Fault Correction	F			Signals	DA									
C6-15	4.2	Performance	Availability/Reliab.	F	NSR	C	Signals	AT									
C6-16	4.3	Maintenance	Test Equip Details	F			Signals	D									
C6-17	5.1	Signal Design	Design	F	Signal Design Principles,703	C	Signals	D		Yes			Verification Form				
C6-18	5.1	Signal Design	Control Tables	F	Signal Design Principles	C	Signals	D		Yes			Verification Form				
C6-19	5.2	Main Equipment Room	Controlled Equipment	F			Signals	DT									
C6-20	5.2	Track Plan	Track Circuit Position	F			Signals	D		Yes			Verification + Review				
C6-21	5.3.1	Track Circuit	Capability-1300m	F	1057	C	Signals	TC		Yes			Verification + Review				
C6-22	5.3.1	Track Circuit	Termination	P	1057	C	Signals	D									
C6-23	5.3.2	Track Circuit	Type/Brand	P	1057	C	Signals	DI									
C6-24	5.3.2	Track Circuit	Maximum Length	P	1057	C	Signals	D		Yes			Verification + Review				
C6-25	5.3.2	Track Circuit	Cross Sectional Area	P	1057	C	Signals	D									
C6-26	5.3.3	Tie in Traction Bonding	Design	P	Signal Design Principles S8	C	Signals	D		Yes			Also Spec - See Verification Report				
C6-27	5.3.3	Tie in Traction Bonding	Positioning	P	Signal Design Principles S8	C	Signals	D		Yes			" "	" "		"	
C6-28	5.3.4	Impedance Bonds	Construction	P	586	C	Signals	I									
C6-29	5.4.1	Track Plan	Signal details	P	703	C	Signals	D		Yes			Verification Report				
C6-30	5.4.1	Signal Sighting	Survey	P	705/703/571	C	Signals	D									
C6-31	5.4.1	Signal Sighting	Form	P	705/703	C	Signals	D,I									
C6-32	5.4.1	Signal Sighting	Track Plan Amendments	P	703	C	Signals	D									
C6-33	5.4.1	Signals Operation	1300m from Control	F			Signals	T									
C6-34	5.4.2	Signal	Construction	P	571	C	Signals	I									
C6-35	5.4.2	Signal	Insulated Terminal	P			Signals	DI									
C6-36	5.4.2	Signal	Cable Screen Label	P			Signals	I									
C6-37	5.4.2	Signals	Mounting Method	P			Signals	D									
C6-38	5.4.3	Turrella Main & Shunt Controlled Signals	Control from CRCC	F			Signals	DT					Outside Contract Scope				
C6-39	5.4.4	Automatic Platform Signal	Signal Replacement Control from CRCC	F	Signal Design Principle A8	C	Signals	DT		Yes			Verification Report				
C6-40	5.4.4	Automatic Signals at nominate locations	Emergency Replacement	F	Signal Design Principle A8	C	Signals	DT		Yes			As C6.39				
C6-41	5.4.4	Tunnel Signals	A Lights	P	Signal Design Principle A9	C	Signals	DI		Yes			As C6.39				
C6-42	5.4.4	A Lights	Construction	P	571	C	Signals	I									
C6-43	5.4.5	Guards Indications	Provision	P	571	C	Signals	I									
C6-44	5.5	Track Plan	Trainstop Position & Identification	P	703	C	Signals	D		Yes			Design Verification Report				
C6-45	5.5	Trainstop	Provision	P	274	C	Signals	I									
C6-46	5.5	Trainstop	Operate to 1200m	P													

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