



(Minor changes to the previous edition are indicated by ◆ placed before the relevant paragraphs)

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1. Scope

This Specification is written to comply with Engineering Standard 1-202 in defining the requirements for the overhaul of all variants of Style F3 relays which are used extensively in the signalling system on the London Underground.

The specification hierarchy which supports these requirements is detailed in Attachment 4 to the Specification.

2. Reference

The text of this document cites other documents that provide information or guidance. These are listed in Attachment 1.

References to British Standards or standards in other standards systems shall be taken to include the words 'or equivalent'.

3. Abbreviations

The following abbreviations are used in this document (if from a published source this is indicated):

CPS	Critical Parameter or Setting
DCN	Design Change Notice
LU	London Underground
OEM	Original Equipment Manufacturer
WSL	Westinghouse Signal Limited

4. Definitions

The Client – The Client is the Infraco representative responsible for administering the contract under which the overhaul work is being performed.

The Contractor – The Contractor refers to the organisation responsible for the delivery of overhauled equipment.

A Front Contact – A front contact provides a very low resistance (short circuit) electrical connection between two terminals of the relay when the relay is in an energised state.

A Back Contact – A back contact provides a very low resistance (short circuit) electrical connection between two terminals of the relay when the relay is in a de-energised state.

5. Introduction

This specification has been written to detail the overhaul requirements of Style F3 Relays which are used in the signalling system on the London Underground.

The F3 Relay is classified as an item of vital signalling equipment which means that it may be used in the critical safety circuits directly affecting the safe movement of trains. It has been designed to fail-safe principles and manufactured to exacting tolerances to ensure that it fulfils its safety role throughout a very extended life. It is a mandatory requirement that a relay that has been overhauled shall have a functional performance, a safety integrity, a reliability, an expected service life in its installed condition and a shelf life equivalent to that of a new relay.

Any failure condition which causes the relay to behave as though

- it is energised, when the voltages required to energise it are not present
- any front and any back contact are closed simultaneously, or
- any contact or coil has an electrically conductive path to any other contact or coil

is classed as a “wrong-side” failure. Wrong-side failures are investigated exhaustively to establish the cause of the failure. Investigations into wrong-side failures will examine materials, processes and the history of overhaul operations to establish the exact cause of the event and to ensure that no other items are likely to suffer a similar failure. An occurrence of a wrong-side failure, or a misoperation showing a tendency towards a wrong-side failure, even if no accident or damage is caused, can be extremely costly to investigate and could result in the need to change many units in service.

Items supplied for overhaul will be complete units which may be in working order or may have failed in service. The failure mode of equipments will vary, ranging from simple causes such as open circuit contacts, to items which have suffered severe damage. In the latter case there will be an element of salvage involved in the overhaul process. The equipment will be supplied in an 'as found' condition after being removed from its working position on the railway.

The service life of this equipment is 10 years. The shelf life is 3 years.

A general view of a Style F3 Relay is shown in Figure A

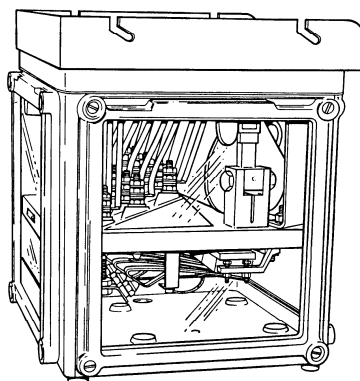


Fig. A General view of a Style F3 Relay

6. Usage of item

The F3 Relay has three main uses, all of which are in safety critical circuits and applications involved with the safe running of the railway. F3 Relays are used:-

- As an output device for delta-units. A delta-unit is an overlay track circuit device used to detect the presence of the leading bogie of a train as it passes through a route set by automatic route setting equipment. The delta-unit is positioned a train length plus 40 feet away from the exit point of a route through an interlocking. Its energisation is required to clear the route that has been taken by the train initiating the route energisation.
- As repeater relays in signal cabins and interlocking machine rooms for trackside located safety relays. Relays used in this mode carry the same safety weighting as the A.C. relays which they are repeating.
- As Tunnel Telephone relays used in conjunction with the tunnel telephone wires which run throughout the length of the non-surface railway. The tunnel telephone system is provided as a means of emergency communication from the train operator to a control point and also as a means of removing traction power by the train operator in an emergency.

The design of the relay has taken into account the high integrity that is expected from the item. Accordingly it is a large piece of equipment which seemingly is doing a very simple task. However, every aspect of the design has a direct influence on the safety of the item and therefore on the safety of the London Underground train service.

The design of the signalling system is based on fail-safe principles and hence the regular and expected failures (wires breaking, fuses blowing, loss of power supply, high resistance or open circuit contacts, etc.) do not cause dangerous situations to arise.

Three variants of the F3 Relay are in current use, being designed to operate on a D.C. supply of nominally 6, 12 or 60 volts. Some 'special' relays may be encountered. These will be dealt with on an individual basis as one-off variants of one of the standard types listed above.

The contacts are arranged as sets made up as a de-energised (back) contact, a common armature and an energised (front) contact. 6 sets of contacts are fitted to 12 volt and 60 volt relays. 4 sets of contacts are fitted to 6 volt relays.

Each variant has its own unique colour scheme for the case and window frames.

7. Equipment design outline

Key design features of all F3 Relays are that they have been designed to include:-

- Construction that is designed to be, as far as is practicable, fail-safe in operation
- An armature that does not rely on any bearing to control its movement. The armature is held in position by flexible nickel silver leaf springs.
- A combination of contact materials, pure carbon and silver, that are non-weldable
- An operating mechanism that only responds to D.C. energisation

The F3 relay is a D.C. tractive armature type of relay which will not respond to energisation with A.C. voltages. The iron circuit utilises brass residual pins to overcome any effect of residual magnetism between the iron core and the armature. Brass spacers and fixings are included in the magnetic circuit of the 60 volt version in place of the iron components used in the 6 volt and 12 volt versions. Since the core dimensions and coil windings are the same for all versions, a 'gap' material introduced into the iron circuit of the 60 volt version reduces the magnetic flux and hence the magnetising force.

The construction employs an inner top plate containing the integral coil and iron assembly, armature mounting arrangements and the contact assemblies. The relay is housed in a standard cast iron vane relay case with rigid wiring between the inner top plate and the standard relay top. A surge suppression diode is fitted across the coil of 12 volt and 60 volt versions.

Gravity, alone, is used to return the relay to its de-energised condition. The free movement of the armature is therefore critical to the correct and safe operation of the relays.

All front and back contacts are pure carbon. The armature contacts are pure silver.

8. Applicability

This specification applies to the following relay variants.

Item	Stores List No.
6 Volt Style F3 Relay	55s64
12 Volt Style F3 Relay	55s391
60 Volt Style F3 Relay	55s39

The Illustrated Parts List, Attachment 2 to this document, forms part of this specification.

9. Critical functions

Critical Functions of the F3 Relay are defined to be:-

Fail-safe Operation: The equipment has been designed and manufactured with the underlying premise that when the relay is de-energized (input voltage below a defined level) the energized contacts will, under all circumstances, open. This prime function of an F3 Relay is supported by other detail requirements which are also critical functions and are also detailed in this list.

High Integrity Electrical Insulation: All electrical wiring and insulating components shall maintain their integrity throughout the life of the equipment. No failure mode shall be allowed to compromise electrical insulation between any part of any circuit within the equipment.



Non-weldability of contacts: The contact materials are specified to be a pair of materials (silver and pure carbon) that have been proven to have a very low probability of welding when used correctly. The composition of the carbon contact is critical to maintain this design goal.

Defined minimum pick-up voltage: The application of the equipment in signalling circuits relies on the relay not energizing if it is supplied with less than the specified minimum pick-up voltage. The pick-up voltage is, to some extent, dependent on the mechanical integrity of the equipment. It is therefore vitally important that balance weights, or any other component that can have the effect of being a balancing component, are securely and reliably fixed in their correct operating position.

Defined minimum drop-away voltage: The application of the equipment in signalling circuits relies on the relay de-energizing if it is supplied with less than the specified minimum drop-away voltage. The drop-away voltage is, to some extent, dependent on the mechanical integrity of the equipment. It is therefore vitally important that balance weights, or any other component that can have the effect of being a balancing component, should be securely and reliably fixed in their correct operating position.

Freedom from mechanical binding. The design of the relay has taken into account the need for the armature to drop to its de-energised position when demanded by a lack of input voltage throughout an extended service life. To this end, no bearings are employed, the armature movement being controlled by phosphor bronze leaf springs. Clearances between components have been kept as large as practical and in most cases can be visually inspected from outside the relay when it is in its operating position.

Electrical Safety. Satisfactory earthing and bonding of the F3 Relay is crucial to ensure that leakage paths to the case or other extraneous metalwork in the event of faults do not give rise to electric shock hazards or to a loss of vital system integrity.

The ability of the item to meet the critical functions listed above throughout its life depends on many factors, not all of which are immediately obvious to people not familiar with all aspects of the design, overhaul and use of the equipment. To ensure that the significance of certain of the detailed requirements is understood and complied with, a number of Critical Parameters or Settings have been designated throughout the text.

Attachment 3 to this Specification lists all the Critical Parameters or Settings [CPS], a reference to the section from which the requirement originates and provides a Criticality Rating of the importance of each CPS item.

The Criticality Rating is based on the severity of the consequence if there is a deviation of the subject parameter from the value specified. Numerical values have been assigned to various levels of the Criticality Rating (CR) according to the table below.

Criticality Rating (CR)	SAFETY RELATED CRITERIA	RELIABILITY RELATED CRITERIA
10	Life critical – sole dependence Occurrence of this deviation alone may lead to an incident causing death or injury.	
8	Life critical – shared dependence Occurrence of this deviation, together with a second deviation which is potentially latent (i.e. not self	

Criticality Rating (CR)	SAFETY RELATED CRITERIA	RELIABILITY RELATED CRITERIA
	announcing), may lead to an incident causing death or injury.	
7	Life critical – contributory Occurrence of this deviation increases the probability of an event which may lead to an incident causing death or injury.	Service critical – sole dependence Occurrence of this deviation alone may lead directly to an incident causing major service delays, and indirectly to the danger of a life threatening incident through enforced use of manual rules for operating the railway.
6		Service critical – shared dependence Occurrence of this deviation, together with a second deviation which is potentially latent (i.e. not self-announcing), may lead directly to an incident causing major service delays, and indirectly to the danger of a life threatening incident through enforced use of manual rules for operating the railway.
5		Service critical – contributory Occurrence of this deviation, increases the probability of an event which may lead to major service delays, and indirectly to the danger of a life threatening incident through enforced use of manual rules for operating the railway.
1	Not life critical	Not service critical

The criticality rating provides a scale of the importance of achieving the specified parameter and therefore of the care needed in designing the process or processes that will lead to the parameter being achieved. The design of the process or processes that will lead to the parameter being met are the responsibility of the Contractor and they shall be designed and documented in accordance with the requirements of Engineering Standard 1-202, Signalling equipment overhaul.

10. Performance parameters

Values for the voltage parameters applicable to each of the three relay variants are as given in Table 1.

10.1 Pick-Up Voltage (V_{p-u})

The pick-up voltage is defined as that voltage which, when applied to the input terminals of the relay, causes any of the front contacts of the relay to close.

10.2 Drop-Away Voltage (V_{d-a})

The drop away voltage is defined as that voltage existing on the input terminals of the relay after having been gradually reduced from the normal voltage which allows all the back contacts to make.

10.3 Normal Voltage (V_{norm})

The normal voltage is defined as the rated voltage for each variant.

Relay Variant		6 Volt	12 Volt	60 Volt
Pick-up voltage (volts)	V_{p-u}	≤ 5.0	≥ 8.8 ≤ 10.0	≤ 35.0
Normal voltage (volts)	V_{norm}	6.0	12.0	60.0
Drop-away voltage (volts)	V_{d-a}	≥ 3.0	≥ 6.0	≥ 20.0

Table 1. TABLE OF OPERATING PARAMETERS

10.4 Contact resistance

The contact resistance, when measured at the rated contact pressure of the relay type and carrying a current of between 0.1 and 1 Amp (AC or DC) flowing through the contact, shall be less than 0.5Ω .

10.5 Insulation Resistance

The insulation resistance between all parts of the electrical circuits and the case of the relay shall be at least $50\text{ M}\Omega$ when measured at 1000V DC.

The insulation resistance between any parts of insulated circuits shall be at least $50\text{ M}\Omega$ when measured at 1000V DC.

11. Equipment configuration

An Illustrated Parts List is provided as Attachment 2 to this document, comprising an itemised list and associated exploded assembly drawings, to describe all three variants of the equipment as identified in Section 8 of this Specification. The Illustrated Parts List contains all relevant drawing numbers.

Drawing CS13427 details the terminal configuration of the detachable top for each type of relay. This drawing shall be used to configure the relay terminals with the exception of the earth terminal shown on the drawing, which shall not be fitted to any relay. All unused terminal positions shall be fitted with blanking plugs (item 2-37).

A convention of using the figure number followed by the item number has been adopted in this document to uniquely refer to specific components where necessary. Thus, item 1-12 is the relay case.

Unless specifically noted, drawings and figures used in this Specification are for reference only.

12. General requirements

12.1 Compliance with specification

No departures from the requirements of this Specification shall be permitted (either permanently or temporarily) without compliance with the relevant change control procedures.



Neither equivalence of process nor substitution of materials shall be recognised by the Client in receiving work performed against this specification. The Client shall have the immutable expectation that equipment overhauled to this version of the specification shall be 100% compliant with the specification herein.

12.2 Workshop environment

A number of operations associated with the overhaul of the F3 relay are sensitive to the ingress of airborne dust and other contaminants. Final assembly of overhauled relays shall therefore be performed in a 'clean' environment.

The silver and carbon contacts are sensitive to contamination from handling. The carbon contacts are prone to absorb grease and soap residues from the skin if touched with bare hands. Lint-free protective gloves shall be worn by operators when handling carbon and silver contacts.

A 'clean' environment is defined to be an area, with defined boundaries, inside which no food or drinks are allowed and no contaminants are generated or are allowed to circulate. A contaminant may be generated by filing, sanding, sawing, cleaning or any other similar operation.

Contaminants shall not be allowed to enter the environment from the surroundings through the airflow from unsuitable conditions

An acceptably clean environment shall not contain:-

- unsealed walls (bare brickwork)
- high ceilings with rafters, beams and light fittings with the potential for the buildup of dust which cannot be easily removed by regular cleaning during shut-down hours
- windows opening into other areas or the outside environment
- through passage routes between other uncontrolled areas

Once a sub-assembly becomes subject to clean area handling it shall not leave the clean area except that it be sealed in a clean transportation container or the relay is complete with all glasses fixed in position.

12.3 Calibre of staff

Any staff involved in the overhaul process shall be competent in the tasks they carry out and the overhauling contractor shall demonstrate this in accordance with the requirements of Engineering Standard 1-203, Competence of personnel working on signal and control systems.

12.4 Operator accountability

Process control documentation is required to be completed by identified certified (stamp-holding) operators and inspectors throughout the overhaul process. Each certified operator and inspector shall possess a uniquely numbered stamp which is traceable to the owner. Only competent operators shall be provided with a stamp. Records of the issue and withdrawal (if appropriate) of every stamp shall be kept and shall be made available to the Client on request. The retention period of these records is required to be indefinite.

13. Overhaul definition

13.1 Full overhaul

A full overhaul will be performed on relays which generally will have been in service for their full routine service life, as defined in Engineering Standard E7060, or which will have been removed from service as a result of a failure.

No item returned after failing in service shall be overhauled until the failure report has been reviewed and accepted by the Client in accordance with a defined arrangement agreed with the Client.

Unless stated to the contrary, all processes detailed in this specification shall be performed for each overhaul.

13.1.1 Dismantle

The relay shall be dismantled in a manner that shall not damage or shorten the life of any component that is required to be re-used. The life of all recyclable components is indefinite.

The items listed below shall be discarded and replaced with new items at every overhaul.

Top Gasket	Window Gaskets (all)	PVC Glass Seals (all)
Diode (if fitted)	Locking tabs (all)	Leaf Springs (both)
Contact Braids (all)	Earth Braid	Internal Wiring
Spade Terminals (all)	Aeronuts (all)	Carbon tips (all)
Screws – (all)	Nuts – (all)	Washers – (all)

The items listed below shall be scrapped and replaced with equivalent items as specified in the detailed parts listing.

Aluminium Top Frames	Aluminium Window Frames	Resin filled breather discs
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The Back Contact Studs (items 3-83), Front Contact Studs (items 3-84) and the Terminal Brackets (items 3-73) and their associated fixing nuts and lockplates shall **not** be removed from the Inner Top Plate (item 2-22).

Counterbalance Bars (items 3-61A and 3-61B) should not be removed from the armature.

Eyelets with disc (items 1-16) shall not be removed from the case at time of dismantling.

13.1.2 Cleaning and stripping

The following shall be implemented after the relay has been dismantled in accordance with Section 13.1.1 above.

All components shall be cleaned and degreased using a technique suitable for that component. A 'suitable technique' shall not cause short term or long term degradation to the component nor shall any solvent used leave undesirable residues on the component which will affect the performance of the component when it forms part of an overhauled unit.

13.1.2.1 Top Frame, Main Case and Window Frames

Components shall be cleaned and stripped back to bare metal using a process that ensures complete removal of all existing paint without causing damage or degradation to the component. Particular attention shall be paid to the preservation of thread forms.

13.1.2.2 Other metallic components

All components shall be cleaned and degreased using a technique suitable for that component.

13.1.2.3 Top Plate

The Bakelite top plate shall be cleaned and degreased.

13.1.2.4 Inner Top Plate

The Inner Top Plate shall be cleaned as a sub-assembly comprising the Top Plate moulding, Back Contact Studs, Front Contact Studs, Terminal Brackets and associated fixing nuts and lockplates. It shall be cleaned with a soft brush or air-line only. This sub-assembly shall not be immersed in any cleaning fluid.

Any corrosion or tarnishing of the lower pole faces shall be removed using metal polish. No other abrasive materials shall be used on the pole faces.

13.1.2.5 Glass

Glass from the side frames shall be cleaned and dried to remove any residue.

13.1.3 Examination and gauging

All components shall be examined for the effects of excessive or unusual wear, general damage, damage caused by misuse or age, electrical arcing or tracking or overheating. All thread forms shall be checked for signs of over-tightening. Items exhibiting damage that will not be corrected by the specified re-furbishing processes shall be discarded.

All occurrences of excessive or unusual wear or damage shall be catalogued and reported to the Client. Signs of electrical tracking or arcing shall be treated as excessive wear.

The subject items of such reports and as much of the unit from which they were removed as possible, shall be saved in their as near as original condition after being discovered and shall be clearly tagged and identified and shall be made available for Client inspection if so desired.

It is critical that **only** those components specified for refurbishment should be reclaimed after failing the wear tolerances specified.

Items not meeting the examination criteria shall be discarded if there is no refurbishment process detailed for it in this Specification.

Major components and items with specific examination criteria are listed below.

All component parts set aside for use at assembly shall be to a current approved design. Modification schemes may have been commenced which may not yet have been fully implemented. Units submitted for overhaul may not be to the current build standard. Some components may therefore require to be modified or discarded.

13.1.3.1 Relay Case (Item 1-12)

The stripped case shall be examined for signs of damage or cracking. No damage or cracking is acceptable.

Tapped holes shall be checked for damage to threads. Damage to threads is not acceptable.

The blanking discs, (eyelet with disc, item 1-16) shall be checked for tightness and soundness. Loose or damaged items shall be replaced with new.

The tapped hole for transit screw shall be ¼" x 40 TPI Whitworth. Cases where this hole is tapped 0 BA shall be set aside for the hole to be opened out to be tapped ¼" x 40 TPI Whitworth.

13.1.3.2 Moulded top plate (Item 2-21)

The stripped Moulded Top Plate shall be examined for signs of damage or cracking. No damage or cracking is acceptable.

A check of the security of blanking plugs in unused terminal positions shall be made. Secure loose or missing blanking plugs as required.

13.1.3.3 Inner top plate (Item 2-22)

The Inner Top Plate sub-assembly shall be examined for signs of damage or cracking. No damage or cracking is acceptable.

A check that the iron circuit inserts are secure and are undamaged shall be made. Items with loose or damaged iron circuits inserts are not acceptable.

A check that the threaded insert studs (four above the top, two below) are secure and undamaged shall be made. Items with loose or damaged inserts are not acceptable.

Check that the attached Back Contact Studs, Front Contact Studs and Terminal Brackets are securely fixed and are in good condition. Replace or tighten as necessary.

13.1.3.4 Armature (Item 3-55)

Two patterns of Armature are in circulation. One is nominally $1\frac{1}{8}$ " wide and the other is $1\frac{1}{4}$ " wide. They are interchangeable in all respects. All gauging and process operations specified are applicable to both patterns.

Items showing signs of corrosion or damage to the plating shall be stripped and re-plated after removing the balance arms.

The front (upper) face of the Armature shall be free from all burrs and blemishes. The Armature shall be checked for straightness and twisting. It shall not be possible to insert a 0.005" feeler gauge under any part of an armature when it is placed face down on a surface plate (Grade B). [CPS01]

The Residual Pins shall be gauged to the dimensions given in Table 2 below. [CPS02]

Relay Version	Front Residual Pin height		Back Residual Pin Height	
	Minimum	Maximum	Minimum	Maximum
6 Volt	0.007"	0.009"	0.015"	0.017"
12 Volt	0.010"	0.012"	0.030"	0.032"
60 Volt	0.022"	0.024"	0.055"	0.057"

TABLE 2. TABLE OF RESIDUAL PIN HEIGHTS

If any pin fails the minimum gauging requirements then all four pins shall be replaced with new ones. 'High' pins shall **not** be filed or machined to bring them back into gauge as the pins have a hemispherical shape which must be preserved. Adjustment of the height of over-height residual pins shall be performed strictly using tools specified in 13.1.4.2 below.

Removal of worn residual pins shall be done in a manner which does not damage the armature and prevent the correct riveting of new pins.

When new residual pins are fitted, the holes for the pins shall be gauged before the new pins are fitted.

A check shall be made to ensure that both Counterbalance Bars are securely fixed to the armature and that they are in good condition. Replace or re-fix as necessary.

13.1.3.5 Coil assembly

The Coil Assembly shall be checked for signs of damage or overheating. Coil connections shall be secure and undamaged.

Resistance of coils shall be measured. For 12 volt and 60 volt coils the resistance shall be $1000\Omega \pm 50\Omega$. For 6 volt coils the resistance shall be $1000\Omega + \text{nil} - 10\Omega$. Coils with resistance outside the specified range shall be rewound. [CPS03]

13.1.3.6 Armature stop screws

The head of the Armature Stop Screws (items 3-70) shall be examined. If they are in good condition with no flats visible on the domed head they may be re-used. Otherwise, replace with new items.

13.1.4 Refurbishment

13.1.4.1 Paint finishes for painted items.

All paint used shall be air drying, suitable for spray application. Products used shall be suitable for the material to which they are applied and shall be compatible with other paint products applied above or below them. It is a particular requirement that no paint applied to the inside of the relay shall flake off any surface to which it has been applied over the whole life of the relay.

13.1.4.1.1 Top Frame (Item 1-8)

All surfaces shall be painted with one coat of undercoat over bare metal. One topcoat of black gloss to be applied to all surfaces over the undercoat.

13.1.4.1.2 Case (Item 1-29)

No flaking paint is acceptable. The finish of the inside of the relay case is required to be to the highest standard with no runs or accumulation of paint which could dry out and peel or craze during an extended life at high temperatures. Adhesion of all coats to the base metal and each other is a crucial factor to the safety of the relay.

All surfaces shall be painted with one coat of undercoat over bare metal.

One topcoat of white gloss to be applied to all surfaces except the bottom, over the undercoat.

Final coat to be a gloss coat, colour coded to requirements of drawing BS14224, applied to the four vertical external faces of the case.

It is permitted to use external masking plates to prevent top colour coding coat from entering inside the relay case. Masking plates for sides of relay shall be smaller than the outline of the window frame to prevent any white base coat from showing when relay is assembled with the window frames.

All threaded holes shall be left free from paint or other debris.

13.1.4.1.3 Window Frame (Item 1-2)

Frames shall be spray painted on all surfaces with one coat of undercoat followed by one gloss topcoat, colour coded to requirements of drawing BS14224.

13.1.4.2 Armature Assembly (Item 3-55a)

New residual pins shall be fitted at all positions on each armature needing refurbishment.

Pins shall be riveted into position using tools in accordance with drawing AS28083 and using an assembly fixture in accordance with drawing AS28072. Pins to be riveted sufficiently to ensure they are secure in their holes without deforming the contour of the head of the pin.

After secure riveting, the height of each pin shall be checked to fall within the limits given in Table 2 above.