CHAPTER 6

THE DESIGN & MANUFACTURING OF METAL TO CARBON RELAYS & SILVER IMPREGNATED GRAPHITE CONTACTS

6.1 INTRODUCTION

The design and manufacturing of metal – carbon relays & SIG contacts were studied at their respective manufacturers and the critical to quality parameters / process capability was analyzed.

6.2 DESIGN & MANUFACTURING OF METAL – CARBON RELAYS

The metal - carbon relays’ production procedure consists of testing of raw material components, processing of raw material to produce finished goods, and testing of final product. Process sheets are provided to the workers at their work place to aid in their work. Control plans are used for testing the components / final product quality. A Quality Assurance Plan detailing the various steps for ensuring quality of material / processes / manpower is formulated and rigorously implemented.

6.2.1 THE MANUFACTURING PROCESS

There are seven stages, from the level of raw material to final product, in the metal - carbon relays’ production system, as enumerated in Table 6.1.

The material management department checks the quality parameters of the raw material components and the material not as per specifications is rejected. The critical raw material is got tested from National Accreditation Board Laboratories at fixed intervals to ensure quality. After testing, the various components are assembled in the form of coil assembly, contact assembly, and relay base in the production shop and finally the relay is produced. All the activities are accomplished by manual labor. The various parameters such as physical, / electrical are evaluated at the end of every level, to ensure process quality.
Table 6.1 Stages of manufacturing process of relays

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6.2.2 RAW MATERIAL COMPONENTS

All the raw materials for metal - carbon relays such as relay coil, armature, heelpiece, contact springs, silver & SIG contacts are tested as per the parameters given in Table 6.1. The salient features of some vital components are as under:

(i) **Armature**

The armature is made of highly permeable low carbon / low silicon steel. It is fixed on a pivot plate and swivels on the heelpiece facade. A phosphor bronze residual pin is riveted into the armature face to ensure that the armature is released every time.

(ii) **Heelpiece**

Heelpiece is made of the same material as armature and is L shaped. It is fixed with a retaining nut onto the base moulding. Together with armature and core, it forms the magnet circuit assembly.

(iii) **Core**
The core is a cylindrical piece made of low permeability and low hysteresis material same as armature and heelpiece. It is centered inside the relay coil and when the current passes in coil, it produces magnetism.

(iv) **Relay coil**

Coil of relay has to be looped on a spindle and is made of high quality copper wire. The coil is then fixed onto the soft iron core. The coil resistance and its numbers of turn are printed on the coil. While testing coils, it must be seen that the covering material, adhesive & printing ink should not corrode the coil and they also should not produce vapors, which will damage relay contacts.

(iv) **Contact Springs**

Contact springs are made of phosphor bronze; the SIG (fixed contacts) and silver (moving contacts) are fixed on the springs. The fixing arrangement of SIG contacts consists of clipping and soldering to the spring, while the silver contacts are fixed by riveting on the springs. The springs’ tail ends are taken out through the relay base and get interlocked into the plug board.

To prevent sulphation / rusting of the components, cadmium / nickel plating / bright dipping is done (Kanakasabapathi, K. S., & Ramasamy, V., 1973). Before plating, components are degreased by trichloroethylene in the vapor degreasing plant. The heelpieces & armatures are lacquered after cadmium plating, while contact springs are bright dipped. Annealing of magnetic circuit material such as phosphor bronze springs and thermo-setting & thermoplastic material is done for stress relieving. Nitrogen is used during annealing to maintain an inert atmosphere to prevent formation of scales.

(v) **Armature sub-assembly**

Armature sub-assembly is done in two stages. The first stage is coining of the residual pin to armature, in which the head of the residual pin is formed to correct height, ensuring correct air gap between armature and core. The second operation of riveting the backstop/retaining clip to armature is done on the semi-tubular machine. After the
process, inspection is done to check that riveting has been done properly and bad riveting is removed and re-done.

(vi) **Heel-piece sub-assembly**

The heelpiece sub-assembly is done on a semi-tubular riveting machine, shown in Fig.6.1.

![Heelpiece riveting](image)

Ref. Compiled from study

Fig. 6.1 Heelpiece riveting

The support bracket is inserted first, then the pivot plate and the heelpiece is put on top into a jig. Then the jig is inserted on the right hand side guide through the fixture in such a manner that one of the holes to be riveted comes against the locating pin in the fixture and riveting is done by pressing the pedal. After this the support bracket is set to its correct position.

### 6.2.3 COIL ASSEMBLY

The coil assembly consists of inserting the relay coil & core into the heelpiece and screwing down a nut in the back. This operation requires high level of accuracy, as it determines the operating values of the relay by controlling the armature stroke and initial air gap. The armature is first assembled to the heelpiece by sliding the pivot plate into the slots in the armature. Then the assembly is placed into the bending fixture in location bases, as shown in Fig.6.2.
The dial gauge meant for measuring the armature stroke is released and set to zero. As shown in Fig.6.3, by pressing the armature down on the backstop, travel is checked, and if it is correct, the gauge is again locked by turning a screw and the assembly is put aside. Then the two bending arms are inserted on both sides and by pressure of hand on the levers, the stroke is either reduced or increased, as required.

After this adjustment is done, the armature is again released and stroke checked with the dial gauge. After the stroke is corrected, the special screw is fitted through the hole in the armature and slide into the position between the support bracket and the heelpiece. The long collar is then pushed down the screw with a special tool for the purpose. The inner
spring and then the outer spring are then placed in position and the spring retaining cap is put on top. The assembly is removed from the fixture and armature travel is then checked with a go/no-go gauge. The collar between the special screw, support bracket and the inner helical spring must be seated properly in position. The armature should not touch the top edge of the heelpiece anywhere throughout its width. It is also to be ensured that the offset from the center for the armature is not more than 0.015 inches and the gap between armature and plate should not be greater than 0.01 inches.

6.2.4 CONTACT ASSEMBLY

There are two subassemblies - for moving and fixed contacts - in the manufacturing of the contact assembly.

(i) Contact sub-assembly for moving (silver) contacts

Assembly is done in two stages. The first stage is the spinning of the silver contact with a spinning machine. The contact rivets are kept on the machine table, the spring is used to turn the head downwards and insert the shank of the rivet into the hole provided into the spring. As shown in Fig. 6.4, uniform pressure is applied for specified period of time by the spinning tool, controlled by the timer device and riveting is done.

Ref. Compiled from study

Fig. 6.4 Silver contact spinning

For proper riveting, it should be ensured that the silver contact is positioned flat and on the correct side of the springs and the springs are not twisted or bent, and don’t have any stains. After the riveting, the contacts are soldered on the springs, to ensure good
electrical continuity, on a resistance-soldering machine. The springs are held ten to fifteen at a time in a fan shape and a pedal is used to operate the machine heating the part to be soldered. The soldering wire is kept straight at the tip and fed into the job and heated. It should be ensured that no solder should drop on the face of the silver contact. During and after the operation, the springs are stored in a tray by suspending them with the contact side upwards with specially shaped rods.

(ii) Contact sub-assembly for fixed (SIG) contacts

The SIG contact is fixed on the spring by means of a clip made of tinned copper. This fixing is done first by means of a clipping machine and then soldered to ensure good electrical conductivity. The carbons and clips are kept on a tray by the side of the machine and are guided downwards together through specially shaped rails. The spring is kept on top of the carbon in a specially shaped die, as shown in Fig. 6.5. For proper fixing, it should be ensured that the clip should be properly & equally turned over and the springs are not twisted or bent, and should not have any stains.

![Ref. Compiled from study](image)

**Fig. 6.5** SIG contact soldering

After the soldering operation, the fixed as well as moving springs are contaminated by the flux and hence it is necessary to clean them before assembly into the relay. Thus, three level cleaning is done – two times by Trichloroethylene in the vapor degreasing plant and one time by distilled water vapor. The trays containing the springs are suspended by rods in the degreasing plant for five to eight minutes, allowing all grease to
be removed. After this, the springs are not touched with bare hands, only with gloves. The fixed springs are then bent on a special fixture, to give them the desired shape and the contact pressure. All the springs are inspected 100% after the sub-assembly operations; they are examined under the magnifying glass for the characteristics of springs / contacts, as well as the quality of riveting / clipping / soldering, and faulty materials are rejected.

6.2.5 RELAY BASE TO SPRING ASSEMBLY

The fixing of springs onto the relay base is done on a fixture, which is pneumatically operated. The base on which the springs are to be assembled is located in the center of the fixture. A clamp in front keeps the base in position and the adjustable length of arm is provided to guide-way for the top of the springs. As shown in Fig. 6.6, just over the base where the contact blocks would come are a number of rods, which, hold the springs in position.

The retaining plate and the two nuts for the two central screws are fixed along with the contact blocks, spacers and the first row of springs. Then the alternative rows of blocks and springs are assembled and finally after pushing in the fingers, the washers are put in to hold the assembly in position. After the assembly, it should be checked that the base & stack screws have been fixed properly. The feet of the contact springs & the connectors are correctly assembled and the contact arrangement is correct. The contact springs
should be in line, the tags on the support springs should not be damaged and the springs should be bright and free from any tarnish.

6.2.6 FINAL ASSEMBLY

In the final assembly of relays, the iron circuit assembly is put on the base, connected electrically to the connectors and linked with the contact arrangement. For this, the lead wires from the coil are cut to correct length and then the leads are soldered to the connectors. The coil leads are then wrapped around the connectors with a pair of small pliers. The operating arms are then located in position through the spring in the order of stacks D, C, B, A. Then the heelpiece assembly is located on the base ensuring that the leads are not trapped between the heelpiece and the base, and is free to move. The operating arm pin is then picked up and inserted using the special shaped pin holder, as shown in Fig. 6.7.

After this, the assembly is kept upside down with the contact showing through the top and the nut in the back is driven using a box spanner. The relay, after the tightening of the rear nut, is placed on a fixture for the rest of the assembly. The adjustment cards are then assembled starting from stack D to stack A, by lifting the support springs holding the adjustment cards against such of those springs meant for the back contact, then pressing the armature to lift the other contacts and pressing down the adjustment card. After that, the armature-retaining strip is located on top of the armature from the left hand side,
while ensuring that the raised part of the strip is towards the lower side. Then the ends of the strips are bent with a pair of pliers. At the end of final assembly it is checked that the springs are in line and in the adjustment card, the operating arm should be correctly assembled and should be in line.

6.2.7 RELAY SETTING AND TESTING

Setting is the last operation in the assembly line before the relay goes for adjustment and testing. Relay setting is done on the setting bench, on which is provided a plug board with a clamp to hold the relay in position, as shown in Fig.6.8. The panel on top is used for choosing the type of relay (single or twin coil) and the coil to be tested while the bottom panel is used for selecting the coil voltage and the particular coil terminals.

![Fig. 6.8 Relay setting test bench](Ref. Compiled from study)

The checking fixture is inserted on the back of the relay and alignment is checked; errors are corrected by nose pliers. On this bench, the height of carbon contacts, correct spring arrangement, and contact pressure are checked. The springs are checked for parallelism and straightened to remove kinks or unwanted bends. The springs are also adjusted so that the contacts line up properly in all the rows. The relay is then plugged into board and checked for its operation at appropriate voltage. The assembled and set relays are passed on to the adjustment & testing bay, where the relays pass through the following stages:

(i) Mechanical adjustments and inspection
In this stage, the various mechanical parameters of the relays such as straightness and alignment of springs, position of all washers, clearance of contact stroke of armature, quality of plating, and tightening of screws are checked and adjusted. The checking fixture is inserted and the alignment & closeness of the feet of the springs are corrected. The simultaneous movement as well as the lift of the contact are also checked and corrected.

(ii) **Electrical adjustments and inspection**

The various electrical parameters such as pickup / release voltage, coil resistance, and contact resistance are measured and adjusted on the Universal Relay Test Set. Relays are fixed on the set by means of plug-in boards and test modules, while external sockets provide a means of connecting auxiliary equipment such as timer, interrupter, and external meters.

(iii) **Fixing of cover**

After the electrical inspection is complete, the holding bracket for the cover is inserted and the cover is positioned. Then, the handle is inserted and the cover fixing nuts are tightened. Label for the relay with serial number is also pasted.

6.2.8 **FINAL INSPECTION**

After two level testing - internal inspection by production shop and quality check by quality department - the relays are thoroughly tested for their quality parameters in accordance with the specifications.

(i) **Visual inspection**

All the relays of the lot are subjected to visual checking, as shown in Fig.6.9, during which, it is seen that there are no loose foreign particles / dust inside the relay, all the components are fixed properly and correctly aligned, adjustment card& operating arm are not tilted, and the cover is free from scratches.
(ii) **Contact resistance measurement**

Contact Resistance measurement is done on 100% relays in the lot, by means of an ohmmeter or multimeter, as shown in Fig.6.10.

![Ref. Compiled from study](image1)

Fig. 6.9 Visual inspection of relays

![Ref. Compiled from study](image2)

Fig. 6.10 Electronic relay test jig

The maximum permissible value of contact resistance is 220 milliohm, and any contact having resistance more than this is considered failed and hence, rejected.

(iii) **Electrical parameters measurement**

The various electrical parameters of the relay such as insulation resistance, coil resistance, release voltage, full release voltage and full operate voltage are measured by fixing the relay on the electronic test jig. The coil resistance is measured at room temperature and then converted at 20°C.
(iv) **Contact pressure / clearance check**

The contact pressure & contact clearance of all the sixteen contacts are checked by fixing the relay on the test jig, as seen in Fig.6.11.

![Ref. Compiled from study](image)

**Fig. 6.11 Contact pressure & clearance checking**

The pressure gauge is used to measure and the fact that pressure between the contacts is within parameters is confirmed. The clearance of contacts is checked with the go / no-go gauge and it should be minimum 0.015 inch.

(v) **High voltage test**

The high voltage test is done in a test apparatus, shown in Fig.6.12, which facilitates isolation of various circuits. Five relays are plugged at a time into the unit and 1 Kilovolt 50 Hertz AC voltage is applied to them for one minute. The test is done in two cycles, and if the first cycle goes through without a breakdown of insulation, the second cycle starts.

![Ref. Compiled from study](image)
If any relay is faulty, the various test points are isolated to segregate the particular faulty components.

(vi) AC immunity test
The relays, which are to be used outdoors in the electrified area, are tested for their ability to withstand induced voltage. The relay is fixed on the immunity test equipment and 300 Volts AC is applied to it. The relay should withstand this voltage and not operate on its application. Fig.6.13 shows the test setup.

(vii) Miscellaneous tests
Various other tests such as non-bridging test (to check the contacts do not make simultaneously), annealing test (to check whether the relay covers are annealed), plating thickness check (to check the plating thickness on magnetic components such as armature, heelpiece, and core, which should be minimum 0.012 mm.) are done on sample relays.

6.2.9 CAPABILITY OF RELAY MANUFACTURING PROCESS
The efficiency of relay manufacturing process at M/s. Crompton Greaves Limited, Pithampur, Indore, was studied, in context to the Indian Railways relay specifications and their own Quality Assurance Program / data sheets. Fig. 6.14 shows the trend of process capability index during the period January 2012 - 13.
The graph clearly indicates that the Cpk was quite high, which indicated that the rejection rate was quite low.

The process capability indices of two Critical To Quality parameters – contact resistance and contact pressure, for December 2012, were as in Fig. 6.15 & 6.16.

Fig. 6.14 Process Capability Indextrend

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The process capability indices of two Critical To Quality parameters – contact resistance and contact pressure, for December 2012, were as in Fig. 6.15 & 6.16.

Ref. Compiled from study

Fig. 6.15 Contact resistance during final inspection

Fig. 6.15 shows that average CR was 46 milliohm, and was never more than the maximum limit of 220 milliohm; the process capability was 2.28, which was quite high.
Fig. 6.16 Contact pressure during final inspection

Fig. 6.16 reveals that the contact pressure ranged from 35 to 45 gram, with an average of 42 gram, and in no case was less than the minimum limit of 28 gram, while the process capability was 1.63, which was found reasonable.

In view of the above discussions, it was concluded that the relay manufacturing process at M/s. Crompton Greaves Limited, Pithampur, Indore, was stable and the quality of relays being manufactured was in accordance to the IR specifications.

6.3 DESIGN & MANUFACTURING OF SIG CONTACTS

The metal-to-carbon relays use Silver Impregnated Graphite contacts, which have very good heat & electrical conductivity due to silver and excellent anti-welding characteristics due to carbon. Silver impregnation is done to achieve high level of electrical conductivity. The contacts are manufactured as per IR specification IRS: S67-85, from graphite blocks having requisite hardness, porosity and specific resistance. Only molded grades of carbon are used for making contacts.

6.3.1 ELECTRO-GRAPHITE BLOCKS

The electro-graphite for SIG contacts is manufactured using the Press – Sinter(PS) process of powder metallurgy, which provides the highest density material. Blended mixture of graphite & binders of correct purity and density is compressed to from graphite
bricks, which are then sintered in a high temperature furnace, for creation of metallurgical bonds between the powder particles. The electro-graphite blocks, thus produced are isostatic. The porosity & density shall be such that when impregnated with silver salt, the silver will be uniformly distributed.

6.3.2 MANUFACTURING PROCESS OF SIG CONTACTS

The SIG contacts are made from graphite blocks, by several cutting, machining & shaping processes (Advance Technology, 2008). Fig.6.17 depicts the flowchart of manufacturing process.

Fig. 6.17 SIG contact manufacturing process flowchart

The various stages of manufacture of SIG contacts are as under:

6.3.3 SHAPING & CHECKING OF CONTACTS
The pieces are cut in stages to be shaped as per the approved drawing, with the help of lathe, milling and grinding machines. There are approximately fifteen operations in the entire process, which are accomplished on various jigs and fixtures. First the brick is gradually cut up in small squares to roughly the required size. The profile of the contacts is also made during this stage. This is known as rough machining. In the next stage, that is intermediate machining, the profile of contacts is machined to the required size. In the third stage, known as finish machining, the surface of the contacts is finished to the required smoothness. Finally, the manufacturers identification mark is made on the finished graphite contact.

While machining contacts from the graphite block, the contacts should be cut axially that is in the direction of molding pressure for obtaining uniform compressive strength. At the end of shaping process, the graphite pieces are visually examined for any seams and cracks. The working surface of contact shall be flat & parallel to the opposite surface and the flatness shall not deviate by more than 0.01 mm at any point on the surface.

### 6.3.4 CLEANING OF CONTACTS

The graphite pieces are then washed in Soxhlet apparatus with benzene vapors for 24 hours, to remove dirt, grease, powdered graphite and other impurities. After this time period, they are washed by triple distilled water and dried in the oven at 100°C for about 5 to 6 hours, so as to make sure that the pieces are completely free from moisture. Now the pieces are ready for impregnation.

### 6.3.5 IMPREGNATION OF CONTACTS

Impregnation is carried out by soaking the contacts in silver nitrate solution under vacuum, of the order of $10^{-2}$ Torr, for adequate time. The silver nitrate should be high purity analytical reagent salt with fine grade silver of purity more than 99.9%, conforming to IS: 5320.

The silver nitratesolution is pored into chamber number 1; the chamber is heated to 120°C (approximately) and the temperature is maintained thermostatically. The graphite contacts are loaded in impregnation vessel (chamber number 2) having vacuum
arrangement. Vacuum, of the order of $10^{-2}$ Torr, is created in chamber number 2 by opening the isolation valve $V_1$, and the chamber is heated up to 135°C within 30 minutes. The vacuum flow valve $V_2$ is kept closed for isolating the chamber number 1 from number 2. Temperature, time and vacuum levels are checked constantly.

When the impregnent (silver nitrate solution) is adequately hot, valve $V_1$ is closed and chamber number 2 is isolated from the suction pipe line; immediately valve $V_2$ is opened so as to allow the hot impregnent to flow into chamber number 2, with the atmosphere pressure, and fill the voids & pores in the graphite matrix with silver nitrate. The pieces are allowed to remain in chamber number 2 along with the impregnent, under vacuum, for approximately one hour and temperature is brought down to room temperature. Then chamber number 2 is detached from the suction line and opened. The semi-impregnated graphite pieces are transferred to another vessel and the entire impregnation process is repeated for 30 cycles, till the pieces are fully impregnated.

### 6.3.6 WASHING OF CONTACTS

The pieces are finally washed gently by triple distilled water to remove any sticking silver nitrate from the surface. Then they are kept in an oven at 100°C for 15 to 20 minutes for removing the moisture.

### 6.3.7 FIRING OF CONTACTS

The process of reduction of silver nitrate into silver is technically known as firing. The dry graphite pieces are packed in mild steel boxes with fine powder of petroleum coke (100 mesh) as reducing agent and sealed with fire clay. Then these sealed boxes are put into a furnace and temperature is raised gradually up to 480°C and maintained for six hours.

The firing terminates at the end of the required time-period and the boxes are removed and impregnation level is checked by weighing the contacts. If found inadequate, the impregnation cycle is repeated, while the properly impregnated contacts are sent for silver plating.
6.3.8 SILVER PLATING OF CONTACTS

The SIG contacts thus prepared have to be silver plated on the bottom surface, by dipping in silver potassium cyanide solution, to help in soldering the contacts to the contact springs. The thickness of electroplating is kept 50 to 60 microns. Plating must not peel off during or after the contact is soldered and it shall give a rigid bonded joint. The contacts are loaded in the plating fixture and placed in the silver potassium cyanide bath and the current and duration of plating are continuously monitored. After the requisite period, the contacts are taken out and sent for washing and cleaning.

6.3.9 FINAL CLEANING OF CONTACTS

To remove water-soluble impurities remaining after electroplating, three-stage cleaning of SIG contacts is done. Small lots are taken at a time to ensure thorough cleaning of contacts.

- First Stage: Contacts are cleaned in ultrasonic bath using triple distilled water at 90˚C to 100˚C. This is repeated five times for ten minutes duration each and every time the water is changed.
- Second Stage: Contacts are washed with water vapor of triple distilled water for a period of fifteen minutes.
- Third Stage: Contacts are dried in hot air at 100˚C for thirty minutes.

After cleaning, the contacts are checked for their conformance to various parameters.

6.3.10 CHECKING & PACKING OF CONTACTS

After the desired amount of silver has been introduced, contacts are checked for the following properties:

- Uniform distribution of silver.
- Compressive strength.
- Electrical resistivity.
- Other requirements as per specification of Indian Railways.
After examination of contacts, they are packed in stainless steel containers in lots of 10,000 per container.

6.3.11 GENERAL REQUIREMENTS OF SIG CONTACTS

Silver Impregnated Graphite contacts, produced as above, shall have the following characteristics, in accordance with the IR specification IRS: S 67-85:

(i) Base graphite of grade 2020 shall only be used for making the contacts.
(ii) The dimensions & tolerances of contacts shall conform to specification IRS: S 67-85.
(iii) The contacts shall not fuse, or weld together with the silver contacts during usage.
(iv) The contacts shall be free from defects such as cracks, chipped off surfaces, inclusion of foreign materials, oxidized free surfaces and seams of carbon un-impregnated with silver, which would tend to increase the contact resistance.
(v) Distribution of silver throughout the volume of contact, as seen in micrographs, shall be uniform and free from defects such as seams, threads, or silver globules.
(vi) The contact resistance between silver & SIG contacts shall not exceed 0.05 Ohm, with 100 milliampere current and 28 gram pressure between them.
(vii) The specific resistance of impregnated graphite (cube of sides 3 cm. each) shall not exceed $2 \times 10^{-4}$ Ohm-cm.
(viii) The compressive strength of contact shall not be less than 700 Kg/cm$^2$.
(ix) The hardness of contact shall not be less than 22 VPN.
(x) The ash content of graphite block shall not exceed 1.5%.
(xi) The SIG contacts shall contain 55% to 60% by weight of silver (without considering the silver plated portion).
(xii) The water-soluble impurities in the finished contacts shall not exceed 0.25%.
(xiii) Each individual contact shall be marked with manufacturer’s identification marks, at a suitable place, but not on the working surface.
(xiv) Each front contact of relays shall be capable of carrying 3 Ampere continuously and 5 Ampere for 30 seconds, without injurious heating when the relay is energized at 125 percent of the specified maximum pick-up current.
6.3.12 TESTING OF SIG CONTACTS

The SIG contacts shall be subjected to various tests, as detailed in the following sections, to check the various electrical and mechanical parameters.

(i) **Visual inspection**

Visual inspection of all the contacts in each lot shall be done by observing them under microscope/ magna-scope having suitable magnification for ascertaining the silver dispersion inside the contact and to ensure that the contacts are free from defects such as cracks, seams, chipped-off surfaces, and precipitated silver. Micrographs of sample contacts shall be taken and preserved.

(ii) **Dimensional accuracy**

Contacts are inspected for dimensional accuracy with go / no-go gauges with samples selected at random out of the lot. The dimensions & tolerances of SIG contacts shall conform to specification IRS:S 67-85(Fig 6.18).

![Representative dimensions of SIG contacts](image)

Fig. 6.18 Representative dimensions of SIG contacts

(iii) **Specific resistance of graphite block**

The specific resistance of graphite block is measured as per the setup shown in Fig.6.19. A cube of 3 centimeter size is used as the test block and resistance is measured between two points on the test block. Three readings each are taken in each of the three axes of graphite block and their average is determined. The specific resistance (in Ohm-cm) is calculated from the formula:

\[ \text{specific resistance} = \frac{R \times L}{A} \]

where:
- \( R \) is the measured resistance (in Ohm)
- \( L \) is the length of the test block (in cm)
- \( A \) is the area of cross-section of the test block (in cm²)
Specific Resistance = \( \frac{\text{Resistance} \times \text{Cross section area}}{\text{Distance X between two probes}} \) \hspace{1cm} (6.1)

(iv) **Contact resistance test**

The contact resistance shall be measured on 5% of the lot quantity with a minimum of 50 contacts. The arrangement is as shown in Fig. 6.20.

![Diagram of contact resistance test](image)

Ref. Compiled from study

Fig. 6.20 Arrangement for measuring contact resistance

The SIG contact is kept in a contact holder having pressure of 28 gram. A current of 100 milliampere is passed through the contact and the resistance is measured.

(v) **Hardness test**
Hardness of SIG contacts is measured through the Vickers Hardness test, conducted on Vickers Hardness Machine (Askeland, D. R., Phulé, P. P., 2006), in accordance to the ASTM E384-11e1 standard, on minimum of 50 number contacts. Force $F$ is applied through a diamond indenter and maintained for approximately ten to fifteen seconds. This causes a square shaped indent on the sample, having diagonals $d_1$ & $d_2$, with an average say, $d$. A microscope is used to measure both the diagonals of the square mark. The Vickers hardness is calculated from the formula

$$HV = \frac{1.854F}{d^2} \quad (6.2)$$

(vi) Compressive strength test

The compressive strength of SIG contacts is measured by the compression test on minimum of 50 number contacts. The stress at which a material is crushed totally is known as compressive strength. The test is carried out on a Universal Testing Machine, in accordance with ASTM E74, ASTM E1012 and ASTM E1856 standards. For this, the SIG contact is placed in between the grips and a servo-hydraulic controlled movable crosshead is used to provide increasing load on the test specimen. The computer system continuously records the load and the final value of load at which the SIG contact is fractured is noted. This is the compressive strength of the contact, expressed in pound per square inch (psi) or Mega-Pascal (MPa).

(vii) Chemical composition test

The various tests to ascertain the chemical composition of SIG contacts shall be carried out on minimum 50 contacts. The chemical parameters, which are measured, are the carbon and silver content in the SIG contacts, the ash content in the graphite block used for making the contact and the water-soluble impurities in the contacts. For this, the contact samples are ground to a fine & homogeneous powder, and various reagents such as Nitric acid and Hydrochloric acid are mixed with it, in stages, and the percentages of various chemicals are determined.

(viii) Functional tests
The following tests are done to check the practical behavior of the SIG contact during relay operation:

Low / high current breaking capacity test - The contacts shall be capable of breaking a current as low as 0.6 Ampere and as high as 5 Ampere, in a non-inductive DC circuit at 125 / 50 Volts respectively, when operated one Lakh times, with the relay energized at 125% of the specified maximum pick-up current for line relays.

Life Test - The contacts shall be capable of withstanding life test for ten Lakh operations. The tests are carried out on two relays: one relay at room temperature and other at 70°C ±2°C. All the contacts are non-inductively loaded, except two front contacts, which are inductively loaded. Contact resistance is measured initially as well as after every one Lakh operations up to four Lakhs and thereafter every two Lakh operations. During and on completion of the endurance test, the contact resistance shall not be more than 220 milliohm.

6.3.13 CAPABILITY OF SIG CONTACT MANUFACTURING PROCESS

The manufacturing process of SIG contacts was studied at M/s. Advance Technology, New Delhi, and the process was found to be stable and within control. The Quality Assurance Program was as per the Indian Railway specification of SIG contact.