621·335·2 (42) **Paper 19**

Locomotives : Nos.E 3056/95 (B.R./A.E.I. Rugby)

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1 Introduction

The Paper describes the 40 Type A locomotives included in the orders for the first 100 locomotives, whose mechanical parts are designed and built by the British Transport Commission; 20 will be built at Doncaster and 20 at Crewe. All the locomotives will be built to the Doncaster design and will use electrical equipment supplied by A.E.I. (Rugby).

Early in 1959 it was decided that the experience gained in the use of semi-conductor rectifiers on multiple-unit electric coaching stock was sufficiently promising to justify the extension of the trial to locomotive type equipments. A preliminary investigation showed that the space and weight saving would permit the introduction of rheostatic brake equipment and the decision was therefore made that these locomotives would be equipped in this way, 30 of the locomotives having germanium and 10 silicon rectifiers.

The locomotive cab layout and frontal appearance is that used for all A.C. locomotives.

The locomotive design was produced by the Chief Mechanical and Electrical Engineer, Eastern Region, in the Doncaster Locomotive Drawing Office to the requirements of the Chief Mechanical Engineer, British Transport Commission. The locomotives will be used on the London Midland Region.

The electrical equipment, which is to requirements of the Chief Electrical Engineer, B.T.C. and designed by A.E.I. (Rugby), is generally similar to that used on locomotives E.3001-23 except for the rectifiers and the braking equipment.

2 Leading Particulars

Total weight	80 tons
Maximum axle weight	20 tons
Weight of electrical equipment (including drive)	39·6 tons
Weight of two bogies (excluding motors and drive)	20·6 tons
Weight of underframe and body	19·0 tons
Length over buffers	56 ft 6 in.
Bogie wheelbase	10 ft 9 in.
Bogie centres	31 ft 6 in.
Wheel diameter	48 in.
Gear ratio	29/76
Maximum service speed	100 m.p.h.
Mean value of accelerating T.E.	48,000 lbs.

Continuous Ratings	*Full Field*	*Weak Field*
Tractive effort (lbs.)	20,000	17,000
Speed (m.p.h.)	60	71
Horse Power	3,200	3,200

Note: The performance figures relate to wheel treads with half worn wheels and a supply voltage of 22·5 kV or 5·63 kV.

The general appearance of the locomotive with overall dimensions is shown in fig.1. The layout of equipment is shown in fig.2. Locomotive performance curves for power and braking are shown in fig.3.

3 Description of Circuits

Most of the circuits for these locomotives are the same as those described in Paper 15. The following paragraphs describe the differences:—

3.1 *The Power Circuits* (fig.4)

The transformer circuit is changed slightly because the rectifier connection has been changed from bi-phase to bridge. The main transformer has only two secondary power windings and the auto-transformer is simplified. The notching arrangements and the number of notches are unchanged.

The semi-conductor rectifier consists of a number of strings of small rectifier cells arranged in series (see 4.4). These strings are connected in parallel groups to form the four arms of a bridge circuit.

The change to semi-conductor rectifiers has eliminated the need for the high speed line breakers. The circuit includes two motor contactors per motor with separate overload protection for each motor to provide isolation in the event of one motor failing and to allow reconnection when rheostatic braking is required.

The rheostatic braking is achieved by excitation of the traction motor fields from a separate step down transformer, whose primary is fed from the main transformer under the control of the main tap changer. The output of this transformer is fed through the normal power rectifiers. The braking is therefore controlled by the main control handle after movement of a selector switch to choose Braking instead of Power. During braking the four traction motor fields are connected in series with each other and a fixed value force-ventilated braking resistor is connected across each traction motor armature. The circuit is arranged so that a partial air brake application is made automatically if rheostatic braking is not maintained once it has been established. The cooling fan motor for ventilating the braking resistance is fed from a section of one of the braking resistors, so that the cooling is proportional to motor voltage and the power to be dissipated.

3.2 *The Auxiliary Circuits.*

These circuits are the same as those described in Paper 15 except that the rectifier ignition, excitation and heating circuits are eliminated.

4 Description of Electrical Apparatus

4.1 *Roof Mounted H.T. Equipment*

As described in Paper 15.

4.2 *The Main Transformer*

Since the locomotive design was at an advanced stage when the change to semi-conductor rectifiers was decided upon, the transformer was retained as nearly as possible in its original form. The only changes are in the windings and were brought about by the change to a bridge rectifier circuit. The ratings of the altered windings are:—

Secondary fixed voltage winding	625 volts, 1810 kVA
Secondary tapped winding	9 × 234 volts, 1730 kVA
	2110/578 volts, 1700 kVA

4.3 *The Tap Changer*

The tap changing and control equipment is similar to that described in Paper 15 except that the lower half of the control frame is substantially modified by the changes in the traction motor circuits. This part of the frame now carries the reverser and the braking group switches in the D.C. side of the excitation circuits. Cutting out of motors only involves opening contactors. The control switch is located near the Fault Indication Panel.

The space formerly occupied by the line breakers now contains the contactor frame which carries eight motor contactors, the Field Shunting Contactors and a D.C. excitation contactor for the braking circuits. The traction motor overload relay is also on this frame.

The remaining items of equipment for braking control are mounted in the space adjacent to the braking resistance; these include the braking group switch for the A.C. side of the excitation circuit and an A.C. contactor for connecting the step down transformer in circuit during braking.

4.4 *Rectifiers*

The rectifier is built up with strings of eight germanium or seven silicon cells mounted on trays. The trays are mounted vertically in a frame and can be slid out for maintenance or complete removal. There are either 20 trays of germanium cells or 12 trays of silicon cells, each tray containing either 64 germanium or 28 silicon cells.

4.5 *Reactors*

As described in Paper 15.

4.6 *Driver's Controls*

As described in Paper 15 except for the power to brake changeover switch incorporated in the Master Controller.

4.7 *Traction Motors*

As described in Paper 15.

4.8 *Auxiliaries*

As described in section 4.9 of Paper 15 except for the rectifier fans which are reduced to two in number and with characteristics suitable for the arrangement of rectifiers.

5 Protection

This is generally as described in section 5 of Paper 15 except for the rectifiers.

Each rectifier tray is fitted with four fuses. The fuses supply either two strings of germanium cells or one string of silicon cells and fault indication of fuse failure is provided by current balance transformers. The connections are arranged so that the two primary windings of the current transformers are in opposition and each winding carries the current fed to one of the rectifier strings; thus the failure of a string fuse produces an output from the current transformer which operates the fault indication system. There are sufficient banks of rectifiers to allow the locomotive to operate under full load with one string of cells cut out. Hole storage capacitors with series resistors are fitted on both types of rectifiers.

6 Mechanical Parts

6.1 *Bogies*

The bogies are shown in fig.5.

The bogie side frames consist of rolled steel channels welded to form a box section: the headstocks and bogie centre are fabricated separately and welded together on assembly. The Alsthom system of radius arm guided axleboxes is used.

The motors are resiliently suspended on the bogie frame as described in Paper 15.

Roller bearing axleboxes support an underslung equalising beam on rubber shear and compression pads, the beams in turn support the frame on four double-coil helical springs.

The body is supported on the bogies through conical rubber pads mounted in the bogie centre which is laterally connected to the body by means of transverse spring stabilisers. The support of the body is completed by four auxiliary side bearing springs per bogie, fitted with manganese rubbing plates.

6.2 *Underframe and Body*

The underframe and body is of an all welded construction, designed to give maximum accessibility for the installation of equipment during erection and at general repair, as shown in fig.6.

It is built up of seven units, comprising:—dragbox and cabs, bogie centres, intermediate sections and transformer (well) section, these being welded together on assembly. The frame construction is illustrated in fig.7.

The body sides, to a point just below the louvres and windows, are an integral part of the underframe, being of $\frac{5}{16}$ in. steel plate. The main body side members, between the cab door channels, are produced in three pieces in order to facilitate bending operations, and are joined by diagonal welds, and stiffened by vertical webs. The top of the body and roof is completely removable, in one piece, between the two bulkheads.

The upper portion of the body and roof is of welded light steel construction, with riveted aluminium panels. Welded aluminium roof traps are provided over each compartment allowing individual pieces of equipment to be lifted from the body of the locomotive.

The louvres for air intake to the traction motor blowers, rectifier compartment and transformer oil cooling radiators are fitted to the upper body side. The air from the traction motor blowers is passed to fixed bellows through fibre glass ducts built into the underframe, giving considerable saving in space and weight with resistance to corrosion.

The draw-gear is built into the main frame.

The body between the two cabs houses the major items of equipment.

The ends of the body adjacent to the cab bulkheads form the auxiliary machinery compartments with a centre portion consisting of two chambers. These chambers are positioned so that their right hand walls, with the adjacent body side, form an access corridor between the ends. The corridor wall formed by the body side carries the brake and control air piping, valves and ancillary equipment and contains four windows.

The driving cab consists of a steel fabricated outer shell, with an inner roof lining of glass fibre and plastic covered plyboard panels.

Below the window level the cab front is of $\frac{1}{8}$ in. steel plate flanged at the top and welded into position to join up with the locomotive main frames which, up to this level, form the cab sides. Reinforcement is provided to give maximum stiffness in front of the driving position.

Cab entrance door frames are fabricated as part of the main frames, forming an arch which spans the locomotive and carries the rear part of the cab roof.

6.3 *Brake*

A vacuum controlled straight air brake operates the air brakes on the locomotive in synchronism with the vacuum brake on the train and a self-lapping straight air brake is also fitted. All the brake equipment is of the latest lightweight type supplied by Westinghouse Brake and Signal Co. to the requirements of the B.T.C. and is quite independent of the rheostatic braking.

A two-stage, two-cylinder reciprocating compressor provides air for all the services.

The four-cylinder reciprocating exhausters provide the vacuum for the continuous brake. Whilst the locomotive is passing through a neutral section only one exhauster is run and this is at maintaining speed.

The deadman's feature is controlled by pilot valves in the cab which is being used and a delay of about six seconds occurs between the release of the pilot valve and the opening of the vacuum emergency valve.

Air passes from the upperstructure to each bogie via flexible hoses and provision is made by chokes so that if one of the hoses to a bogie fails, the brake via the other hose remains available.

Clasp brake rigging on each bogie is operated by four combined brake cylinders and slack adjusters.

Sanding, Warning Horn and an anti-slip brake controlled by a driver's push-button are also fitted.

6.4 *Rheostatic Brake.*

The characteristic of this brake is shown in fig.3 giving a braking effort of 24,000 lbs. between 10 m.p.h. and 21 m.p.h., falling to 8,000 lbs. at 70 m.p.h. absorbing approximately 1,000 kW.

The rheostatic brake has been fitted to reduce brake and tyre wear especially when holding unfitted freight trains on falling gradients.

SUMMARY

The Paper describes the 40 locomotives whose mechanical parts have been designed and are being built by British Railways, ordered for the first stages of the A.C. Electrification. The main differences between these and the remainder of the first 100 locomotives are the use of semi-conductor rectifiers and rheostatic braking.

The locomotives are built to the same general particulars as the remainder, i.e.—

80 tons weight
3,200 H.P. Continuous Rating Weak Field
100 m.p.h. maximum speed
48,000 lbs. T.E. during acceleration

The Paper describes the unusual construction of the main frame which is formed from a welded assembly of seven separate sections and the use of the lower half of the body sides as main frame members to reduce weight. A second feature is that the upper parts of the body sides are easily removable to give improved access to the equipment mounted in the body.

The bogies are based on the Alsthom design and include Alsthom drives built up into a frame designed for lightweight and economic production.

The semi-conductor rectifiers are arranged in trays with 64 germanium cells or 28 silicon cells per tray.

The electrical equipment is otherwise generally similar to that described in Paper 15, except for the arrangements for the rheostatic brake which are described in detail.

RÉSUMÉ

L'exposé décrit les 40 locomotives dont les parties mécaniques ont été étudiées par les Chemins de Fer Britanniques qui les fabriquent maintenant. Ces locomotives ont été commandées pour les premières phases de l'électrification en courant alternatif. Les différences principales entre celles-ci et le reste des 100 premières locomotives sont l'emploi de redresseurs à semi-conducteurs et de freinage rhéostatique.

Ces locomotives sont construites avec les mêmes caractéristiques que les autres du groupe:

Poids:	80 tons
Puissance continue au champ réduit:	3,200 H.P.
Vitesse maximum:	100 m.p.h.
Effort à la jante pendant l'accélération:	48,000 lbs.

L'exposé décrit la construction non usuelle du châssis principal qui est formé en soudant sept parties différentes et l'emploi de la moitié inférieure des côtés de la caisse comme parties du châssis principal en vue de réduire le poids. Une autre particularité est que les parties supérieures des côtés de la caisse sont facilement enlevables afin d'améliorer l'accessibilité de l'équipement monté dans la caisse.

Les bogies sont basés sur la construction Alsthom et comprennent les transmissions Alsthom montées dans un châssis qui est construit pour être léger et économique.

Les redresseurs à semi-conducteurs sont groupés en forme de plateaux avec chacun 64 cellules à germanium ou 28 cellules à silicium.

L'équipement électrique est semplable à celui décrit dans le rapport 15, à l'exception des dispositions pour le freinage rhéostatique qui sont décrites en détails.

ZUSAMMENFASSUNG

Der Bericht beschreibt die 40 Lokomotiven, die für die erste Stufe der Wechselstrom- Elektrifikation bestellt wurden. Die mechanischen Teile wurden von der 'British Railways' konstruiert und werden von ihr gebaut. Die Hauptunterschiede zwischen diesen 40 und den andern 60 Lokomotiven sind die Anwendung von Halbleiter-Gleichrichtern und Widerstandsbremse.

Diese 40 Lokomotiven werden mit den gleichen Charakteristiken gebaut wie die andern 60, d.h.—

Gewicht – 80 tons
Leistung – 3,200 h.p. Nennleistung bei geschwächtem Feld
Höchstgeschwindigkeit – 100 m.p.h.
Zugkraft während der Beschleunigung – 48,000 lbs.

Der Bericht beschreibt ferner die ungewöhnliche Konstruktion des Hauptrahmens, welcher aus sieben einzelnen Teilen besteht, die dann zusammengeschweisst werden. Um das Gewicht zu reduzieren, werden die unteren Hälften der Kastenseiten als gewichttragende Hauptrahmenteile verwendet. Im Weiteren können die oberen Teile der Rahmenseiten leicht entfernt werden, damit der Zutritt zu der in den Rahmen hinein montierten Ausrüstung erleichtert wird.

Die Drehgestelle basieren auf der Alsthom-Bauart und sind mit Alsthom-Antrieben ausgerüstet. Der Leichtgewicht-Rahmen, in den die Drehgestelle montiert sind, ist für eine wirtschaftliche Produktion konstruiert worden.

Die Halbleiter-Gleichrichter sind in Einheiten angeordnet, wobei jede Einheit 64 Germanium-Zellen oder 28 Silizium-Zellen enthält.

Mit Ausnahme der Anordnung der Widerstandsbremse, welche ausführlich beschrieben ist, ist die elektrische Ausrüstung im Allgemeinen ähnlich mit jener beschrieben in Bericht 15.

RESÚMEN

Este folleto describe las 40 locomotoras cuyas partes mecánicas han sido proyectadas y están siendo construidas por los British Railways; este pedido se destina a las primeras etapas de la electrificación por corriente alterna. Las diferencias principales entre estas y las restantes de las 100 primeras locomotoras son el empleo de rectificadores a semiconductor y frenos reostáticos.

La construcción de estas locomotoras sigue las mismas especificaciones generales que las demás, a saber.

80 tons de peso
3,200 h.p. de régimen contínuo en campo reducido
100 m.p.h. de velocidad máxima
48,000 lbs. de fuerza tractiva durante acceleración

El folleto describe la construcción anormal del bastidor principal formado por un conjunto soldado de siete secciones y el empleo de la mitad inferior de los costados de la carrocería como largueros de bastidor principal para reducir peso. Otro rasgo es que las partes superiores de los costados de la carrocería son facilmente desmontables para dar mejor acceso al equipo montado en la carrocería.

Los bogies se fundan en el diseño Alsthom e incluyen transmisiones Alsthom montadas en un bastidor proyectado con vistas a ligereza de peso y producción económica.

Los rectificadores a semiconductor están dispuestos en bandejas de 64 elementos de germanio o 28 elementos de silicón por bandeja.

Por los demás, el aparellaje eléctrico es similar al discrito en el folleto 15, excepto el arreglo de los frenos reostáticos que se describe detalladamente.

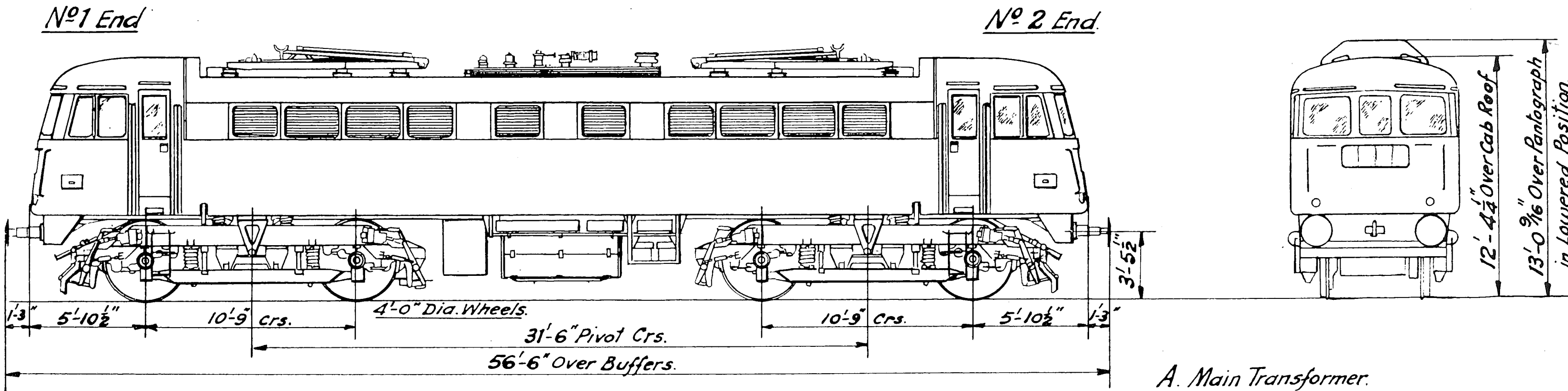

Fig.1 Outline of locomotive. Nos.E 3056/95

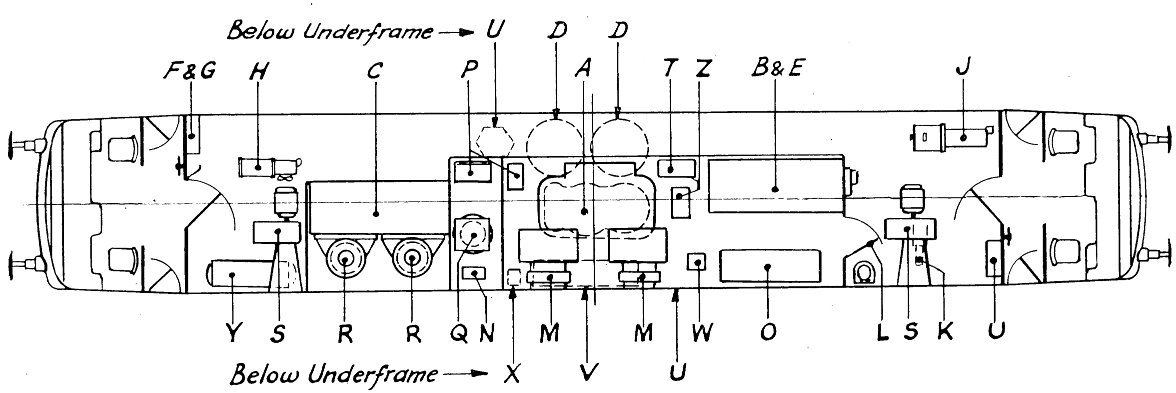

Fig.2 Layout of equipment. Nos.E 3056/95

A. Main Transformer.
B. Tap Changer.
C. Rectifier Frame.
D. Smoothing Reactors.
E. Control Equipment Frame.
F. L.T. Fuse Cupboard.
G. Fault Indication Panel
H. Main Compressor.
J. Exhausters.
K. Auxiliary Compressor.
L. Interlocked H.T. Compartment Door.
M. Transformer Oil Radiators.
N. Hole Storage Capacitor.
O. Motor Contactor Frame.
P. Braking Excitation Equipment.
Q. Braking Resistors & Blower.
R. Rectifier Cooling Fans.
S. Traction Motor Blowers.
T. Auxiliary Transformer.
U. Battery Charging Equipment.
V. Battery Charging Rectifier & Battery.
W. Train Heating Panel.
X. Field Divert Resistor.
Y. Main Reservoir.
Z. Tap Change Reactor.

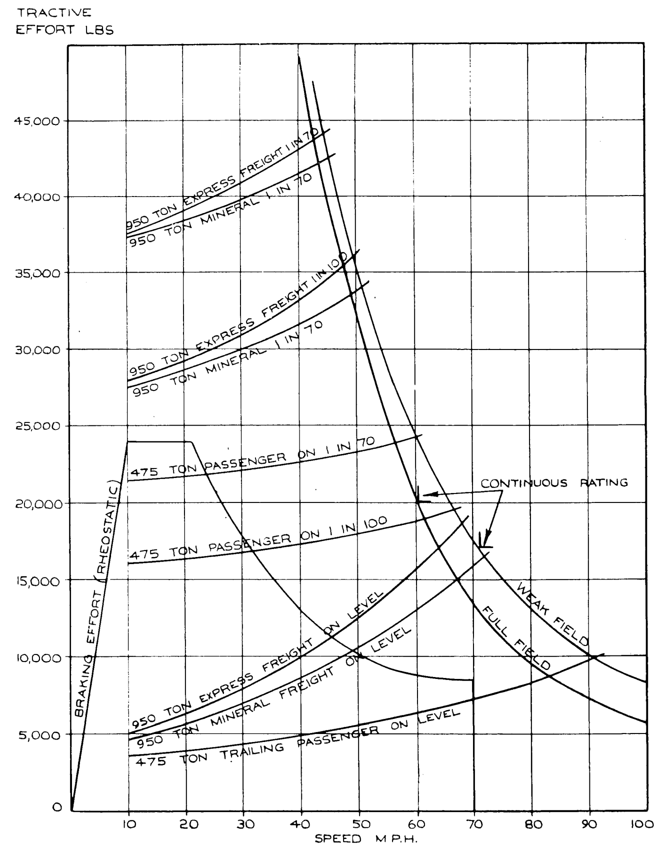

Fig.3 Locomotive performance characteristic. Nos.E 3056/95

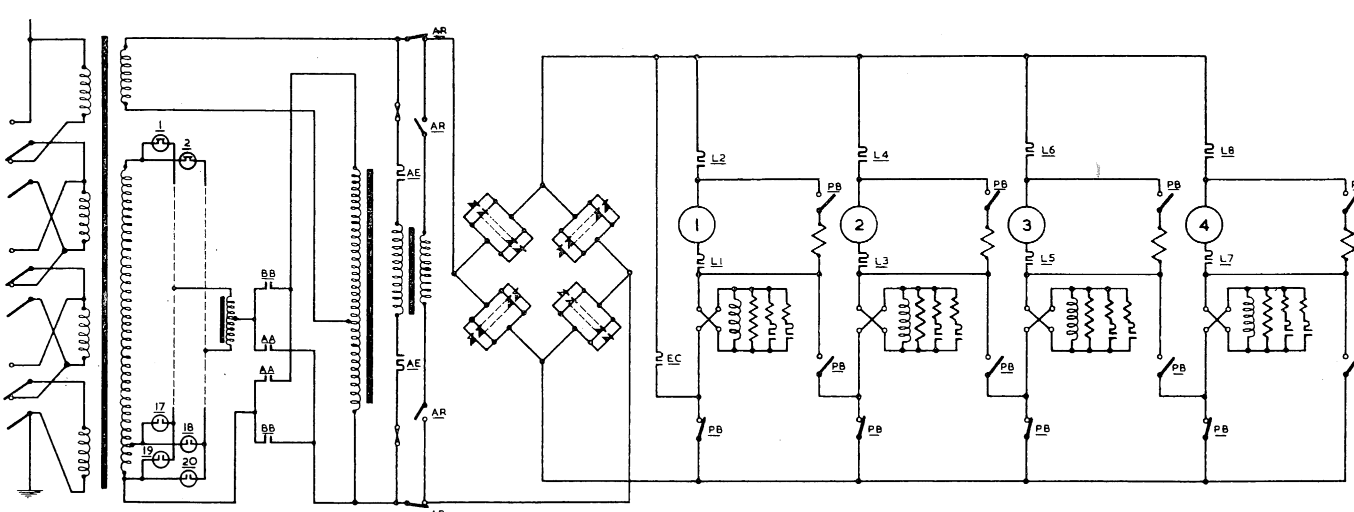

Fig.4 Power diagram. Nos.E 3056/95

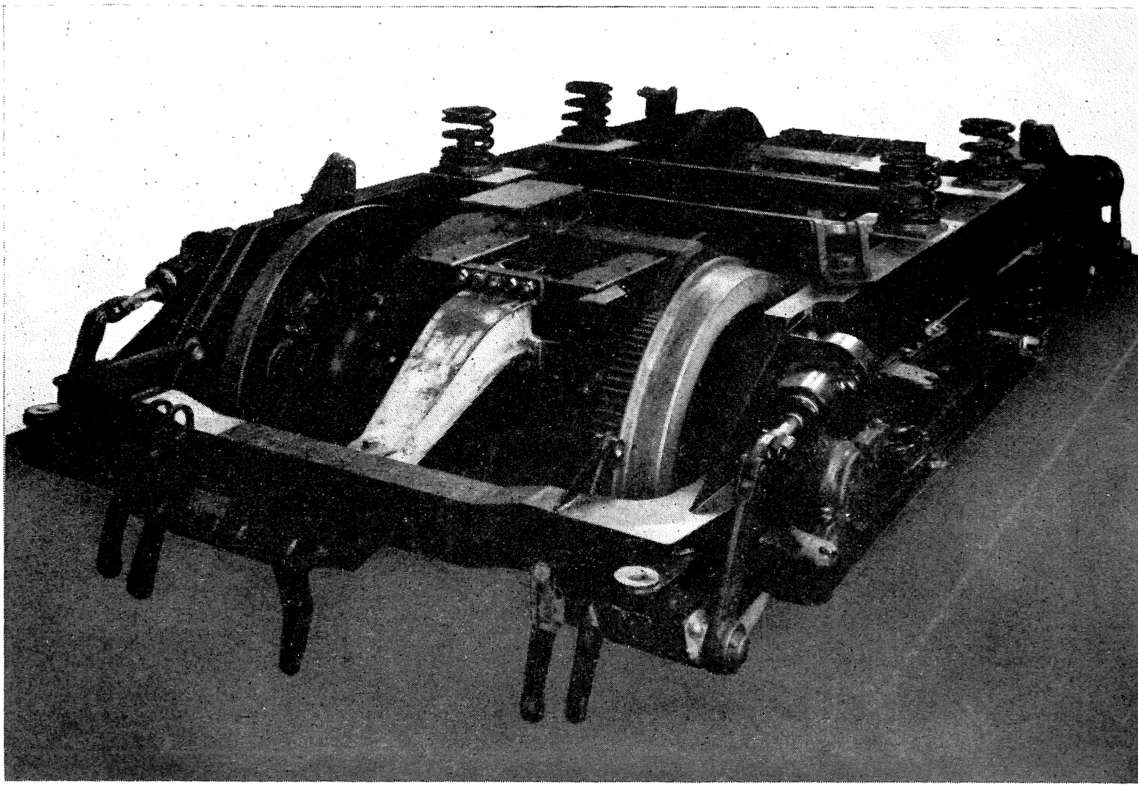

Fig.5 Bogie. Nos.E 3056/95

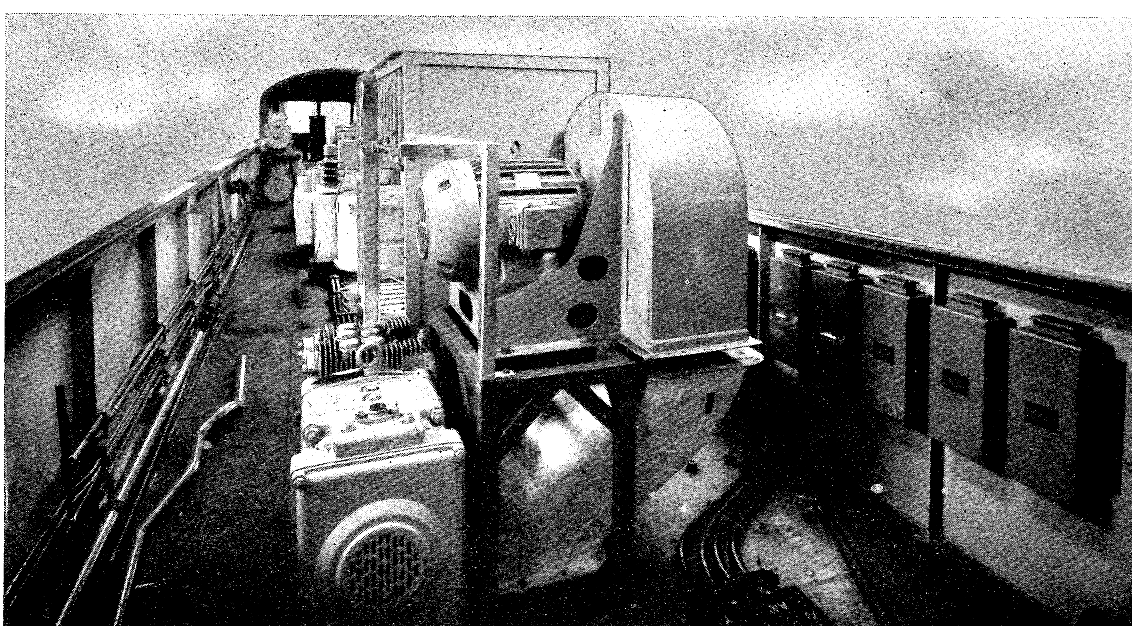

Fig.6 Equipment mounted on frame. Nos.E 3056/95

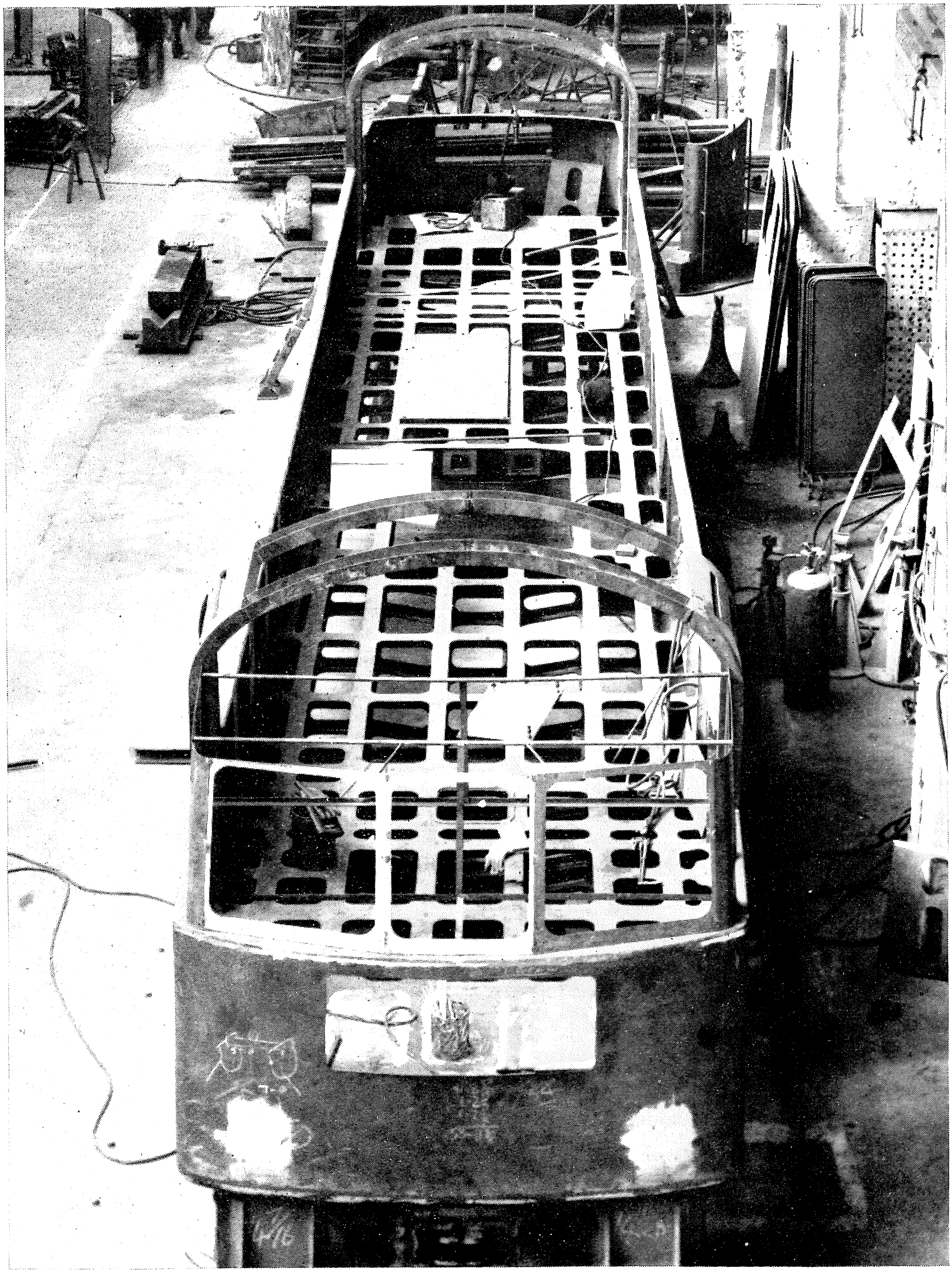

Fig.7 Frame construction. Nos.E 3056/95

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