DESCRIPTION

OF

ERMAN THREE QUARTER TRACK ARMOURED TROOP CARRIER

CHASSIS TYPE ZgKW 3t

VAUXHALL MOTORS LIMITED.

LUTON.

ENGLAND.

THE ZUGKRAFTWAGEN

3.t CHASSIS.

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ISSUED:
AUGUST 1944

THE ZUGKRAFTWAGEN 3.t CHASSIS.

SCHEME OF REPORT:-

NOTE REGARDING NOMENCLATURE OF VEHICLE DESCRIBED IN THIS REPORT:

The chassis, which is the subject of this report, has been referred to throughout as that of a ZGKW 3.t. This designation is not strictly correct, but has been used in the past by those familiar with the vehicle and is, therefore, continued here.

Basically identical three-quarter-tracked chassis are employed by the Germans for accommodating several different types of body and all are known by an appropriate "Sonder-Kraftfahrzeug" number. "Sonder-Kraftfahrzeug", usually abbreviated "Sd.Kfz.", is the German for "special motor vehicle" and numbers with this prefix are used to classify many special German military vehicles including those of the three-quarter-tracked range. The designation "Zugkraftwagen", abbreviated "Zgkw", is reserved for these three-quarter-tracked vehicles, generally fitted with an open troop-carrier body, and always intended for haulage purposes, usually in connection with a gun.

The sources of information, upon which this report was based, relate specifically to the chassis which is basically similar to that of the Zgkw 3.t but which is intended to accommodate an armoured troop-carrier body. In view of this, the chassis would more correctly be termed that of an Sd.Kfz.251.

THE ZUGKRAFTWAGEN 3.t CHASSIS.

INTRODUCTORY NOTE:

We have recently been carrying out an investigation into the design of the three-quarter-tracked series of German Military Vehicles included under the general classification "Zugkraftwagen" or "ZGKW". Particular attention has been paid to the models known as the ZGKW. 3.t and ZGKW 5.t. In this report, an attempt has been made to set out, in fairly concise form, the results of our investigation with regard to the chassis of the ZGKW 3.t model.

The basis of the investigation has been a combined study of the chassis of a ZGKW 3.t, Model 251, loaned to the Engineering Department by the School of Tank Technology, and of German instruction manuals and parts lists relating to this type of vehicle. It should be understood, that upon any specific facts stated in the matter which follows, either the two sources of information were in agreement, or these facts were obtainable from one source only. Any inconsistency between the two sources of information has been clearly stated.

Note Regarding Illustrations:

Plates 1 to 18) are reproductions from German manuals: the diagrams from one
Plates 19 to 56) manual and the pictorial illustrations from another.

Plates 57 to 96 are photographs of the vehicle which was in our possession and were taken at the Works.

Plates 97 to 100 are reproductions from a report upon a "Bussing Nag" ZGKW 1.t.

SPECIFICATION:

Type:	Three-quarter-tracked Zugkraftwagen 3.t chassis to standard German War Office design as built by several manufacturers and designed, with only minor modifications, to fulfil several different purposes and to accommodate several different types of body.
Purpose of chassis inspected:	To form the basis of an armoured troop-carrier and tractor suitable for trailing loads up to 3 tons.
Manufacture of vehicle inspected:	Unknown.
Date of manufacture:	Believed to be since 1938 (from examination of manufacturers' stampings on various units; the radiator bore the inscription "22.12.40" and the main brake operating valve, "Year 1938").
Engine:	Type - Maybach; a standardized German War Office design produced by several manufacturers. Manufacture of engine of vehicle inspected - Nordeutsche.

Engine named	-	"Nordbau"
R.A.C. rating	-	30.1 H.P.
No. of cylinders	-	6
Bore and stroke	-	90 x 100 m.m. or 90 x 110 m.m.
Capacity	-	4170 c.c.
Compression ratio	-	6.7 : 1

WEIGHTS AND GENERAL DIMENSIONAL PARTICULARS:

(Figures marked ✕ are of German origin).

Chassis weights:

Total; in condition as received at the Works: 4.57 tons.

Front axle:) Loads borne by the front-axle
) and tracks respectively of the
Tracks:) chassis, as received, were not measured, but German values for the ZGKW 3.t with laden troop-carrier body are as follows:

Total:	7100 Kgm. ✕
Front axle:	1200 Kgm. ✕
Tracks:	5900 Kgm. ✕

General dimensions:

Overall length:

a) chassis - front wheels to rear towing hook: 213.5"

b) with open, troop-carrier body: 216.5" ✕

c) with armoured, troop-carrier body: 224"

Overall width:

a) chassis - hub to hub: 77.5"

b) with open, troop-carrier body: 78.7" ✕

c) with armoured, troop-carrier body: 82"

Ground clearance:

a) below front axle: 12.6"

b) minimum (below armour plating): 11.0"

Ground contact:

a) tracked portion: 71"

b) wheel base (centreline of front wheel to centreline of rear bogie): 143"

Wading depth: 19.7"

PERFORMANCE:

(Quoted from German manuals).

"Normal" engine speed:	2800 R.P.M.
Engine output:	100 B.H.P. at 2800 R.P.M.
Maximum speed on road:	34 M.P.H.
Normal trailed load:	3 tons (approximately).
Hill climbing ability on loose sand with trailed load:	12° slope
Hill climbing ability on loose sand without trailed load:	24° slope
Approximate fuel consumption on the road:	10 miles/gallon
Fuel consumption cross-country:	up to 6.2 gallons/hour
Radius of action:	150 miles
Turning circle:	44 feet

GENERAL COMMENTARY:

The ZGKW 3.t vehicle covered by this report is designed to serve as an armoured troop carrier and is, in general, used by Panzer and Engineer Units of the German army. It is one of a range of some seven three-quarter tracked German vehicles used in various types of German motorised formations and which vary from the tracked motor cycles for airborne units up to the ZGKW 18.t used for tank recovery, the 't' usually representing the trailed load. As an example of this, the ZGKW 3.t is also used to tow guns or trailers weighing approximately 3 tons.

An important point about these vehicles is the ratio between the front axle weight and the weight on the tracks which is 1 : 4.8 on the 3.t.

Although we have had no experience of actually operating one of the 3.t types of vehicle, the cross-country performance of the type as a whole is very good and certainly is far superior in this respect to any 4 x 4.

The particular 3.t vehicle covered by this report was captured in Libya in 1941.

We have no indication whatever of the maker of this particular chassis.

We should like to record our appreciation of the great help obtained from the War Office M.I.10, who supplied a great deal of very useful information.

J.H. ALDEN.
Commercial Vehicle
Experimental Engineer.

DESIGN ANALYSIS OF CHASSIS:

The ZGKW 3.t is one of the series of German military vehicles which have come to be known as the three-quarter-tracked type of vehicles. There is thus a conventional wheeled-vehicle type of front axle carrying a pair of pneumatic-tyred, Ackerman-steered front road wheels. The major part of the weight of the vehicle, however, is borne on two flexible, endless tracks which are supported upon bogie wheels and which extend the full length of the chassis available rear of the front wheels.

The general chassis layout will be readily apparent from Plates 1 and 57. Plate 1 is a diagram reproduced from a German manual. The individual units of the chassis are described under their respective headings on the pages which follow.

DESIGN ANALYSIS OF CHASSIS (CONTINUED).

SECTION 1 - FRAME.

Description of Design.

Frame assembly.

Included in: Layout diagram: Plate 1.
Pictorial illustrations: Plates 35, 36 and 37.
General photographic views: Plates 57 and 58.

The frame of this vehicle is a very rigid assembly consisting of two deep-webbed side-members and thirteen closely spaced cross-members. The general form of the assembly is clearly shown in Plate 35. There are no rivets anywhere in the assembly. All cross-members are welded to the side-members and butt and T-welded joints are favoured.

The chassis which came into our possession was intended to accommodate an armoured body. Armoured plates were thus bolted beneath the frame across the whole of its width, whilst the smaller vertical plates protected the webs of the side-members. All the armoured plates were spaced from the frame members, to which they were bolted, and cone-headed bolts were used for their attachment. The vertical plates protecting the side-members will be seen in Plate 57.

The rigid construction of the frame assembly itself, aided by the reinforcement provided by the "under-belly" armour plating and the armoured body, must have resulted in an extremely rigid body-frame unit when the vehicle was complete.

Frame side-members.

Included in: Layout diagram: Plate 1.
Pictorial illustration: Plate 35.
General photographic view: Plate 57.
Metallurgical report: Pages 175 - 187.

DESIGN ANALYSIS OF CHASSIS - SECTION 1 - FRAME. (CONTINUED).

Frame side-members (continued).

The side-members are channel-section steel pressings of general form shown in Plate 35. The side-member web depth is constant from the scuttle to the sixth bogie torsion bar housing (No.10 cross-member) approximately. Rear of this the web depth decreases slightly and behind No.11 cross-member the whole member is set up with a considerably reduced web depth. The large hole just forward of this upward set permits the idler-wheel fulcrum arm to pass through the side-member. Forward of the scuttle, the side-members are set inwards and upwards. The upward inclination is continued with progressively decreasing web depth as far as cross-member No.2

The width of the upper and lower flanges of the side-members is constant throughout their length.

Frame cross-members.

Included in:	Layout diagrams:	Plates 1 and 6.
	Pictorial illustrations:	Plate 35 and Pages 177/8 & 182 of the Metallurgical Report.
	General photographic views:	Plates 57, 58 and 59.
Metallurgical Report (elliptical-section members only):		Pages 175 - 186.

For the purposes of this description only, the cross-members have been assigned numbers corresponding with their order in the frame assembly from front to rear.

Cross-Member No.1: This cross-member is at the extreme front end of the frame. It is channel-section pressed-steel member of varying web depth and can be seen in Plate 59. The hole and tubular welded bracket in the centre of the web accommodates the starting handle when in use.

DESIGN ANALYSIS OF CHASSIS - SECTION 1 FRAME. (CONTINUED).

Frame cross-members (continued).

Cross-Member No.2: No.2 cross-member is a fabricated, welded assembly with two deep triangular webs. Bosses are welded to the lower apices of these webs and carry the pivot pin by which the front spring is mounted. The deep triangular webs of this member are stiffened by sheet-metal ribs linking it with the front cross-member (cross-member No.1) and welded to both members.

Cross-Member No.3: This is also a fabricated, welded member and is mainly a box section. It is situated just rear of the engine, where it serves to carry the two rear engine mountings, the two forward-projecting brackets of which can be seen in Plate 35.

Cross-Member No.4: Situated immediately behind No.3 cross-member, this is a tubular member of circular section. It serves to carry the hubs of the track driving sprockets at its extreme ends, where it projects through the webs of the side-members. Vertical flat strengthening plates are welded between the inner edges of the upper and lower flanges of the side-members adjacent to cross-member No.4 and the cross-member passes through, and is welded to, both the strengthening plates and the webs of the side-members.

Cross-Members No's 5 to 10: On a centreline 15" rear of that of cross-member No.4 is the first of six tubular members of elliptical section, each of which serves as a tunnel for the torsion bars by means of which the bogies are suspended. Two torsion bars are accommodated inside each member, one supporting a left hand bogie and one a right hand.

At each end of these members, two elliptical-section castings are inserted which serve to carry the bogie wheel-carrier arm bearings. The two castings are spaced by a tubular distance piece, see sectional diagram Plate 6; the inner one is secured in position by five plugs of weld, whilst the outer one is flanged and the

DESIGN ANALYSIS OF CHASSIS - SECTION 1 - FRAME. (CONTINUED).

Frame cross-members (continued).

flange is welded to the web of the side-member. So good was the fit between the inner casting and the cross-member, in the case of the specimen which was cut open for investigation, that it proved impossible to insert a .003" feeler gauge between the two parts anywhere around the elliptical periphery of the casting. The flange of the outer casting is drilled with two large holes to provide clearance for the torsion bars and there are tapped holes which accommodate the tap bolts by means of which the torsion bar anchorage plate is attached. The flanges of the outer castings can be seen clearly in Plate 35, where they appear as bosses along the web of the side-member. Further details of the construction described above will be apparent from the illustrations on pages 177 to 179 of the Metallurgical Report.

Cross-Member No.11: Distant 21" rear of the No.10 cross-member (centreline to centreline), this is also a tubular member but of circular section. The idler wheel suspension fulcrum arms are mounted upon this member and the ends of the member project through the side-members to enable it to perform this function. This member is joined to the side-member in a manner similar to that described above with reference to No.4 cross-member; it is thus welded both to the side-member webs and to the strengthening plates linking the inside edges of the upper and lower flanges of the side-member.

Cross-Member No.12: This is a pressed-steel cross-member of channel section and is linked to cross-member No.13 by central welded longitudinal struts.

Cross-Member No.13: No.13 cross-member is situated at the extreme rear of the frame assembly and carries the towing hook. It is a channel-section pressed-steel member similar to No.12 to which it is linked. There are also diagonal bracing members welded between the rear cross-member and the side-members.

DESIGN ANALYSIS OF CHASSIS - SECTION 1 - FRAME. (CONTINUED).

Front towing hooks.

Included in: General photographic view: Plate 59.

Two solid towing hooks are secured rigidly to the front end of the frame; the hooks are not shown in any of the reproductions from the German manuals but can be seen, one at the forward end of each side-member, in the general photographic view of the front of the vehicle, Plate 59.

Reinforcing plates are welded to the webs of the side-members in the neighbourhood of the towing hook attachment and a circular boss of about 2" diameter projects from each of these plates. The upper end of each towing hook is formed as a flat plate, through which is drilled a hole of approximately the same diameter as the boss projecting from the frame. The hook is thereby fitted to the boss and the joint is closed by a ring of weld. In addition, three large-diameter bolts pass through the side-member, the reinforcing plate and the towing hook and are clamped by nuts on the outside.

The towing hooks themselves are each made in two parts joined by a butt-weld in the position indicated at 'X' on Plate 59.

Rear towing attachment.

Included in: Layout diagram: Plate 1.
Pictorial illustrations: Plates 36 and 37.
General photographic view: Plate 57.

There appear to be two alternative types of rear towing attachment for the ZGKW 3.t, i.e. the assembly shown in Plate 36, together with its component parts, and that shown in Plate 37, as both these illustrations were reproduced from the same manual. In both types the main design is centred round the spring-loading of the coupling assembly, with respect to the frame, by a device involving a good deal of friction.

DESIGN ANALYSIS OF CHASSIS - SECTION 1 - FRAME. (CONTINUED).

Rear towing attachment (continued).

The vehicle which was loaned to the Engineering Department carried an assembly of the type depicted in Plate 37. In this plate the complete assembly is shown at (32), whilst the component parts are set out beneath this view.

The functions of the various parts will probably be apparent from the views shown. The flanged and webbed tubular bearing, (37), is bolted directly to the rear face of the rear frame cross-member (cross-member No.13), the same bolts being employed to secure parts (33) and (36) to the inside of the cross-member. The large-diameter parallel journal of the eye rod, (51), is a good sliding fit inside the above bearing, and this is the only bearing between the sliding and fixed parts of the assembly. The part labelled (54) in Plate 37 is a barrel-shaped spring-steel tube, with a wide longitudinal split. Flanged washers, (53) and (55), just fit on the extreme ends of the barrel tube and present conical interior surfaces to it so that when these two washers are drawn together axially, by a force, they result in closing of the longitudinal split in the barrel-shaped tube against its elastic resistance. The axial thrust resulting from the action of this "barrel spring" is ultimately borne on the sliding assembly by the nut, (58), and on the fixed parts by the plate, (36).

A load/deflection graph of the spring unit from the rear towing attachment assembly of the ZGKW 3.t loaned to the Engineering Department, will be found on page 407

Dimensional Data.

(Scaled from vehicle except where marked *)

Overall length of frame assembly (front of front cross-member to rear of rear cross-member):	195.5"
Width across outside of side-members:	39.5"

DESIGN ANALYSIS OF CHASSIS - SECTION 1 - FRAME. (CONTINUED).

Dimensional Data (continued):

Gauge of side-members:	0.161"
Maximum web depth (constant over centre length of side-member, see descriptive matter above):	12.6"
Width of lower flange of side-members:	2.4"
Width of upper flange of side-members:	2.4"
Depth of side-members at extreme front end:	3.9"
Depth of side-members at extreme rear end:	4.6"
Spacing of tubular cross-members:-	
Centreline of No.4 to centreline of No.5:	15.0"
" " No.5 " " " No.6)	
" " No.6 " " " No.7)	
" " No.7 " " " No.8)respectively:	14.5"
" " No.8 " " " No.9)	
" " No.9 " " " No.10)	
" " No.10 " " " No.11:	21.0"
Cross-member No.1:- Gauge:	0.169"
Width of lower flange:	2.3"
Width of upper flange:	2.3"
Cross-member No.2:- Gauge:	0.252"
Cross-member No.3:- Gauge:	0.156"
Cross-member No.4:- Outside diameter:	3.9"
Cross-members No's 5 to 10:-	
Gauge:	0.133"
Length of major axis of outer ellipse of section:	6.7"
Length of minor axis of outer ellipse of section:	4.8"
Cross-member No.11:- Outside diameter (over main length):	4.1"
Cross-member No.12:- Gauge:	0.175"

DESIGN ANALYSIS OF CHASSIS - SECTION 1 - FRAME. (CONTINUED).

Data Resulting from Experiment upon Parts from Vehicle:

Laboratory reports upon materials of construction:

Where examination of materials has been carried out, reference to the appropriate Laboratory reports has been made at the top of the sub-section dealing with the parts concerned.

Torsion test upon frame assembly:

The frame assembly was stripped of all extraneous components. Tests were carried out with and without bogie and idler-wheel-suspension torsion bars assembled in the frame. Angular deflections of the frame at the chosen stations are graphed on pages 408, 409 and 410.

A full report upon the tests of torsional stiffness carried out upon the chassis frame will be found in Vauxhall Motors Limited Experimental Report No.1218 pages 10 to 14 inclusive.

Load/deflection test of spring unit from rear towing attachment:

A graph plotted from the load/deflection test will be found on page 407 The friction feature of this unit will be readily observed.

A report of this test will be found in Vauxhall Motors Limited Experimental Report No.1218 pages 62 to 63 inclusive.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS.

Description of Design.

Engine assembly.

Included in: Layout diagrams: Plates 1 and 18.

Pictorial illustration: Plate 19) Also Plates) 97 - 100 inclusive.

General photographic view: Plate 57) (see text below).

Apart from one external pictorial view of the power unit (Plate 19), no reference to this unit was made in either of the German manuals which were drawn upon for illustrations for this report. Furthermore, the engine of the ZGKW 3.t, which was loaned to the Engineering Department, was not dismantled whilst in our possession.

According to documentary evidence of German origin, however, power units of identically similar basic design, capacity, bore and stroke, are fitted to the 1.t and 3.t models of the Zugkraftwagen range. A vehicle of the ZGKW 1.t type was also loaned to the Engineering Department recently for examination and repair and at that time our Engine Section took advantage of the opportunity afforded, to dismantle and inspect, and also to test, the power unit. Extracts from the report issued by this section, at that time, upon the design and test of this power unit, are therefore included herewith:- (design, pages 15 to 22 ; test, pages 32 to 40; illustrations, Plates 97 to 100).

"Brief description of German "NORDBAU" Engine - the Power Unit from a Bussing N.A.G. Semi-Track Vehicle.

Bore 90 m.m. (3.543")

Stroke 110 m.m. (4.33")

Swept Volume: 4.198 litres R.A.C. Rating 30.1

Compression Ratio 6.43/1 (Approx).

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED).

Engine assembly (continued).

"Crankcase.

"Monobloc in cast iron of robust construction, carrying eight main bearings, the rear main being two small width bearings, placed one either side of the crankshaft timing gear.

"The main bearing shells are bronze backed white metal lined, totalling 5 m.m. thick, and located in the crankcase and bearing caps by small dowels, the clutch thrust being taken on the crankshaft location at the rear bearing.

"The crankcase walls are cast well below the crankshaft centreline and each bearing diaphragm is carried down to the bottom flange in the form of ribs having bulb edges. (See photograph Plate 100).

"The cylinder bores are lined with full length dry liners.

"Cylinder centres:- 106 m.m, and 118 m.m between centre cylinders.

"Oil baffles are fitted at the bottom of the cylinder barrels.

"Crankshaft.

"Fully balanced, machined all over.

"Journals 70 m.m. dia. by:- Front 42 m.m. long.
Inter. 31 " "
Centre 42 " "
Rear 23 " "
Rear 19 " "

"Crankpin 55 m.m dia. x 44 m.m long, the effective length, however, is only 36 m.m due to the large chamfer on each side of the bearing.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED)

Engine assembly (continued).

"It is interesting to note that the con. rod bearing area per square inch of piston area is .311 compared with .272 for the 28 H.P. Bedford engine, and that the German engine big end is lead bronze lined.

"Crankwebs 15 m.m thick by 150 m.m at the widest turned 170 dia. about the crankshaft journal axis, and tapered to 40 m.m wide at the crankpin. (See photograph Plate 99).

"The crankshaft has hollow pins and journals bored 25 and 40 m.m respectively, and sealed by end caps, bolted through.

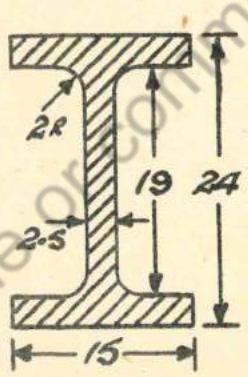
"There are 12 - 10 m.m dia. coupling bolts in the rear coupling flange for flywheel, and 8 - 8 m.m dia. bolts in the front coupling flange for attaching the Torsional Vibration Damper and Belt Pulley. (See sketch page 19)

"Main Bearing Caps are of cast iron and are checked into the crankcase (see photograph Plate 100) and secured by 2 - 10 m.m studs per bearing. Each nut is numbered to its respective stud and locked by a split pin.

"Connecting Rod.

"Fully machined all over, the strut is of "H" section of normal design.

"Flanged steel backed lead bronze bearings are fitted of a total thickness of 3 m.m, secured by 2 - 10 m.m dia. fitted bolts with "D" heads, and nuts locked by split pins, each nut numbered to its respective bolt.



"Connecting rod centres 182 m.m giving a rod/crank ratio of 3.33/1

"Hollow fully floating gudgeon pin 24 m.m dia. O.D. x 15 m.m I.D.

"The complete connecting rod assembly weighs 2.154 pounds.

Big end	1.715 pounds.
Small end	.419 "

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Engine assembly (continued)

"Piston.

"Ricardo slipper type in light alloy fitted with ring equipment:- 2 - 3 m.m wide pressure rings and 2 - 5 m.m maxi-groove (slotted) type scraper rings for oil control, one fitted in skirt.

"The piston assembly complete weighs 1.625 lbs. The engine number is stamped on each piston.

"Timing Gears.

"The gear train comprises of the crankshaft gear, the idler, and the camshaft gear. They are mounted at the rear end of the engine immediately in front of the flywheel, thus relieving them of any transmitted crankshaft torsional oscillation that may be present. The idler gear is of compounded fabric and the remainder in steel, all are 30 m.m wide helical gears, with 36 teeth in crankshaft wheel, 72 in camshaft wheel, and 44 in oil pump wheel driven off the underside of the crankshaft wheel.

"The magneto is driven off the idler gear, and the Dynamo, water pump and fan are driven by 'V' belt from the pulley on the front end of the crankshaft.

"Cylinder Head and Valve Gear of cast iron, incorporating seven bearing housings for the overhead camshaft 64 m.m dia., white metalled lined, ranging from 18 to 28 wide, supporting a camshaft of simple harmonic cam form, with roller followers 40 m.m dia. x 8 m.m wide running on a plain pin 12 m.m dia. (See photographs Plates 99 and 100).

"The rocker brackets supporting the two hollow rocker shafts are mounted direct, on to the camshaft bearing pedestals, and bolted through to the cylinder block by the cylinder head holding down bolts, of which there are four per cylinder 12 m.m dia.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED)

Engine assembly (continued)

"Inlet rocker levers are assembled on the rocker shaft placed on the inlet side and exhaust rockers on a separate shaft on the exhaust side of the head, running on eccentric bushes with a quadrant plate cast integral, thus forming a means of adjustment of valve clearance.

"Incidentally the valve rockers are very heavy and cumbersome, with no visible means of lubrication to the roller pin, the difficulty of effective lubrication here makes wear inevitable, even in engines of normal speed.

"Close control of clearance volumes in the head can be maintained since the combustion space can be, and is machined, being shaped as the segment of a sphere.

"Valves are inset at an included angle of 60° approx.

"The inlet valve has a tulip head and exhaust valve a convex head.

DESCRIPTION.	INLET VALVE.	EXHAUST VALVE.
Port Dia.	43 m.m	36 .m.m
Valve Head Dia.	47 m.m	40 m.m
Valve Stem Dia.	9 m.m	10 m.m
Seat Angle	30°	30°
Valve Lift	.339"	.334"
Valve Opens) Crankshaft Degrees)	3° A.T.D.C.	31° B.B.D.C.
Valve Closes) Crankshaft Degrees)	53° A.B.D.C.	12° A.T.D.C.

(Valve clearance .010 - Hot).

"Lubrication System

"Dry Sump

"The engine sump is merely a cover plate, pressed with shallow depressions at either end, and at the centre for oil pump clearance, and to provide small suction wells for the scavenge pumps, of which there are two. The rear scavenge pump is driven

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Engine assembly (continued).

"from the crankshaft gear wheel, and running at .82 of engine speed, and is mounted on the rear main bearing cap, and the second scavenge pump, mounted on No.2 bearing cap is driven by a hollow square ended tube, from the driven spindle of the rear pump.

"Pumps are interchangeable and have a common delivery through the crankcase wall to an external tank bolted to the crankcase, of approx. 3 gall. capacity. The pressure pump is assembled on a facing at about the centre of the engine inside the crankcase, and driven by a spindle passing through a cast pocket to pick up the drive from the camshaft gear.

"Pressure suction is from the external tank, delivering through crankcase wall to an external oil cooler bolted to the crankcase thence through an oil filter (Autoclean type) to the annulus formed by the oil pump spindle passing through the cast pocket, so forming a small pressure reservoir. All main and connecting rod bearings are fed by a gallery pipe secured to the main bearing caps, which gets its supply from the reservoir through drilled passages in the centre main bearing cap.

"Oil is fed into the hollow journals of the crankshaft, the supply to the big end coming from both adjacent mains, forming a double feed. No oil holes appear in the main and rod bearing shells, the oil being fed into a groove machined on the outside dia. of the shell, and so into the bearing by way of slots machined at the joint at each side.

"There are two $\frac{1}{4}$ dia. holes in the mains and one 3/16 dia. and two 5/32 dia. holes in big end bearings for oil supply from hollow crank.

"The rocker gear, through the medium of the hollow rocker shafts also draws on the pressure reservoir for its supply, draining back through holes drilled in the cylinder head.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Engine assembly (continued).

"The two scavenge pumps deliver 4.8 galls. per min. and the pressure pump 1.5 galls. per min. at 1000 R.P.M. engine (calculated at 85% efficiency).

"The pressure relief valve is built into the filter body and is set to relieve at 3.5 atmospheres (approx. 50 lb/sq.in.) See sketch on page 39.

"Water Pump and Dynamo are bolted together and the assembly is bolted to crankcase, the dynamo in a cradle, and driven by 'V' belt from the crankshaft pulley. A three vane pump impeller is employed together with a packed gland.

"To replace a dynamo entails the removal of the water pump and the dismantling of same. The suction from the radiator bottom tank is delivered through the oil cooler and thence to the engine entering the cylinder block at No.3 cylinder, circulating, around the cylinder block and head, and out at the front end of the cylinder head to radiator top tank.

"Magneto

"Driven from idler wheel and is rotating magnet type of Bosch manufacture, with auto-centrifugal advance device.

"Carburettor. (See also pages 22 - 23).

"Solex type 40 J.F.F.2 Dual down draught with 26 m.m dia. chokes fitted in 40 m.m dia. tubes.

Jet Settings.	Primary.	Secondary.
Choke	26 m.m	26 m.m
Main Jet	125	120
S.R. Jet	55	Nil.
Correction Bleeds	6 x 1.4 m.m	6 x 1.4 m.m
Emulsion Tube	2 x (4 x 1.0 m.m)	2 x (4 x 1.0 m.m)
S.R. Air Bleed	Variable	Nil.
S.R. Well Supply	4 x 1.5 m.m	Nil.
Starter Jets - Air	53	
Fuel	250	

Flow curve page 38.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Engine assembly (continued).

"Clutch. (See also page 30).

"The clutch housing is cast in light alloy of orthodox design, incorporating a twin plate clutch of the Borg and Beck type. The centre rubbing plate is of cast iron 16.5 m.m thick.

"Friction discs 250 m.m O.Dia. x 155 m.m I.Dia. 10 spline shaft 35 O.D. x 29 I.D. The final drive coupling $3\frac{7}{8}$" O.D. with six 5/16" dia. bolts on a $3^{5}/16$" P.C.D. - $2\frac{1}{4}$ dia. spigot.

"Attached is the Experimental Department's standard engine test sheet and relevant power curves, etc.

R.A. WATSON."

Some details which are available with regard to the components of the ZGKW 3.t chassis which might be included under the heading "POWER UNIT AND POWER-UNIT CONTROLS", are not included in the above report and are, therefore, reproduced below.

Carburettor.

The carburettor from the vehicle which came into our possession was sent to Messrs. Solex Limited (London) for examination and extracts from their report are included herewith:-

"This carburettor is identical with the carburettor of the same type No. IW.9858, subject of our report of the 26th March 1942, and is fitted with the same setting.

"This is the first carburettor we have had complete with the air entry adaptor to connect to the air cleaner, and this part is of particularly good design, giving ample volume."

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Carburettor (continued).

"Report on 1 Solex Carburettor - Type 40 JFF2. No. I.W.9858.

26th March, 1942.

"This carburettor is almost identical to one of the two carburettors of the same type, the object of my report of the 3rd January, 1942, i.e. Carburettor No. L.T.5806. In this early report the carburettors had been called type 40 DFF2, owing to the corroded state of the labels, which made the type letters almost unreadable. This new carburettor is in a much better condition and the type can be easily read as IFF2., the 'I' being written in the German way 'J'.

"The only difference between this carburettor and No. L.T.5806 are:-

"1. The throttle levers are somewhat different, but they provide the same type of interconnection, i.e. the throttle lever to which the main controls are attached opens its own throttle about 2/3 of the way before an extension striking the lever on the other throttle spindle causes this second throttle to open. The radii of the levers are so arranged that both throttles reach their full open position at the same time.

"2. At the ends of the spindles opposite to the levers are fitted two short levers which were probably used for anchoring a tension spring forcing always the second throttle towards its closed position.

"3. There are no throttle stops for either the full open of idling position. This was probably arranged on the controls.

"4. The idling screw is fitted on the side of the carburettor and not inside the air intake.

"In all other respects this carburettor is identical with Carburettor No. L.T.5806.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Carburettor (continued).

"Both sides of the carburettor have not the same setting. We will call side No.1 that to which the main controls are attached and which is also the one where the idling screw is fitted. No.2 will be the other side.

	Side No.1.	Side No.2.
Choke Tube	26	26
Main Jet	125 x 51 (225 cc)	120 x 51 (200 cc)
Pilot Jet	55 (37 cc)	None.
Needle Valve	2 m.m.	2 m.m.
G.A.	5.5	
G.S.	250 (595 cc)	

"The parts used are:-

Choke Tube	No. 50459
Needle Seating	" 51305/7
Needle Washer	" 2260
Starter G.S.	" 50676/2 (but two lateral holes drilled 1.75)
Starter G.A.	" 50906
Starter Valve	" 50979/2
Main Jet Carrier	" 50694 (but 8 m.m hole becomes 9.25, and 4 - 0.5 holes become 1.5 dia.)
Main Jet	No. 50442
Main Jet Cap	" 51478
S.R. Tube Carrier	" 51479
S.R. Tube assembled similar to that shown on 51480 but projects 29 m.m and has calibration at bottom 55. (No lateral hole below carrier as shown on 51480)	
S.R. Adjustment Screw	No. 50549
Spring for ditto	" 50550

"There is no intercommunication between either the float chambers of the throttle tubes, and since the carburettor was fitted to a 6 cylinder engine it must be assumed that there is some intercommunication inside the induction manifold between the two branches leading to the carburettor outlets. The operation would then be - at part throttle only side No.1 is operating, and not until full power is required does side No.2 deliver petrol to the engine. The object is evidently to obtain full power without losing the flexibility and smooth operation at the lower speeds."

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Carburettor (continued).

"Report on Two Solex Carburettors - Type 40 DFF2.

3rd January, 1942.

"General lay-out:

"The above two carburettors were linked up together as per sketch attached. *

"It will be seen from this that the two outer throttle levers are interconnected and are forced towards the closed position by a spring, but are not directly connected to the main control. The main control is attached to one of the two inner throttle levers, which are also interconnected.

"The lever to which the main control is attached carries an arm E. which for a given throttle opening comes in contact with a peg carried by a special lever L. on an extension of the outer spindle of the same carburettor.

"It follows from this scheme that when cruising, the inner throttle tubes only are delivering mixture to the engine. The outer throttle tubes come into operation only after the inner throttles are more than half opened.

"The position of the inner throttles for which contact occurs with the lever L. may, during preliminary tests, be varied by moving the latter since it is clamped round a cylindrical extension of the spindle, but on production carburettors it is pinned in a fixed position.

"To avoid risk of damage to the outer butterflies when the accelerator pedal is released, an adjustable stop is provided at the end of the lever L. This stop comes in contact with the wall of the float chamber.

"The carburettor air intakes are provided with bridge pieces to which may be secured an air bend.

* This was a copy of the original report and no sketch was attached.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED)

Carburettor (continued).

"Each carburettor has a single petrol connection, although there are four alternative positions for it on the cover, marked P. on the sketch attached. Each pair of petrol bosses lead into a gallery feeding the needle valves of the inner and outer float chambers, but the two galleries do not intercommunicate. The needle valves (one per float chamber) must, therefore, be fitted on the same side as the petrol connections and blank plugs fitted on the other side.

"Float chamber mechanism:

"Each carburettor has two entirely separate float chambers.

"Each float chamber includes two independent floats (weighing 24 grs. each, 50 m.m dia. outside the lid, 49 m.m dia. around the shell, maximum thickness 29 m.m, thickness at the periphery 24 m.m).

"Some interaction between the two floats is obtained by a special tubular shaft revolving round the same axis as the floats and carrying two extensions (one at each end) which rest on top of the float arms and are interposed between the latter and the needle valve shank. A pin driven through the tubular shaft limits its rotation, probably to prevent damage to the floats if, when dismantling, the carburettor is tipped over.

"The object of the complication introduced by the tubular shaft is not clear, since for steep angles of tilt, the petrol level will not remain as stable in relation to the jet as with our scheme. It has, however, the following advantages:-

"If a float becomes punctured it can be individually replaced.

"Also, no appreciable torque is transmitted through the tubular shaft, and it may, therefore, lengthen the life of the soldered assemblies.

DESIGN ANAIYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Carburettor (continued).

"Another peculiarity of these float chambers is that there is little facility for the fuel to flow from one side to the other. The only intercommunication is through the channel feeding the main jet. For a sudden variation of tilt, there may, therefore, be a temporary tendency for the carburettor to flood.

"Finally, the float pivot is well above the centre of the float which will cause marked differences of float leverage when the vehicle is tilted and will, therefore, upset the level.

"Main jet system:

"The main jet system consists of a 12 assembly main jet fitted in the usual 12 Ass. jet well for downdraught carburettors. In the centre of the jet cap is fitted a pilot jet (type 40/46 ZNV) which picks up the petrol through a tube dipping into the bore of the main jet.

"There is only one such pilot jet per carburettor, and it is fitted in the side which is always in operation, i.e. the inner side. In the other side there is only a pilot jet body minus the dip tube. The choke tube is our usual 35/40 downdraught type.

"Idling system:

"The idling mixture is controlled by an air regulating screw (standard pattern for 35 M.H. Carburettors), the air being taken from a point inside the air intake.

"The idling mixture escapes at the throttle edge of the inner throttle tubes through 2 orifices, one at the upper, the other at the lower edge of the throttle. The butterfly is our old bossed type (40 m.m).

"The throttle spindles are 10 m.m dia. and special dust covers are fitted at the outer end of each bearing. They are formed by a ring of soft material kept by a circlip round the spindle and the inner edge is spread out against the bearing end-face and is held there by a small brass pressing and two screws.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Carburettor (continued).

"Starting:

"Each carburettor is equipped with a starter, on the usual principle. The following peculiarities have been noticed, however:-

"The GS. jet, although interchangeable with ours, have their calibration located in the two lateral holes. Also, whilst they are stamped 340, they have the flow of 250 jets, i.e. 950 cc.

"The starter jets are fed from one float chamber only in each carburettor, the right hand one looking at the Solex name plate.

"There is only one GA. jet per carburettor, size 5.5, which appears very small for a carburettor of this size, and unlikely to give sufficient volume for very cold starting.

"The starter disc valve is of the usual pattern for self-starter carburettors of the commercial type (size 35/40), but only one of its two outlets orifices is operative. The other orifice does not register with any channel leading to the manifold but with a blind hole.

"The starter outlet is located in the inner throttle tube of each carburettor.

"General remarks:

"Although the carburettors, as finally assembled, must be paired, the castings are identical and symmetrical. They are made into right or left hand carburettors by simple machining operations.

"The castings (die-castings) are apparently made from a different alloy from ours. Its composition will be ascertained.

"The main jet setting differs in the inner and outer tubes, probably to compensate for the obstructions caused in the inner tube by the pilot dip tube.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Carburettor (continued).

"The setting is as follows:-

	Inner F.C.	Outer F.C.
Choke Tube	30	30
Main Jet	170 x 51	165 x 51
Pilot Jet	55	None
Needle Valve	2.0	2.0
GA.	5.5	
GS.	340 (reading 250 and flowing 950 c.c.)	

"When the carburettors were dismantled it was noticed that the outer float chambers were much more corroded than the inner ones; in fact, the latter were almost clean. Also the floats from the badly corroded float chambers had a much thicker deposit at a short distance from the lowest point.

"Starting from this point, there was a thin white coating on the float extending for about ¼ of its height, then a very thick white coating appeared decreasing in thickness progressively towards the top of the float but remaining everywhere thicker than at the bottom.

"Also all steel parts were deeply rusted up. Apparently some water, and probably sea water, has reached the carburettor inside and outside.

"Also, a great amount of sand was found in the choke tubes, and on the butterflies, but we could not form an opinion as to how this sand could have remained stuck in compact masses on the various surfaces where it was found deposited. Perhaps a deliberate attempt was made to wreck the engine by throwing sand into the air intakes. Certainly, as received, the throttle controls and spindles, which were stuck solid by rust, were not in the normal position for an engine which has been simply switched off. The inner butterflies were half open and the lever arm E. was just in contact with the peg on the lever L. Apparently the engine was kept racing to the last minute.

"It will be noticed that no jets, except the GS. jets, are accessible from the outside."

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Engine mountings.

Included in: Layout diagram: Plate 1.
Pictorial illustrations: Plates 19 and 35.

Front-end mounting of the engine consists of a transverse, fabricated arm, bolted to brackets from the side-members and suspending the engine at the centre in a totally enclosed, circular, rubber bush.

At the rear, the engine is mounted, both sides, on projections from the crankcase casting, which are carried in large, rubber-bushed bearings with detachable caps secured to frame cross-member No.3. The L.H. rear mounting projection can be seen below the starter in Plate 19 and one of the bearing caps is shown at (2) in Plate 35.

Clutch.

Included in: General photographic view: Plate 96.

Details of the type of clutch employed in the ZCKW 3.t are set out in the report by our Engine Section on page 22. A photograph of the housing and striking mechanism of that from the vehicle which was examined at the Works is shown in Plate 96.

A clutch stop is incorporated in the rear of the clutch housing.

Clutch operating linkage.

Included in: Layout diagram: Plate 12.
Pictorial illustration: Plate 44.

Clutch and brake pedals are mounted on brass bushes upon the same short cross-shaft and their depression is resisted by similar coil tension springs. The linkage to the cross-shaft, borne in the clutch-housing and operating the striking fork, will be seen in the layout diagram, Plate 12.

Accelerator and throttle control.

Included in: Layout diagram: Plate 11.
Pictorial illustration: Plate 43.
General photographic view: Plate 67.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED):

Accelerator and throttle control (continued).

A lever-type accelerator pedal is employed, pivotted from a small, double-bent, fabricated, welded, bushed bracket bolted to the scuttle and is situated conventionally just to the right of the brake pedal. Foot-contact is made through a rubber roller carried in the forked end of the lever. Provision is also made for manual throttle control by a short lever operating in a quadrant bolted to the dashboard.

Both foot and manual throttle controls and their linkage to the carburettor are very well shown in the external and sectional diagrams on Plate 11 and further explanation is scarcely required. The manner in which the foot and hand controls are linked by a pin and slotted rod will be appreciated; movement of the pedal is thereby independent of the hand lever, but minimum throttle opening is determined by the setting of the latter in the usual way. Two types of manual control are apparently available as evidenced by the illustration on Plate 43. That on the vehicle which was examined was of the type shown on the left hand side of this plate in which the quadrant is toothed internally and the pawl is held in contact with it by a small compression spring.

A feature of interest on the vehicle which came into our possession was the bristle grommet employed for closing the elongated aperture through which the accelerator pedal projects.

Dimensional Data.

(Scaled from vehicle except where marked *)

Dimensional data relating to the power unit will be found included in the text of the report by our Engine Section (pages 15 to 22).

In addition, the following figure is quoted from a German manual:-

Oil capacity of engine: 2.63 gallons. *

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED)

Data Resulting from Experiment upon Parts from Vehicle.

A similar power unit (see page 15) removed from a ZGKW 1.t vehicle was tested to the standard Experimental Procedure and the report by our Engine Section is included herewith:-

"Power Performance and Fuel Consumption of Nordbau Engine.

"Test completed 5.12.42.

"Purpose of test.

"To obtain power performance and fuel consumption data from dynamometer tests of a Nordbau engine.

"Materials tested.

"Nordbau engine, removed from Bussing N.A.G. half-track vehicle (see page 34 for full details).

"Test procedure.

"Before testing it was necessary to dismantle and overhaul the engine. This involved decarbonising, grinding in the valves and fitting new parts to the scavenge pumps.

"After overhaul and reassembly the engine was mounted on No.4 test bed and prepared for testing, i.e. run for an hour or so, head bolts tightened, tappets adjusted and ignition set. Trial power tests were run on pool petrol, octane No.69 approx. and pool petrol doped with ethyl fluid to give an octane No. of 75. The only gain with doped fuel was a slight decrease in the detonation. All further tests were carried out on pool petrol.

"Preignition was encountered at high speeds. Various types of plug were tried and the K.C. F.12. Zircruhd type plug was the only plug suitable for these tests.

"At this stage several valve spring breakages occurred, which appeared to have been started by localised areas of corrosion on the springs. As all the springs showed signs of this corrosion, a new set was made and fitted. No further trouble was experienced.

DESIGN ANALYSIS OF CHASSIS - SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS (CONTINUED)

Data Resulting from Experiment upon Parts from Vehicle (continued).

"A standard full throttle power and fuel consumption test was then carried out. For this test, the carburettor was in the standard fixed jet condition as received; the flow curve is given on page 38 no air cleaner was fitted and the Shop exhaust system was used.

"Test results.

"Comment.

"As seen from the power curves, no readings were taken below 1800 r.p.m. The reason for this was that any attempt to run the engine for more than a few minutes at any speed, below 1800 r.p.m., resulted in spitting-back through the carburettor with consequent loss of speed and power until the engine stopped. This effect was present at throttle openings from full down to approx. 1/3 load. Below 1/3 full load the engine would run normally.

"Nothing could be found to account for this effect, and it was attributed to faulty mixture distribution."

REPORT NO. PAGE 34 Report BUSSING NBG SHEET OR PAGE NO. 13

VAUXHALL MOTORS LIMITED

STANDARD ENGINE TEST LOG SHEET

GENERAL INFORMATION

OBJECT OF TEST Standard power and road load fuel consumption test. (Using Bedford OY road loads and speeds).

ENGINE NORDBAU MOD. SER. NO. 550699 NO. CYL. 6 BORE 3.54" STR. 4.24" DISPL. 256.2cu.C. R6.43-1 ins.

WHERE OBTAINED (DESCRIBE CONDITION) Removed from Bussing N.A.C. half track vehicle, obtained from W.V.P.E. Farnborough, for overhaul and testing.

VALVES	SIZE (PORT & HEAD)		SEAT ANGLE	MAX. LIFT	LASH (HOT. COLD)	OPENS (HOT. COLD) LASH	CLOSES (HOT. COLD) LASH
INTAKE	43 m/m	47 m/m	30°		.010"	3° A.T.D.C.	53° A.B.D.C.
EXHAUST	36 m/m	40 m/m	30°		.010"	31° B.B.D.C.	12° A.T.D.C.

ARRANGEMENT & DESCRIPTION Angularly disposed, included angle between valves 60°

CAMSHAFT (STD.. EXP.. PT. NO.) Overhead, gear driven. RAMP. (DEG.. HEIGHT. HEIGHT DEG.)

CYLINDER HEAD (STD.. EXP.. PT. NO. TYPE) Combustion space, segment of sphere 89 m/m dia. at face x 25 m/m deep.

CYLINDER NO.	1	2	3	4	5	6	7	8	AVG.
VOLUME IN HEAD									4 & 5

THICKNESS. COMPRESSED GASKET .043/.047 DIST.. TOP OF BLOCK TO PISTON downswept between cyls.

MANIFOLDS (STD.. EXP.. PT. NO.. NO. LEGS. TYPE) EXHAUST 6 legs, oblong shaped ports and passages 68 x 30 m/m., exhaust I. D. LEGS 37 x 45 m/m I. D. HEADER 37 m/m. I. D. RISER

INTAKE 6 legs.

HEAT CONTROL (DESCRIBE) Tapping of exh. manifold, two 24 m/m dia. pipes to end from intake and exhaust.

CARBURETOR (STD.. EXP.. MAKE. MODEL. TYPE. CHOKE SIZE. JETS. DESCRIPTION See note below for setting. Solex, 40.J.F.F.2. Twin choke barrel type.

AIR CLEANER (MAKE. TYPE) FUEL PUMP (MAKE. PT. NO.) Solex.

PISTONS: (STD.. EXP.. PT. NO.. FITS. MTL.) Light alloy. Ricardo slipper type.

RINGS (NO.. TYPE) 2 compression 3 m/m wide, and 2 scraper, slotted, 5 m/m wide, one below gudgeon pin.

EXHAUST SYSTEM: PIPE (O. D.. LENGTH) 5 ft. 2.1/16" O.D. steel pipe to shop exh. system. TAIL PIPE (O. D.. LENGTH

MUFFLER (MAKE. TYPE. O. D.. LENGTH) -

IGNITION: GENERATOR (MAKE. MOD.. PT. NO.. DRIVE RATIO) Not known. .85 x crankshaft r.p.m. COIL (PT. NO.)

DISTRIBUTOR (MAKE. MOD.. PT. NO.) Bosch magneto. J.6.N6L3.

SPARK PLUGS (MAKE. MOD.. DIAM.. REACH. GAP) A.C. Zircrund, F.12. 14 m/m. 1/2", .015" FIRING ORDER 1,5,3,6,2,4,

BREAKER CLEARANCE .012" TYPE SPARK CONTROL Automatic. INITIAL AUTO SETTING T.D.C.

COOLING SYSTEM: FAN (DIAM. PITCH. NO. BLADES. DRIVE RATIO) 19.3/4" dia. 6 blades, blade length 6¾", blade angle, 20° at tip, 40° ~~at base~~ c/shft

EQUIPMENT & SETTINGS AS TESTED: FAN (ON. ~~OFF~~) MUFFLER & TAIL PIPE (~~ON~~. OFF) AIR CLEANER (~~ON~~. OFF) RADIATOR (~~ON~~. OFF) F.p.m.

CARB. ADJ. (STD.. FIXED. ~~MARKED~~) FUEL HD. ON CARB. Pump

SPARK CONTROL (AUTO.. ~~MANUAL~~) MANIFOLD HEAT ADJ. Standard.

ACCESSORY EQUIPMENT Generator not charging.

FUEL: COMMERCIAL NAME Pool SP. GR. .754 AT 60 °F KNOCK RATING (IF KNOWN) 69 approx.

OIL: COMMERCIAL NAME Castrolite S. A. E. NO. GENERAL MOTORS NO.

NOTE: (GENERAL OPERATION. TEST SETTINGS. ETC.)

Carburetter Setting.

	Primary Barrel	Secondary Barrel
Choke	26 m/m	26 m/m
Main Jet	125	120
S.R. Jet	55	Nil.
Correction bleeds	6 x 1.4	6 x 1.4
Emulsion tube	2 x (4 x 1.0)	2 x (4 x 1.0)
S.R. Air bleeds	Variable	Nil.
S.R. Well supply	4 x 1.5	Nil.

Starter jets. Air 55
Fuel 120

FORM G M R 74-A.

PAGE 85 FROM BUSHING NOS.

BRAKE POWER, FUEL AND AIR

DATE 2.11.42. SHEET No. 14

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1		NOMINAL SPEED			1800	2000	2200	2400	2600	2800	3000	3200	3400	3500	3800	4000				
2	PRESSURES	BAR. CORR.	29.00	plus	.408	.408	.405	.405	.402	.402	.402	.402	.402	.400	.400	.400				
3		VAPOR PRESS			.203	.171	.227	.251	.251	.265	.284	.272	.316	.219	.261	.284				
4		BAR. DRY	29.00	plus	.205	.237	.178	.154	.151	.137	.118	.130	.086	.181	.139	.116				
5		DEPR. CARB.																		
6		ABS. CARB. PR.																		
7		CARB. PR. DRY																		
8		MAX. PR. SPARK																		
9		B.L. SPARK			22	25	26	30	32	33	32	33	33	33	33	33				
10		DETONATION			N	B.L.	DET	DET	B.L.	B.L.	N	N	N	N	N	N				
11		CARB. AIR TEMP.			82	84	86	88	91	93	97	96	97	94	97	99				
12		CARB. DENSITY																		
13		C.F. TO IND			.990	.990	.992	.995	.999	1.000	1.003	1.002	1.004	1.000	1.005	1.007				
14		103 °F BRAKE																		
15		TOTAL REVS.																		
16		AVG. R. P. M.																		
17		AVG. BRAKE LOAD			141.1	147.4	149.6	147.9	145.2	142.4	138.6	134.6	129.4	123.8	117.1	108.4				
18	OBS.	B. M. E. P.																		
19		FRIC. LOAD			19.5	21.5	23.3	25.4	28.2	30.8	33.5	36.3	39.0	42.6	46.1	49.7				
20		IND. LOAD			160.6	168.9	172.9	173.3	173.4	173.2	172.1	170.9	168.4	166.4	163.2	158.1				
21	CORR.	LOAD (IND.)			159.0	167.1	171.3	172.3	173.2	173.2	172.6	171.3	169.0	166.4	164.0	159.2				
22		BRAKE TORQUE			183.2	191.1	194.5	193.0	190.5	187.1	182.9	177.3	170.7	162.8	155.0	144.0				
23		B. M. E. P.			107.8	112.8	114.3	113.5	112.0	110	107.6	104.2	100.4	95.6	91.1	84.6				
24		I. M. E. P.			122.8	129.0	132.2	133.0	134.0	133.8	133.2	132.2	130.6	128.7	126.8	123.0				
25		I. H. P.																		
26		B. H. P.			62.7	72.8	81.3	88.1	94.2	99.6	104.2	107.8	110.3	111.4	111.8	109.5				
27		BRAKE LOAD			139.5	145.6	148.0	146.9	145.0	142.4	139.1	135.0	130.0	123.8	117.9	109.5				
28		CORR. MECH. EFF.			87.7	87.2	86.5	85.2	83.6	82.3	80.6	78.8	77.0	74.3	71.8	69.0				
29	WATER	WT. RATE																		
30		TEMP. DIFF.																		
31		HEAT																		
32																				
33	FUEL	TIME/ 150 ~~cu. ft.~~ c.c. mins.			.414	.375	.350	.325	.303	.284	.266	.252	.242	.229	.226	.220				
34		SPEC. BRAKE lbs-hr.			36.1	39.8	42.7	46.0	49.3	52.6	56.2	59.3	61.8	65.2	66.0	67.7				
35		LBS./B.H.P.-HR.			.568	.538	.519	.519	.522	.528	.540	.550	.562	.576	.593	.625				
36	AIR	VOL. RATE																		
37		ORIF. DENS.																		
38		WT. RATE																		
39		WT. RATE DRY							FULL THROTTLE POWER TEST.											
40		SPEC. BRAKE																		
41		SPEC. IND.																		
42		VOL. CARB.																		
43																				
44		VOL. EFF.																		
45		AIR-FUEL RATIO																		
46																				

FULL THROTTLE MOTORING FRICTION

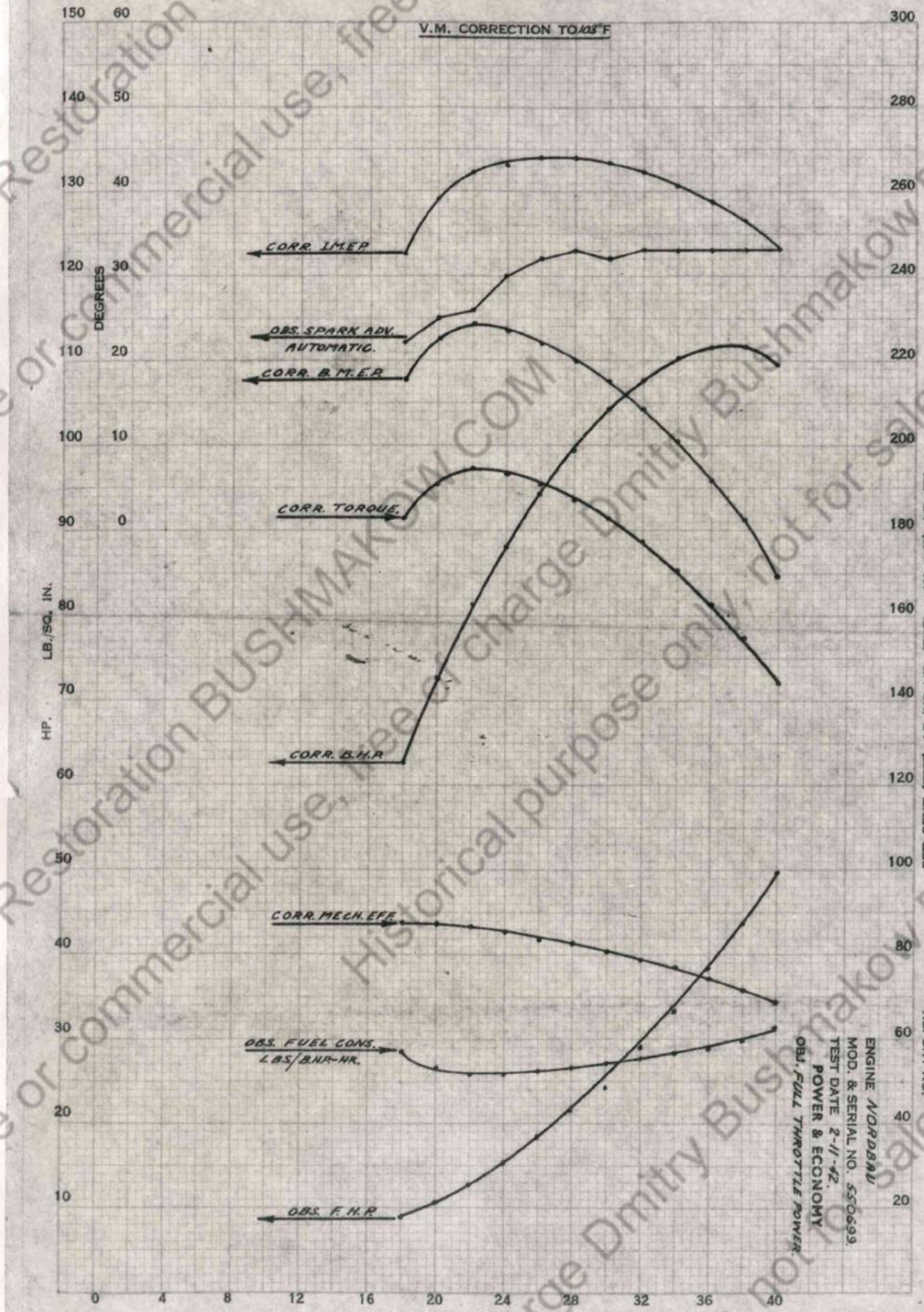
47	NOMINAL SPEED																			
48	F. M. E. P.																			
49	F. H. P.			8.76	10.7	12.8	15.2	18.3	21.6	25.1	29.0	33.2	38.3	43.7	49.7					

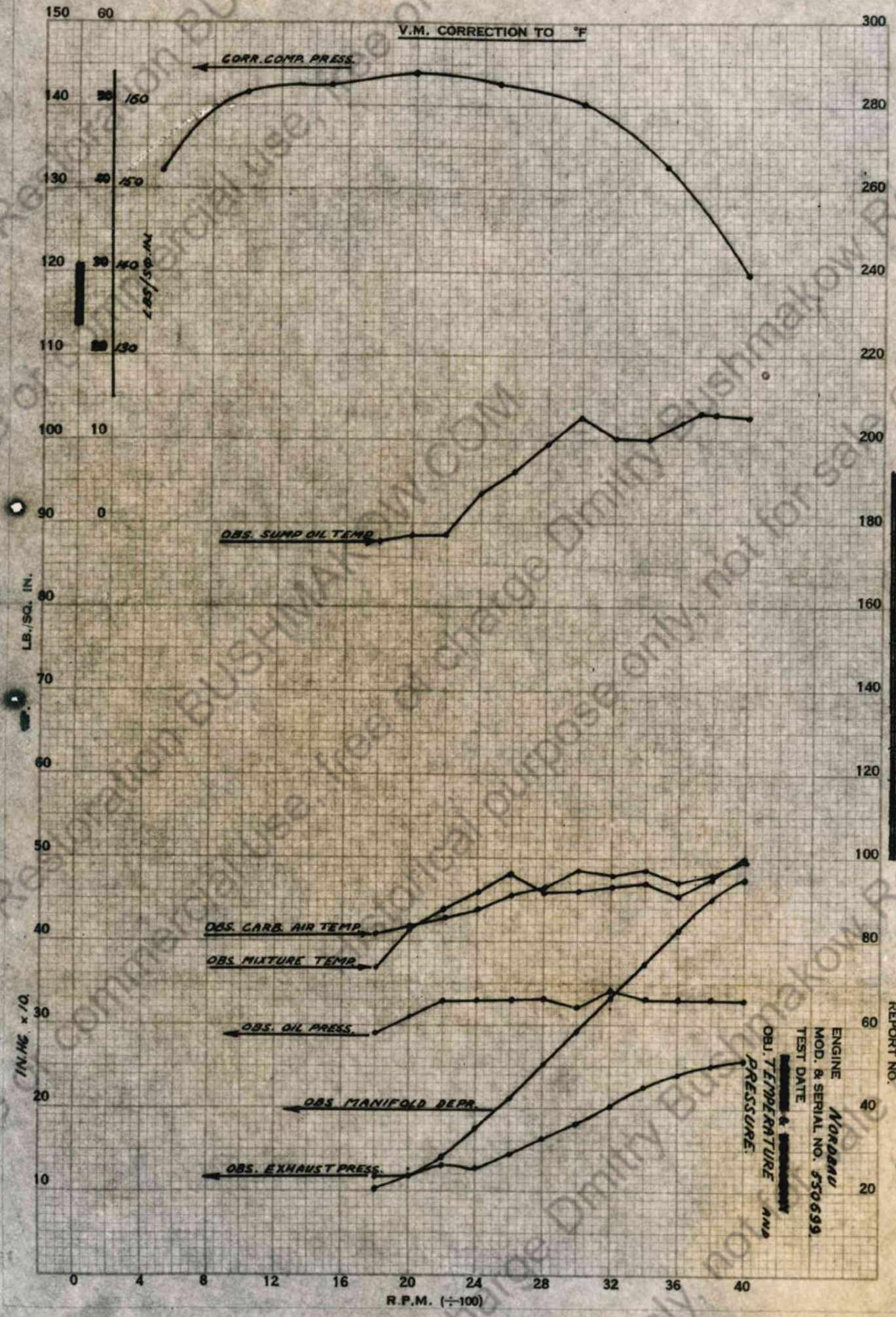
FULL THROTTLE COMPRESSION

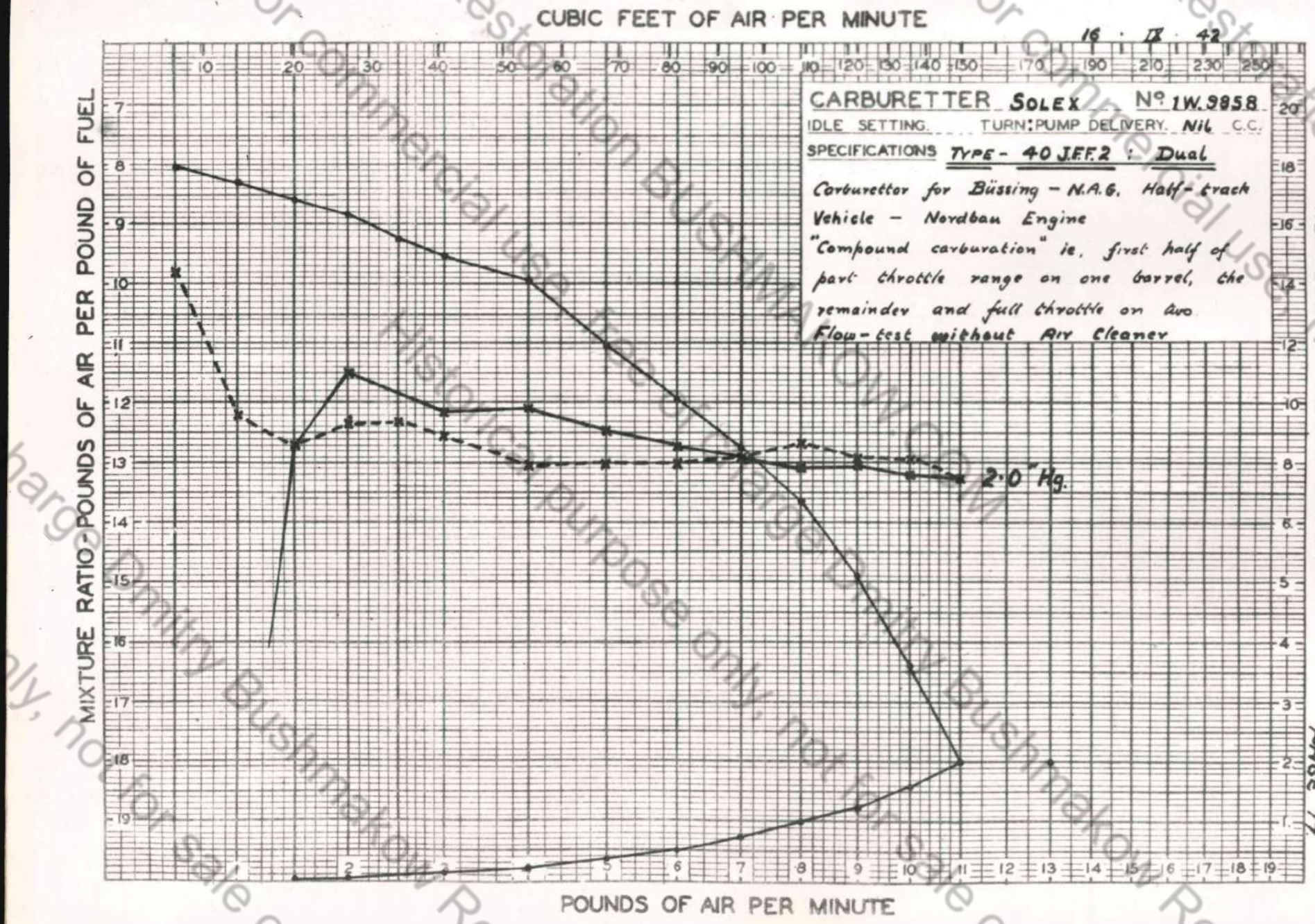
BAR. CORR. FOR TEMP. 29.9

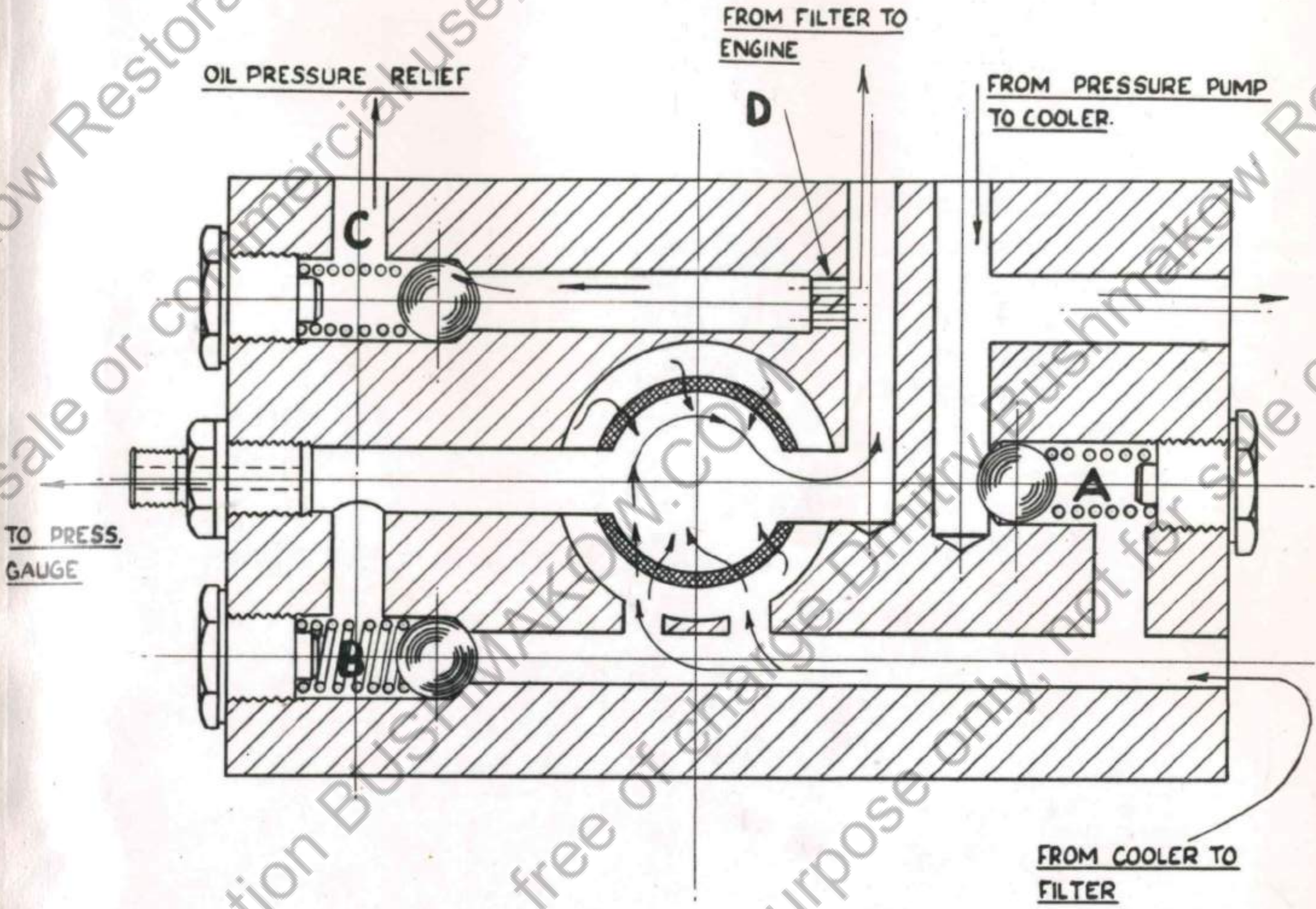
50	NOMINAL SPEED		500		1000		1500		2000		2500		3000		3500		4000			
51	A.V.G. OBS. PR.																			
52	A.V.G. CORR. PR.		152.3		161.5		162.5		164.1		165.3		160.6		152.8		139.7			

FORM G.M.R. 75/1.


V.M. CORRECTION TO 113°F
CORR. IMEP
OBS. SPARK ADV. AUTOMATIC.
CORR. B.M.E.P.
CORR. TORQUE.
CORR. B.H.P.
CORR. MECH. EFF.
OBS. FUEL CONS. LBS/B.H.P.-HR.
OBS. F.H.P.
DEGREES
HP.
LB./SQ. IN.
PER CENT
LB./HP-HR. (FUEL × 100)
LB.-FT.
R.P.M. (÷100)
ENGINE NORDBAU
MOD. & SERIAL NO. 550699.
TEST DATE 2-11-42.
POWER & ECONOMY
OBJ. FULL THROTTLE POWER.
PAGE 36 FROM BUSHMAKOW REPORT
SHEET OR PAGE NO. 15
REPORT NO.

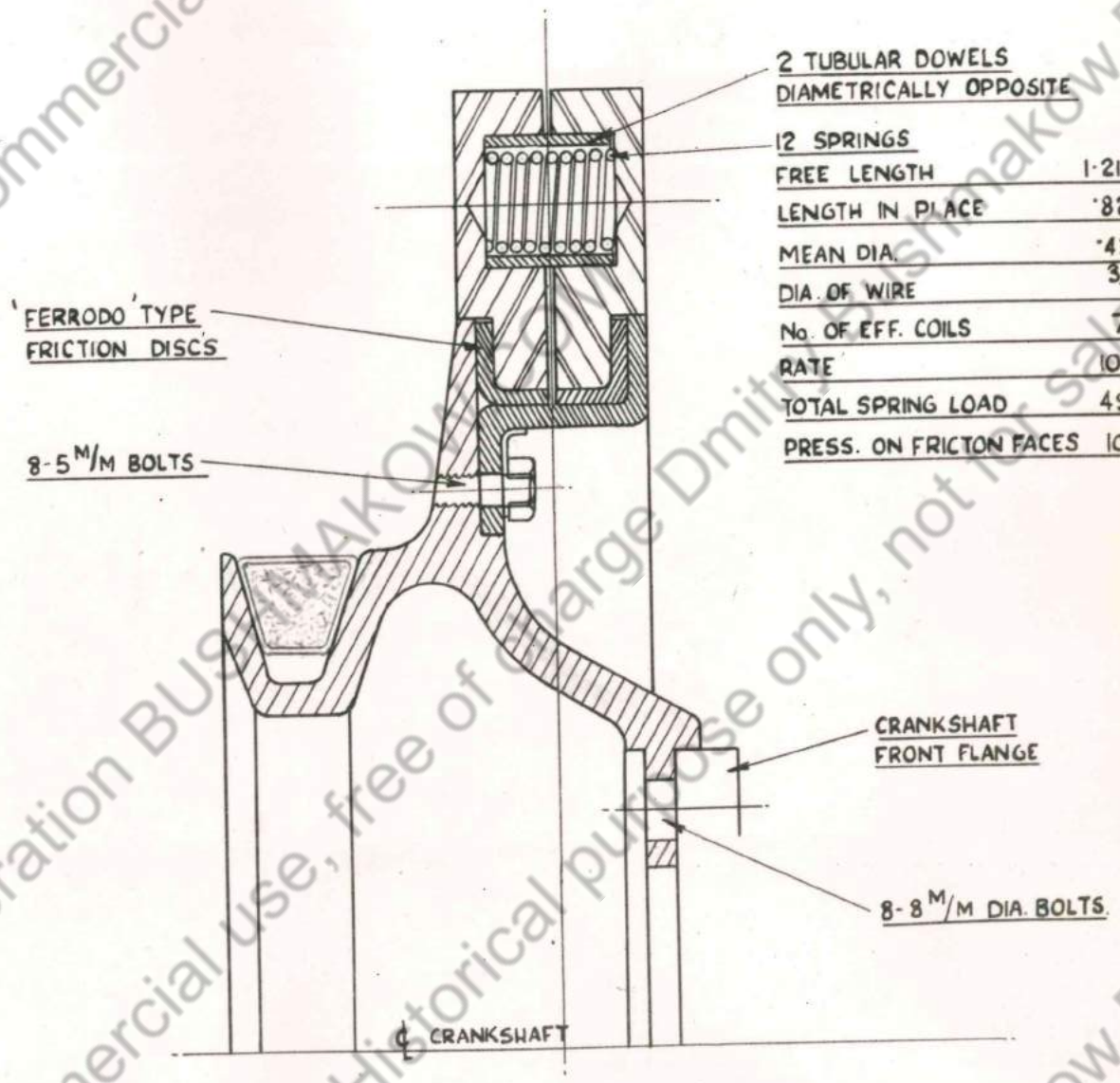

V.M. CORRECTION TO °F
CORR. COMP. PRESS.
LBS/SQ.IN.
OBS. SUMP OIL TEMP.
OBS. CARB. AIR TEMP.
OBS. MIXTURE TEMP.
OBS. OIL PRESS.
OBS. MANIFOLD DEPR.
OBS. EXHAUST PRESS.
LB./SQ. IN.
IN. HG. x 10
DEGREES F.
R.P.M. (÷100)
PAGE 37 - FROM BUSHING AND REPORT.
SHEET OR PAGE NO. 16
REPORT NO.
ENGINE
MOD. & SERIAL NO. 530699.
TEST DATE
OBJ. TEMPERATURE AND PRESSURE.


CUBIC FEET OF AIR PER MINUTE
16 · IX · 42
CARBURETTER SOLEX Nº 1W.9858
IDLE SETTING. TURN: PUMP DELIVERY. Nil C.C.
SPECIFICATIONS TYPE - 40 J.F.F.2 : Dual
Carburettor for Büssing - N.A.G. Half-track Vehicle - Nordbau Engine
"Compound carburation" ie, first half of part throttle range on one barrel, the remainder and full throttle on two
Flow-test without Air Cleaner
2·0" Hg.
MIXTURE RATIO - POUNDS OF AIR PER POUND OF FUEL
VACUUM - INCHES OF MERCURY.
POUNDS OF AIR PER MINUTE
PAGE 38 - FROM BÜSSING'S WAR REPORT.
PAGE 17



ANY EXCESSIVE 'BUILD UP' OF PRESSURE OR BLOCKAGE IN THE COOLER IS TAKEN CARE OF BY VALVE 'A' WHICH BY-PASSES THE OIL DIRECT TO THE FILTER, SIMILARLY, WHEN SILTING UP OCCURS IN THE FILTER, OIL IS BY-PASSED THROUGH VALVE 'B' DIRECT TO THE ENGINE BEARINGS. OIL PRESSURE RELIEF VALVE 'C'.
SMALL HOLES AT 'D' HAVE A DAMPENING EFFECT ON THE OIL ENTERING THE RELIEF VALVE, AND PREVENT THE BALL CHATTERING ONITS SEAT.

'NORDBAU' ENGINE FILTER HEADER (LUB-OIL)



'NORDBAU' TORSION VIBRATION DAMPER

SCALE :- FULL SIZE

DESIGN ANALYSIS OF CHASSIS - SECTION 3 - PETROL, EXHAUST AND WATER COOLING SYSTEMS.

General Design.

Petrol system.

Included in: Layout diagram: Plate 18.
Pictorial illustrations: Plates 50 and 54.
General photographic view: Plate 57.

Petrol is delivered from a single petrol tank mounted between the frame members to a type 40 JFF.2 Solex carburettor, by a mechanical fuel pump of the diaphragm type. A diagram of the petrol system appears on Plate 18.

Carburettor.

See Section 2 - Power Unit and Power-Unit Controls, pages 21 to 29.

Air cleaner.

Included in: Pictorial illustration: Plate 54.

No air cleaner was fitted to vehicle which came into our possession.

An air cleaner is shown in Plate 54, however, (reproduced from one of the German manuals) and from the view shown, it would appear to be of the oil bath type and of fairly generous proportions.

Fuel pump.

Included in: Layout diagram: Plate 18.

The fuel pump was not dismantled but appeared to be a typical Solex diaphragm-type mechanical pump, driven from the valve timing gears at the rear of the engine.

Petrol tank and delivery pipes.

Included in: Layout diagram: Plate 18.
Pictorial illustration: Plate 50.
General photographic view: Plate 57.

The tank, as will be seen from the above illustrations, is of an individual shape and is designed to give the greatest capacity in the space available between the

DESIGN ANALYSIS OF CHASSIS - SECTION 3 - PETROL, EXHAUST AND WATER COOLING SYSTEMS (CONTINUED):

Petrol tank and delivery pipes (continued).

side-members, cross-members and idler suspension units.

It is housed between the side-members above and between cross-members No's 9, 10 and 11. Mounting plates are welded to the cross-members and anchorage of the tank is by two straps with threaded ends. There is felt packing between the tank and the plates upon which it rests and canvas strips beneath the anchorage straps.

A drain plug is situated in the bottom of the tank at the lowest part and a filler plug in the top at the rear, the latter presumably being accessible through the body. In the centre of the tank at the top, is the delivery pipe union, and beside this, a coiled-pipe breather. The petrol tank accessories are shown in Plate 50 and from this plate it would appear that there are alternative feed systems. The vehicle inspected had a single petrol delivery pipe leading to the scuttle but Plate 50 shows an alternative dual system which is apparently intended to give a reserve fuel supply. A three-way tap, such as that shown at (16) in Plate 50, was fitted to the vehicle which was examined but one of the unions was blanked off.

Petrol pipes throughout the system were of copper.

Exhaust system.

Included in: Layout diagram: Plate 1.

Pictorial illustration: Plate 51.

Apparently two distinct exhaust systems are available, viz. that shown in Plate 1 or that represented by the silencers in Plate 51. It would appear also that two variations of the latter system have been used and that this type of silencer is intended to be mounted on the front of the scuttle. On the vehicle which was examined in the Engineering Department, however, there remained no exhaust system beyond the manifold.

DESIGN ANALYSIS OF CHASSIS - SECTION 3 - PETROL, EXHAUST AND WATER COOLING SYSTEMS (CONTINUED):

Water cooling system.

Included in: Layout diagram: Plate 17.
Pictorial illustrations: Plates 19, 47 and 48.
General photographic view: Plate 59.

Circulation is effected by the water pump bolted to the rear of the generator and cooling by a large conventional-type radiator for which two fans provide the air stream. The circuit includes the radiator film block, the oil cooler, the water pump, the cylinder block and the radiator top tank.

Radiator.

Included in: Layout diagram: Plate 17.
Pictorial illustration: Plate 47.
General photographic view: Plate 59.

The general form of the radiator can be seen in Plates 47 and 59. It is of the vertical tube type in which the vertical tubes are surrounded by an imitation honey-comb to provide additional cooling surface. There is a typical brass header tank and a light filler cap of fabricated sheet brass. The outer shell of the radiator is formed by two similar fabricated sheet metal halves drawn together and thereby clamped to the core by four bolts; felt packing is included between the core proper and this outer shell. The radiator is mounted directly, with the exception of the insertion of a strip of felt packing, on the forward flange of No.2 cross-member. Tap bolts anchor the radiator to this member and there are thin rubber insulators beneath the heads of these bolts. At the top, the radiator is steadied by two brace rods linking it with the scuttle; the rods are secured to an angle plate, which is, in turn, rivetted to the header tank. This mounting arrangement provides a very rigid support for the radiator.

DESIGN ANALYSIS OF CHASSIS - SECTION 3 - PETROL, EXHAUST AND WATER COOLING SYSTEMS (CONTINUED):

Radiator fan cowl.

Included in: Layout diagram: Plate 17.
Pictorial illustration: Plate 48.

Air is drawn through the radiator film block by twin fans apparently of cast aluminium alloy. The two fans are identically similar and are carried in bearings assembled in the bosses formed at the centres of the two apertures of the large fan cowl shown in Plate 48. This cowl appears to be a light alloy casting of similar composition to that of the fans and is secured to the core by four tap bolts.

Drive to the two fans is effected by individual pulleys and 'V' belts. The fan spindles each carry a fan and a pulley wheel on opposite sides of the bearing in fan cowl boss. An intermediate spindle, mounted high up on the front of the engine, carries three pulley wheels of equal diameter from which belts are taken to both fan spindle pulleys and to a pulley on the front end of the crankshaft.

Water pump.

See Section 2 - Power Unit and Power-Unit Controls, page 21.

Radiator hoses.

Included in: Pictorial illustration: Plate 19.

There are three short hoses in the water cooling system, all of which are visible in Plate 19, viz: one from the radiator to the oil cooler, one from the oil cooler to the water pump, and one from the cylinder block to the radiator top tank. On the vehicle which was examined, two of these were of a non-rubber, canvas-like material, whilst the remaining one was apparently rubber. It is quite possible, however, that these hoses had been removed and replaced before the vehicle came into our possession.

DESIGN ANALYSIS OF CHASSIS - SECTION 3 - PETROL, EXHAUST AND WATER COOLING SYSTEMS (CONTINUED):

Dimensional Data.

(Scaled from vehicle except where marked *)

Petrol Tank:	Width at forward end:	31.4"
	Width at rear end:	26.4"
	Length:	42.0"
	Maximum depth:	14.3"
	Capacity of fuel tanks - main tank:	21.9 galls.*)These
	reserve tank:	2.2 galls.*)capaci- ties do not refer to Model 251 to which a reserve tank is not fitted.
	Level of oil in "Delbag" filter:	0.6" approx.*
Cooling System:	Total water capacity:	5.7 gallons *
Radiator:	Overall height (including filler cap):	20.8"
	Overall width:	36.6"
	Frontal area of cooling element:	140. sq.in.
	Outside dia. of inlet pipe:	1.6"
	Outside dia. of outlet pipe:	1.5"
Fans:	Tip dia.	14.6"
	Blade angle:	25° approx.
Fan Belts:	Thickness:	0.49"
	Maximum width:	0.63"

Data Resulting from Experiment upon Parts from Vehicle.

No such data has been obtained relating to the petrol, exhaust or water-cooling systems.

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION.

Description of Design.

Front axle layout.

Included in: Layout diagram: Plate 9.
Pictorial illustrations: Plates 38, 39 and 40.
General photographic views: Plates 59, 60 and 61.

The general layout of the front axle of the ZGKW 3.t is typical of wheeled-vehicle practice. Pneumatic-tyred, pressed-steel wheels are bolted on the hubs which are, in turn, pivotted at either end of the axle beam by a typical king-pin/steering-knuckle arrangement. Steering is effected through steering arms, tie rod and drag link typical of the parts usually associated with the Ackerman Principle.

A single transverse leaf spring is employed for suspension and the front axle is braced by a tubular framework of wishbone form.

There are no brakes on the front wheels.

Front axle beam.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 38.
General photographic views: Plates 59, 60 and 61.

The front axle beam is a forging of approximately square section with a downward bowed form as viewed from front. Inclined tapered holes are drilled in the eyes for the king pins and there are bosses and lugs for spring and shock absorber link attachment. Tapered holes are drilled beneath the spring anchorage bosses to accommodate the wishbone axle-bracing members.

Steering knuckles.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 39.
General photographic views: Plates 59, 60 and 61.

The steering knuckles are machined forgings of basically conventional design. The

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION (CONTINUED):

Steering knuckles.(continued).

stub axle incorporates two parallel journals for the taper roller wheel bearings and provision is made for an oil seal inside the inner bearing. The two members of the left-hand knuckle "fork" and the lower member of the right-hand are taper-drilled horizontally to accommodate the steering arm.

Steering arms.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 39.
General photographic views: Plates 59, 60 and 61.

The steering arms are apparently drop forgings and their form will be seen from a study of Plates 39 and 61. All the steering arms project backwards from the steering knuckles and the method of attachment of each one is the same. The steering-knuckle end of each arm is machined down to a smaller diameter than that of the original forging and a fine thread is cut upon it. Immediately behind the threaded link is a taper which is drawn firmly into the corresponding taper hole in the steering knuckle under the action of a castellated nut carried on the threaded end of the arm. The nut is locked by a split pin. A collar is formed as part of each arm sufficiently far behind the taper that its forward face does not contact the knuckle and a flat is machined on one side of the collar to engage with a corresponding flat on the knuckle, thus preventing relative rotation of the two parts.

Conventional eyes are formed on the ends of the steering arms remote from the knuckles and are taper-drilled to accommodate the ball pins of the tie rod and drag link joints.

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION. (CONTINUED):

Steering tie rod.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 39.
General photographic view: Plate 61.

The left-hand ball-joint housing is welded to the hollow rod, whilst there is a threaded-tube attachment for the right-hand ball-joint housing, enabling the length of the rod to be adjusted. Adjustment is locked by two clamp bolts.

King pins.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 39.
General photographic view: Plate 61.

The partly tapered form of the king pins, which are driven into tapered holes in the eyes of the front axle beam, can be seen from the above reproductions. The thrust, due to the load upon the front axle, is borne by the lower faces of the king pins which are in contact with the internal surfaces of the brass bushes, screwed into the lower members of the steering knuckles. This design thus appears to transmit the whole front axle load through the fine threads of these brass bushes.

A central oil duct is drilled through the whole length of each pin and lubricates the upper bearing in the steering knuckle. Lubricant is fed from a nipple in the lower bush of the knuckle.

Front hubs.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 39.
General photographic views: Plates 60 and 61.

The front hubs are castings of the form shown in the above reproductions. There are eight stiffening ribs on the inside of each hub, i.e. one mid-way between each wheel-attaching stud. The small-diameter outer end of each hub is threaded

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION (CONTINUED):

Front hubs (continued).

externally to carry a heavy, fabricated, welded, steel dust-cover.

Front-wheel bearings and oil seals.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 39.
General photographic view: Plate 61.

There are two taper roller bearings to each hub, by means of which the hubs are carried on the steering knuckles.

An oil seal is pressed into the extreme inner end of the boss of each hub. These seals are of a conventional design, commonly employed on motor vehicles; the basic form will be recognized from a study of the sectional view of the L.H. hub seal on Plate 9. There is a light sheet-metal casing made in two parts between which is gripped the L-section sealing element of rubber-like material. An annular coil spring is employed to maintain a complete circumferential seal between the flexible element and the journal which it surrounds. The hub oil seals are accommodated on special journals, machined on the wheel-carrying spigots of the steering knuckles.

Front road wheels.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 39.
General photographic view: Plate 59.

Pressed-steel, disc wheels are employed and their form is well shown in the illustrations referred to above. The rim of each wheel is secured to the shell by 18 rivets and the outer flange of the rim is detachable to permit removal of the tyre, being normally held in position by a large circlip.

Each wheel is attached to the hub by eight flange studs which are held on the inside by thin nuts, locked by shakeproof washers of the external-tooth type. The wheel is clamped to the hub by eight cap nuts: spherical-seated lockwashers are

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION (CONTINUED):

Front road wheels (continued).

inserted between the nuts and the suitably countersunk holes in the wheel.

Front tyres.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 39.
General photographic view: Plate 59.

The pneumatic tyres are of rubber or synthetic rubber and have a cross-country (Geländе) type of tread.

Front wheel suspension.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 38.
General photographic views: Plates 59, 60 and 61.

Suspension of the front axle is effected by a single, transverse, leaf spring with movement controlled by axle-slings, bumpers and shock-absorbers. Details of the above components are given under their respective headings.

Front road spring assembly.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 38.
General photographic views: Plates 59, 60 and 61.

The form of the single, inverted, semi-elliptic, transverse, leaf spring is shown clearly in the illustrations referred to above. A nine-leaf pack is shown in the German manual illustration but the spring from the vehicle which came into the Engineering Department incorporated eleven leaves, although the general design of the spring was otherwise similar.

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION (CONTINUED):

Front road spring assembly (continued).

The lowest plate is wrapped to form an eye at the left-hand end of the spring and the second plate is wrapped 90° round the first to give support to the eye (see diagram). The second leaf of the spring which was examined at the Works was not thus wrapped but appeared to have been roughly flame cut just above the centreline of the eye, although no reason why this should have been done was apparent.

The spring eye is brass-bushed to accommodate the shackle bolt, and the latter is, in turn, carried in the left-hand spring-anchorage bracket, which is bolted to the axle beam. At the right-hand end, the lowest plate bears upon a shoe which is formed as part of the right-hand spring-anchorage bracket. The lowest two plates are set to pass through this bracket beneath the bolt which it carries between its vertical members.

The ends of all the spring plates are partially speared, i.e. speared ends flattened at the tips. There are four substantial clips by means of which the spring plates are clamped together, and each clip is secured to one of the plates by a single rivet. The plates are drilled at the centre and accommodate a fairly large diameter centre-bolt carrying a castellated nut.

The spring centre-clamp takes the form of two castings drawn together by four long bolts, see Plate 9. The lower casting, at the same time, forms the substantial trunnion by which the front spring is mounted. Through this trunnion passes the longitudinal pivot pin which is, in turn, borne in the bosses welded to the deep triangular webs of frame cross-member No.2. This pin is the only rigid linkage between the spring and the frame, and permits pivotting of the front spring about its centre, in a vertical plane, controlled only by the shock-absorbers, check-straps and bumpers.

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION (CONTINUED):

Spring bumpers.

Included in: Layout diagram: Plate 9.
Pictorial illustrations: Plates 35 and 38.
General photographic views: Plates 59, 60 and 61.

Two rubber blocks, suspended between the spring and the front axle, prevent excessive deflection of the former. A lip is moulded on each rubber block and, by means of this, it is carried in a bent-strip retainer pinned to the lower casting of the spring centre clamp. The same pins are also used to support the axle slings.

Smaller rubber blocks are pinned to fabricated, welded retainers which are welded to the side-members adjacent to No.2 cross-member. These bumpers serve to prevent excessive pivotting of the spring and front-axle assembly about the central mounting pin.

Axle slings.

Included in: Layout diagram: Plate 9.
Pictorial illustration: Plate 38.
General photographic views: Plates 59, 60 and 61.

Two braided, metal check-straps pass round the front axle about 6" apart, slung from the front spring-mounting trunnion. Holes are drilled in each end of the check straps by means of which they are supported from the same pins which carry the lower spring bumpers.

The end-finishing of the check straps is worthy of note. The strap is folded back and a small pin inserted inside the fold. Sheet metal is wrapped round the folded end of the strap and holes are drilled through the folded strap and wrapped sheet-metal together. The small pin which is inserted in the fold of the strap can be seen in the right hand bottom corner of the photograph of the strap (12) in Plate 38.

When the strap is in tension this pin bears upon the upper edges of the sheet metal eye and prevents any tendency of the strap to pull through the eye.

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION (CONTINUED):

Front-axle bracing.

Included in: Layout diagram: Plate 9.

Pictorial illustration: Plate 40 and pages 192 - 214. of the Metallurgical Report.

General photographic views: Plates 60 and 61.

Metallurgical Report: Pages 188 - 215.

The tubular wishbone front-axle bracing is clearly illustrated in the above reproductions. Solid pieces are welded to the ends of the tubes, machined to a taper and threaded as shown in the pictorial view.

The tapered lengths of the front ends of the members of the wishbone are drawn firmly into tapered holes, drilled completely through the front-axle beam beneath the spring anchorages, by thin, castellated nuts on the threaded extreme front ends of both members of the wishbone. The rear ends of the members are secured to the cross piece (65) in Plate 40 by similar nut and taper joints.

The rear end of the wishbone is attached to No.3 cross-member through the ball joint shown in section in Plate 9 and in exploded pictorial view in Plate 40.

A ring of welding on one of the tubular wishbone members of the vehicle which came into our possession appeared to indicate repair of a failure. The position of this welding has been indicated by the Laboratory in their sketch on page 192.

Shock absorbers.

Included in: Layout diagram: Plate 9.

Pictorial illustration: Plate 38.

General photographic views: Plates 59, 60 and 61.

The front-axle suspension incorporates two shock-absorbers which are of the double-acting, piston type and are mounted one below each side-member. The general form of the main castings will be seen in Plates 38 and 61. Two pistons are actuated inside the main cylinder of each casting by a one-piece, central, steel cam and the

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION (CONTINUED).

Shock absorbers (continued).

pistons are linked together to effect the return motion. The cylindrical part of the casting is closed at the ends by octagonal caps which are screwed into position. A good seal is made beneath the caps by the insertion of a rubber ring and also of a thin, circular sheet-metal disc which covers the end of the cylinder.

The valves are situated at the centre of each piston and the circular valve flaps are lightly spring loaded. Each shock-absorber is mounted by two large-diameter bolts and nuts on a fabricated, welded bracket, welded to cross-member No.1 and projecting downwards from it.

Each shock absorber arm is mounted by a splined joint on the same shaft which carries the cam and the eye, at the end of the arm remote from the shock-absorber, is fitted with a steel bush, by means of which the forked vertical link is attached to it. The attachment of the shock-absorber links to the lugs projecting forward from the front axle beam is clearly shown in Plate 59. There are rubber insulators on either side of the axle beam lugs and each link is threaded and carries two pairs of lock-nuts between which the insulators and lugs are sandwiched.

The long filler tubes of the front shock-absorbers are worthy of note. The setscrews closing their upper ends can just be seen projecting above the top edge of the front cross-member in Plate 59.

The shock-absorbers are manufactured by Boge and Son.

The velocity/load characteristics of the front shock absorbers were investigated on our shock-absorber testing machine and a graph plotted from the results appears on page 411. It will be seen that the front shock absorbers are apparently designed to act chiefly upon rebound.

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION (CONTINUED):

Dimensional Data.

(Scaled from vehicle except where marked *)

Front Axle Beam:	Section:	2.2" x 2.4"
Steering Arms:	Diameter of threaded ends:	0.79"
	Threads per inch:	17" (approx).
Steering Tie-Rod:	Outside dia.	1.2"
Maximum front wheel steering lock:		36°
Front Wheels:	Track:	65.0" *
	Deviation of wheels from parallel:	2° * Equivalent to 0.16" (front of tyres to rear of tyres)
	Rim base dia.	18.5"
	Pitch circle dia. of wheel-fixing studs:	10.7"
	Tyre size:	190 x 18
	Recommended tyre pressure:	2.75 atmospheres absolute *
Shackle Bolt diameter:		0.78"
Centre Pivot-Pin diameter:		1.31"
Front-Axle Bracing:	Outside diameter of tubing:	1.6"
	Crest diameter of threaded ends:	1.01"
	Distance between centrelines of extreme front ends of the two members of the fork:	43.4"
Front Shock Absorbers:	Piston diameter:	2.1"
	Arm length:	8.7"
Front Road Spring Assy:	Free camber of assy. (as removed from vehicle):	3.6"
	(after cleaning and greasing):	4.1"
Load/deflection relationship of assembly:		see pages 413 - 416.

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION (CONTINUED):

Dimensional Data (continued).

Individual plate dimensions:-

Width of Leaves: 2.7"

Leaf No.	Av.Thickness (ins).	Dev.Length (ins).	Radius of Curvature (ins).
1	0.301	46.8 ½	60
2	0.307	47.6	60
3	0.305	41.3	55
4	0.297	37.8	45
5	0.295	33.8	45
6	0.295	29.9	45
7	0.299	26.0	45
8	0.265	21.9	40
9	0.264	17.9	35
10	0.265	13.5	35
11	0.255	9.5	35

½ This measurement was taken from the roughly burnt end of the plate, (see text).

Data Resulting from Experiment upon Parts from Vehicle.

Laboratory reports upon materials of construction:

Where examination of materials has been carried out reference to the appropriate Laboratory reports has been made at the top of the sub-section dealing with the parts concerned.

DESIGN ANALYSIS OF CHASSIS - SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION (CONTINUED):

Load/deflection test of front road spring assembly:

The single, transverse front road spring assembly was load/deflection tested upon the Olsen machine both in the condition removed from the vehicle and in a clean, corrosion-free condition with an inter-leaf dressing of grease. In both cases tests were made with and without the centre clamp. Graphs of these tests appear on pages 413 to 416.

Dimensions of the spring are given on page 56 and a full report upon the investigation which was carried out into the design will be found by reference to Vauxhall Motors Limited Experimental Report No.1218, pages 15 to 22 inclusive.

Velocity/load characteristics of front shock-absorbers:

The front shock-absorbers were set-up in turn on the shock-absorber test-rig in the Experimental Shops and tests were carried out in accordance with Vauxhall Motors Limited Engineering Test Procedure, Passenger Chassis Section, Schedule No. R.4. The resulting graphs are reproduced on page 411.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION.

Description of Design.

Layout of track-laying units.

Included in: Layout diagram: Plate 1.
General photographic view: Plate 57.

The rear end of the vehicle is carried on two endless, flexible tracks which extend approximately three-quarters of the length of the chassis.

The tracks are of conventional tracked-vehicle design insomuch as they are flexible in a vertical plane by virtue of their construction of solid links or track-shoes, joined together and freely pivotted with respect to each other by the track pins.

Each track is carried on a driving sprocket at the front end and on an idler wheel at the rear. Between these are six pairs of rubber-tyred, pressed-steel bogie wheels which carry the weight of the vehicle.

Individual items of the track-laying units are dealt with under their respective headings.

Driving-sprocket units.

Included in: Layout diagram: Plate 5.

Each driving-sprocket assembly and final-drive gear-train form a single unit, the general layout of which is clearly illustrated in Plate 5. Further details of the individual components of these units are given below under their appropriate headings.

Driving-sprocket stub axles.

Included in: Layout diagram: Plate 5.
Pictorial illustration: Plate 28.

The driving-sprocket stub axles are hollow spigots, flanged at one end and machined all over. The flanged end of each axle is secured to the corresponding flange at each end of frame cross-member No.4 by eight tap bolts. The outer ends of the hollow axles are closed by brass plugs. Each axle is tapered towards the outer end but incorporates

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Driving-sprocket stub axles (continued).

two parallel journals upon which the parallel-roller, sprocket-wheel-hub bearings are pressed.

Driving-sprocket bearings.

Included in: Layout diagram: Plate 5.

Pictorial illustration: Plate 28.

Two parallel-roller bearings carry the driving-sprocket hubs on each stub axle. The inner and outer bearings are of different sizes.

There are two steel distance-pieces between the inner bearing and the adjacent shoulder on the axle. The first spans the radius between the shoulder and the journal, whilst the second serves as the inner flange for the roller bearing. The bearings are separated by a hollow, frustroidal, cast distance-piece, and the outer bearing is held against this distance-piece by a circular nut locked with a tab washer.

Driving sprocket hubs.

Included in: Layout diagram: Plate 5.

Pictorial illustration: Plate 28.

The general form of the hollow, ribbed castings, which form the hubs for the driving sprocket wheels, will be seen from the sectional diagram and pictorial view referred to above. The hubs carry the sprocket wheel at one end and the final drive gear wheel at the other, the former is attached by studs and the latter by tap bolts. The outer end of the hub casting is threaded externally to take a large, fabricated, welded, steel hub cap.

Final-drive gears.

Included in: Layout diagram: Plate 5.

Pictorial illustration: Plates 28 and page 218 of the Metallurgical Report.

Metallurgical Report: Pages 218 - 224.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT.)

Final-drive gears (continued).

The final-drive gears consist of one gear wheel and one pinion to each final-drive unit, both of which are clearly shown in the above reproductions.

The pinion is integral with the short shaft upon which it is carried and is mounted in two parallel-roller bearings which are borne in the final drive case and cover respectively. The inner end of the shaft is splined to accommodate the flange piece, (28) in Plate 28, through which the drive is transmitted.

The gear wheel is carried on the hub and secured to it by eight tap bolts. Part of the plain portion of these bolts is of a greater diameter than the crest diameter of the threads and the tapped holes in the hub are counterbored accordingly. Each bolt is locked by a tab washer.

Final-drive gear case and cover.

Included in: Layout diagram: Plate 5.

Pictorial illustration: Plate 27 and pages 226 - 237. of the Metallurgical Report.

Metallurgical Report: Pages 226 - 239.

The gear case and cover are malleable castings clamped together at their peripheral flanges by tap bolts, thus forming a housing for the final drive gear wheel and pinion. No intermediate gasket or other packing is used.

Each gear case is clamped to the circular flange at the end of No.4 cross-member by the same eight tap bolts by which the stud axle is secured to it.

Small cover plates, (10) and (6) in Plate 27, are secured to the main gear case and cover by setscrews and hold the outer races of the pinion roller bearing in position. The gear case is provided with a filler cap and a breather pipe, both of which are shown in section in Plate 5.

Eight tap bolts secure the main-brake flange-plate to the gear-case cover.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Final-drive-pinion bearings.

Included in: Layout diagram: Plate 5.

Pictorial illustration: Plate 28.

There are two similar parallel-roller bearings to each pinion. The inner races are pressed on the parallel journals of the pinion shaft on either side of the pinion, whilst the outer races are carried in the gear case and cover respectively. The latter are located longitudinally by the cover plates secured to the case and to the cover by hexagonal and countersunk screws respectively.

Final drive gear case oil seals.

Included in: Layout diagram: Plate 5.

Pictorial illustration: Plate 27.

Two oil seals are fitted to each final drive unit, i.e. one seal for each shaft projecting from the housing. The seals are of the conventional design described with reference to the front-wheel-bearing oil seals and the sealing elements are of the same material. The seals for the pinion shafts are carried in the cover plates shown at (6) in Plate 27 and bear upon machined journals on the gear-case end of the coupling flange pieces, (28) in Plate 28. The hub seals are pressed into a circular recess in each gear case cover; they bear on specially provided, machined journals on the outside diameters of the inner ends of the hub castings and guard the main brakes against entry of oil from the hubs.

Driving-sprocket wheels.

Included in: Layout diagram: Plate 5.

Pictorial illustration: Plate 27 and pages 242 - 250. of the Metallurgical Report.

General photographic view: Plate 57.

Metallurgical Report: Pages 240 - 286.

The major part of each driving-sprocket wheel is a one-piece casting including the central shell, the brake drum, the two rims, the sprocket teeth and the narrow-section

Driving-sprocket wheels (continued).

ribs by which the central shell of the wheel is joined to the rims.

The track is carried on the rubber tyres of the driving sprocket and the drive is transmitted by contact between the sprocket teeth and the large teeth of the track shoes, projecting inwards from the assembled track. (See Track Shoes). The tyres are of solid rubber and are moulded on the grooves of steel bands, which are, in turn, pressed on the rims of the sprocket wheel. The form of the sprocket teeth can be clearly seen in the pictorial and sectional views referred to above. The rollers are an easy running fit on the pins which carry them between the two cast members of each sprocket tooth. These pins are a tight fit in the tooth castings and the outside of the casting at both ends is burred over to retain the pins.

Bogie wheels.

Included in: Layout diagrams: Plates 1 and 6.

Pictorial illustrations: Plate 31 and pages 259 - 268. of the Metallurgical Report.

General photographic views: Plates 57 and 62.

Metallurgical Report (coupled type bogie): Pages 257 - 270.

All the bogie wheels are of fabricated, welded and rivetted pressed-steel construction and carry rubber tyres; they are arranged in pairs and there are six pairs of bogie wheels on each side of the vehicle. Each pair of wheels is a welded and rivetted assembly and is carried on an individual arm, suspended by torsion bar.

Very close spacing of the comparatively large-diameter wheels is permitted by the lapping of alternate pairs. To enable this, alternate assemblies are of a different form. On each side of the vehicle, there are thus three assemblies comprising pairs of closely spaced and coupled bogie wheels and three assemblies in which the wheels are sufficiently widely spaced to overlap the former assemblies.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Bogie wheels (continued).

The general form and layout on the chassis of both types of bogie wheel assemblies can be seen from the sectional, pictorial and layout views referred to above.

Widely Spaced Assemblies:-

Positions: Bogies No's 2, 4 and 6, left-hand and right-hand.

Construction: Each assembly is built up on a tubular hub-piece with flanges at each end to which the bogie wheels are secured. The rims of the wheels are welded to the webs.

The tubular part of the hub-piece is of fairly thin gauge material but heavier flange-pieces are welded into each end of the tube and carry the two parallel-roller bearings upon which each bogie is mounted. An oil seal is also carried just inside each inner wheel-bearing. At the outer end, the hub piece is threaded internally to take a heavy, cast hub cap. When screwed tightly in position, the hub cap bears upon the outer race of the outer wheel bearing. Little importance is apparently attached to the precise tightness of this cap, however, as indicated by the device provided for locking same. This consists of a wire circlip reposing in an annular groove in the hub. A single hole of slightly greater diameter than that of the wire of the circlip is drilled in the hub and a similar single hole in the cap. One end of the wire circlip is bent to project radially inwards and a positive lock is thus provided when the positions of the two holes coincide.

The webs are of pressed steel and are punched with large holes around which the metal has been turned back to form a reinforcing flange. A wide flange is formed round the outside of the webs and to this the rim is secured. Six holes are drilled near the centre of the web for attachment to the hub-piece. Rivets, with heads countersunk in the flange of the hub-piece, are used for this purpose on the inner wheel of the pair but, in the case of the outer wheel, six studs, screwed in the outer flange of the hub-piece, are employed, thus permitting easy removal of the wheel to provide access to the inner wheel and to the coupled bogies.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Bogie wheels (continued).

The rims of the widely spaced bogie wheels are steel bands which are grooved as a key for the solid rubber tyres, shown in section in Plate 6, which are vulcanized on them. The tyres on the vehicle which was inspected were marked: "WORWERK 575/50 - (505)".

Coupled Assemblies:

Positions: Bogies No's 1, 3 and 5 left-hand and right-hand.

Construction: Pressed-steel webs are welded to the tubular hub-piece and rivetted to the rims. The hub-piece is of tubular form of fairly thin gauge material similar to that described above with reference to the widely spaced bogies. There are no inner end-pieces of heavier material, however, and the outer end-pieces, which are welded to the tube and carry the wheel bearings and hub cap are not flanged since the method of attachment of the web differs from that of the widely spaced bogies.

The webs are of pressed steel, fluted and punched for strength and lightness, and welded to the hub-pieces. They are flanged to permit attachment to the rims which is effected by 20 small cup-headed rivets.

The webs of the two wheels of the assembly are coupled by twelve cup-headed rivets carrying distance pieces.

The rims are grooved to provide a key for the rubber tyres and, in addition, a deep flange of fairly heavy section is formed on the inner edges of both rims to act as a guide for the inward projecting teeth of the track. The tyres are of similar form to those of the widely spaced bogie wheels and are of identical section. The tyres on the coupled bogies of the vehicle in our possession differed from those on the widely spaced assemblies in that they were marked "CONTINENTAL 575 x 50".

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Bogie-wheel-carrier arms.

Included in: Layout diagram: Plate 6.

Pictorial illustration: Plate 30 and pages 273 - 277. of the Metallurgical Report.

General photographic views: Plates 64 and 65.

Metallurgical Report: Pages 271 - 280.

The bogie-wheel-carrier arms are forgings of general form shown in the above reproductions. In conjunction with the torsion bars, employed for bogie suspension, they serve to mount the bogies flexibly upon the frame. The mode of assembly in the chassis with the wheel-carrying spigot rear of the mounting spigot is shown in the photograph reproduced as Plate 64, which was taken with the bogie wheels removed. There are left and right hand versions of the arms but all those on the same side of the vehicle are identical, i.e. no modification is required for the two different types of bogie assembly. Moreover, the blanks of the left hand and right hand arms were obviously identical and only the machining operations differentiate between the two.

A boss is provided on each arm for shock-absorber-link attachment although use is only made of this in the case of the arms for No.6 bogie wheels, since it is only in the suspension of these that shock absorbers are incorporated. There is a projection on each forging for contacting the rubber bumper and the surface of the former is suitably inclined to strike the bumper normally. The wheel-carrying axle is solid and tapered but incorporates two parallel journals for the wheel bearings. The opposite end of the arm is of similar external shape but is hollow; on the vehicle it is borne in two needle roller bearings which are, in turn, accommodated in castings incorporated in the frame. A separate sub-section on page 68 has been devoted to the mounting of the wheel-carrier arms in the frame. The torsion bar passes through the full length of the hollow member of the arm and the splined end of the former is fitted into a corresponding hole in the crank boss of the latter.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Bogie-wheel-carrier arms (continued).

Longitudinal movement of the torsion bar with respect to the arm is prevented by a bolt passing through the arm and engaging with an annular groove in the splined length of the torsion bar.

Bogie wheel bearings.

Included in: Layout diagram: Plate 6.
Pictorial illustration: Plate 30.
General photographic views: Plates 64 and 65.

Each bogie wheel is carried on the wheel-carrier arm by two parallel roller bearings of different sizes. The bearings are separated by a cylindrical distance-piece and are held in position on the axle of the wheel-carrier arm by a thin, circular nut, carried on the threaded end of the latter.

Washers of alternative thicknesses are inserted between the distance-piece outer support and the inner race of the outer bearing to provide means of adjusting the alignment of the bogie wheels (see SERVICE, REPAIR AND MAINTENANCE TRANSLATION, page 157). The thinnest washer, on the vehicle which was inspected, was approximately 0.15" thick and it was found that use of a thinner washer would have impaired the free rotation of the roller bearings.

Bogie hub oil seals.

Included in: Layout diagram: Plate 6.
Pictorial illustration: Plate 30.
General photographic view: Plate 65.

There is one oil seal to each bogie assembly situated just inside the inner wheel bearing. The seals are of the standard pattern used on this vehicle, examples of which were described under the heading "Front-wheel bearings and oil seals", on page 49.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Bogie hub oil seals (continued).

A distance piece with a large flange, (16) in Plate 30, spans the radius between the journal and the shoulder of the bogie-wheel-carrier arm to permit of good seating of the inner wheel bearing. The outside of the cylindrical part of this distance piece serves as a land for the bogie-hub oil seal and the large, lipped flange protects the oil seal from the direct ravages of external agents (see sectional diagram).

Bogie-suspension torsion bars.

Included in: Layout diagram: Plate 6.
Pictorial illustration: Plate 30.
General photographic view: Plate 63.
Metallurgical Report: Pages 281 - 288

All the bogies are suspended by torsion bars. There is one torsion bar to each bogie; all the bars are identical and the dumb-bell form is clearly shown in Plate 30. Opposite splined ends of each torsion bar are similar, with exception of the annular groove in the end upon which the wheel-carrier arm is borne, which serves as a means of locking the arm to the torsion bar (see Bogie-wheel-carrier arms).

The torsion bars are housed in the hollow elliptical-section cross-members of the frame, which, by virtue of the capped-ends and welded assembly, are free from the ingress of foreign matter. There are two bars in each housing, i.e. one supporting a left-hand bogie and one a right-hand. This method of housing the torsion bars (side by side) necessitates the location of all the left-hand bogie-suspension units slightly in advance of the corresponding right-hand units.

The ends of the torsion bars remote from the bogies which they carry are splined into anchor plates, bolted to the frame.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Bogie-suspension torsion bars (continued).

Load/deflection and fatigue tests of bogie-suspension torsion bars, from the vehicle which was in our possession, were carried out, and torsional-rate data, together with observations upon fatigue life, will be found on page 83

Bogie-wheel-carrier arm mounting and torsion bar anchorage.

Included in:	Layout diagram:	Plate 6.
	Pictorial illustration:	Plate 30 and pages 291 - 293 of the Metallurgical Report.
	General photographic views:	Plates 64 and 65.
	Metallurgical Report (torsion-bar-anchorage plate):	Pages 289 - 295.

Each wheel-carrier arm is mounted in the frame in two needle-roller bearings one of which is carried in each of the two castings which are welded into the ends of the elliptical-section cross-members, (see Frame cross-members, pages 8 to 10).

A sectional diagram showing one of the bogie-wheel-carrier arms assembled in the frame will be found on Plate 6. It will be seen that the inner races of the two needle-roller bearings are separated by a tubular distance-piece, carried at each end on L-section rings, which are a loose fit on the journals upon which they are mounted and which bear longitudinally against the inner races. The outer races are pushed into their appropriate, elliptical-periphery, cross-member castings, but it will be seen that the outer bearing race only just enters the frame casting and that the greater part of it is borne in the torsion-bar anchorage plate. The inner races and intermediate distance-piece, etc. are drawn on their respective journals by a circular nut, carried on the threaded extreme end of the arm member, whilst there are shoulders in the elliptical-periphery castings and in the anchorage plate to locate the outer races. The circular nut on the carrier-arm spigot is locked by a "one-position" wire-circlip device similar to that described with reference to the locking of the bogie hub caps on page 63. Entry of dirt and loss of grease is prevented by two felt packing rings, one of which is carried in an internal groove

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Bogie-wheel-carrier arm mounting and torsion bar anchorage (continued).

in the anchorage plate outside the outer bearing and the other which is situated inside the inner bearing, is borne in an annular groove in the bearing-mounting nut. No provision is made for replenishment of lubricant for the needle-roller bearings without dismantling the assembly.

The torsion bars are splined into the wheel-carrier arms at one end and at the opposite end are anchored in the splined holes of the torsion-bar anchorage plates, one of which is shown at (13) in Plate 30. Each anchorage plate is located on the boss at the end of the appropriate elliptical-section cross-member of the frame by a large dowel, and is secured to it by six tap bolts.

Bogie suspension bumpers.

Included in: Layout diagram: Plate 6.
Pictorial illustrations: Plates 30 and 35.
General photographic views: Plates 62 and 64.

Excessive deflection of the torsion bars is prevented by bumpers carried on the side-members. There is one bumper assembly to each bogie, consisting of a rubber block, (28) in Plate 30, carried in a fabricated, welded, sheet-metal retainer by a pin, (29) in Plate 30. The retainers are welded to the side-members and are clearly apparent in Plate 35.

Contact with the bumper is made by a projection from the bogie-wheel-carrier arm which is so graded to strike the lower face of the bump pad squarely in the "bump through" position.

Bogie suspension shock-absorbers.

Included in: Layout diagram: Plate 6.
Pictorial illustration: Plate 30.
General photographic view: Plate 57.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Bogie suspension shock-absorbers (continued).

Shock-absorbers are incorporated in the suspension of the No.6 bogies on either side of the vehicle only. Generally, these shock-absorbers are of the same pattern as those included in front suspension; the casings, end-caps, mounting etc. are identical and only the valves, arms and links appear to differ from the front shock-absorbers. The form of the links and steel-bushed arms will be apparent from Plate 30, and further details of the design of the remaining parts of the shock-absorber will be found by reference to SECTION 4 under the heading "Front shock-absorbers".

The velocity/load characteristics of the rear shock-absorbers, as obtained by experiment, upon the specimens removed from the vehicle which was inspected, are graphed on page 412.

Idler wheels.

Included in: Layout diagram: Plates 1 and 7.
Pictorial illustration: Plate 33.
General photographic view: Plate 57.

Each idler-wheel assembly consists of two pressed-steel, rubber-tyred wheels. With one small exception they are identical in design and construction to the coupled type of bogie-wheel assemblies. The exception is the set of small, strengthening ribs, welded between the tubular hub-piece and the shell of the wheel (compare the pictorial view of the idler wheel in Plate 33 with that of the coupled type of bogie wheel in Plate 31). This detail would not appear to be sufficiently important to prevent interchangeability of ilder and bogie wheels in the field in the face of a shortage of the correct parts, however. This view appears to be confirmed by the fact that the left-hand idler wheel of the vehicle which came into our possession incorporated none of the strengthening ribs referred to above.

For details of the design, construction and dimensions see "Bogie wheels" (coupled-type) page 64.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Idler-wheel-carrier arms.

Included in: Layout diagram: Plate 7.

Pictorial illustrations: Plate 33 and pages 301 and 307 of Metallurgical Report.

General photographic views: Plates 62 and 66.

Metallurgical Report: Pages 295 - 317.

The arms upon which the idler wheels are carried are machined forgings of the form shown in the reproductions referred to above.

The wheel-carrying axle is tapered but incorporates two parallel journals and a threaded end, carrying a large nut. By means of these, the idler wheel is mounted upon parallel-roller bearings, see sectional diagram and Plate 33. At the opposite end, the carrier arm is formed into a similar tapered axle with two parallel journals but of somewhat largerproportions than the wheel-carrying axle. This larger axle is carried in the idler-wheel fulcrum arm in two plastic journal bearings. There are two tapped holes in the end of the axle to permit of the attachment of the retaining cap for the inner bearing.

Two lugs are provided on the main body of the forging for the track adjustment attachment (see "Track tension adjustment" page 75).

Idler-wheel fulcrum arms.

Included in: Layout diagram: Plate 7.

Pictorial illustrations: Plate 32 and pages 320 - 323. of Metallurgical Report.

General photographic views: Plates 58, 62 and 66.

Metallurgical Report: Pages 318 - 329.

The idler-wheel fulcrum arms perform the function of supporting the wheel-carrier arms from the frame through the torsion bar suspension. Each arm consists of three castings; the main casting and the two bearing caps, (2), (3) and (7) in Plate 32 respectively.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Idler-wheel fulcrum arms (continued).

The fulcrum arms are mounted on the circular-section tubular frame cross-member No.11, which, upon reference to SECTION 1 - "FRAME", will be observed to project through the webs of both side-members. The two bearings upon which the fulcrum arm is supported are located one on either side of the side-member.

The bearing caps, (3) and (7) in Plate 32, are part of the plastic bushed bearings, by means of which the fulcrum arm is supported on the cross-member. They are each attached to the main casting by four studs and are located by a dowel. The tubular portion of the fulcrum arm passes through the large hole cut in the web of the side-member and carries the idler-wheel-carrier arm. The torsion bar by means of which each idler wheel is suspended, is attached to the fulcrum arm through a circular cover plate, (11) in Plate 32. The torsion bar is splined into the cover plate, which, in turn, is attached to the fulcrum arm castings (cap and main casting) by six tap bolts.

There are left-hand and right-hand versions of the idler-wheel fulcrum arm, the main difference between the two being the greater length of the right-hand arm, designed, presumably, to compensate in some measure, for the rearward mounting of all the right-hand bogies with respect to their left-hand counterparts.

Both forks of the main casting of the fulcrum arm are cored hollow for lightness (see sectional diagram).

Idler-wheel suspension torsion bars.

Included in: Layout diagram: Plate 7.
Pictorial illustration: Plate 32.
General photographic view: Plate 66.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Idler-wheel suspension torsion bars (continued).

Suspension of each idler wheel is effected by means of an individual torsion bar. The two torsion bars, i.e. those for the left hand and right hand idlers respectively, are identical and their splined-ended, dumb-bell form is clearly shown in the above reproductions. Both torsion bars are mounted on the same centreline and are housed inside the tubular No.11 frame cross-member with the result that their length is necessarily rather less than half that of those suspending the bogies.

Each torsion bar is splined into the end cover plate of the idler-wheel fulcrum arm. The splined, inner end of the bar is accommodated in a cylindrical plug which is a good fit inside the cross-member and which is anchored to the latter by two dowels welded in position (see sectional diagram).

Idler-wheel bearings.

Included in; Layout diagram: Plate 7.
Pictorial illustration: Plate 33.

The idler wheels are each mounted upon the carrier arms upon two parallel roller bearings of different sizes. The dimensions and installation are identical with the corresponding bearings upon which the bogie wheels are mounted.

Idler-wheel oil seals.

Included in: Layout diagram: Plate 7.
Pictorial illustration: Plate 33.

Here again the design, dimensions and installation are identical with the corresponding parts of the bogies.

Fulcrum arm bearings.

Included in: Layout diagram: Plate 7.
Pictorial illustration: Plate 32.
General photographic views: Plates 58 and 66.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Fulcrum arm bearings (continued).

Journal bearings, incorporating fabric-based, plastic bushes, are employed for supporting the fulcrum arms upon No.11 cross-member and for mounting the idler-wheel carrier arms inside the fulcrum arm.

The bearings employed in the first-mentioned function are shown pictorially in Plate 32, the bushes being identified by the numbers (4), (5) and (8). Collars are welded to the circular-section, tubular cross-member to provide shoulders for the bearings and the whole is machined to present a good bearing surface to the bushes. The bush for the inner bearing is made in six pieces to facilitate assembly and assembly of the fulcrum arm upon the cross-member is effected by adding the bearing caps. One-piece, cylindrical bushes pressed into their respective housings are employed for the remaining three bearings of each assembly. The two fulcrum-arm-support bushes are located each by one dowel but no such means of locking the idler-wheel-carrier-arm bushes is provided. There is an annular groove in each of the castings backing the cross-member bearing bushes and these grooves are fed with lubricant from grease nipples in the bearing caps. The bushes themselves are drilled to link the oil duct with the working surface of the bearing and across each hole is an oil-retaining groove.

The idler-wheel-carrier-arm bearings are lubricated from a nipple situated in the casting between the two bearings. The bushes of these bearings are also grooved for oil retention.

Fulcrum-arm-bearing oil seals.

Included in: Layout diagram: Plate 7.

Pictorial illustrations: Plates 32 and 33.

Felt washers are used for sealing purposes on all the fulcrum-arm bearings. There are two washers for each of the fulcrum-arm-support bearings, two of these being carried in grooves in their respective castings and one being fitted between the

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Fulcrum-arm-bearing oil seals.(continued).

casting and the shoulder on the cross-member. There is one washer to the inner and two to the outer wheel-carrier-arm bearings. The two washers outside the outer bearing make a seal on both sides of the distance piece.

The location of all the washers referred to above can be seen in the sectional diagram, Plate 7.

Track tension adjustment.

Included in: Layout diagram: Plate 7.

Pictorial illustrations: Plate 33 and page 301. of the Metallurgical Report.

General photographic views: Plates 57, 62 and 66.

The idler-wheel-carrier arm is mounted in bearings in the fulcrum arm in such a manner that the centreline of the idler wheel can swing through the arc of a circle when movement takes place in these bearings. This method of mounting is employed as a means of adjustment of the track tension. Movement of the idler-wheel-carrier arm in the bearing in the fulcrum arm, thus results in either increasing or decreasing the effective distance between the centres of the driving sprocket and the idler wheel according to the direction of movement. The position of the idler-wheel-carrier arm is determined by the threaded rod, (37) in Plate 33.

The layout of the mechanism, by means of which track adjustment is effected, is shown in the left-hand diagram on Plate 7 and a sketch, showing the idler-wheel-carrier arm and threaded adjustment rod assembly, appears on page 301.

The threaded rod, which controls the position of the idler wheel, is obviously only effective in preventing movement of the idler wheel in a forward direction, since the nuts, which this rod carries, bear only on one side of the wheel-carrier arm and the pin at the forward end of the threaded rod is borne in open-ended slots in the lugs of the fulcrum arm casting, and is rigidly held against rearward movement only.

Track tension adjustment (continued).

The tension in the track passing round the idler wheel maintains the latter in a stable position.

The pin, by means of which the threaded rod is linked to the fulcrum-arm casting, is of "rolling-pin" form, the large-diameter centre length fitting freely into the eye of the former and the smaller-diameter end sliding in the lugs of the latter. This pin is designed to shear should the tension in the track at any time become too great. Spare shearing pins are carried on the vehicle.

The threaded adjustment rod passes through the bush, (36) in Plate 33, which is supported in the two lugs of the wheel-carrier-arm. The two lock nuts on the rod control the position of the bush along it and apply pressure, through a suitably shaped distance piece, (39) in Plate 33.

In the sectional diagram, Plate 7, a cover, G.1889, for the threaded, track-tension-adjustment rod is shown, but there was no such cover on the vehicle which we inspected.

Track-shoe assemblies.

Included in:	Layout diagram:	Plate 8.
	Pictorial illustration:	Plate 34 and pages 332 - 339. of the Metallurgical Report.
	General photographic view:	Plate 57.
Metallurgical Report:		Pages 330 - 343.

The main body of each track shoe is a casting, carefully ribbed for strength, drilled and cored for lightness. The individual shoes are linked together by the track pins each one of which is rigidly fixed to the forked end of one casting and is carried in needle-roller bearings in the opposite end of the adjacent casting. From each shoe, a large tooth projects towards the inside of the track, as assembled on the vehicle; a rubber pad is carried on the outside. The track is stated by one of the German

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Track-shoe assemblies (continued).

manuals which was consulted to be of type, ZGKW.50/280/140. The appearance of the assembled track will be seen in Plate 57.

The surface presented by each shoe, to the inside of the track, in the assembled position, is quite flat except for the large tooth referred to above, and clearly visible in Plate 8. The flat, inside surface of the track rides on the rubber tyres of the driving sprocket, idler and bogie wheels, and the large teeth engage with the rollers on the teeth of the driving sprocket. The track shoe teeth are hollow, and during manufacture the core is removed through an aperture in the tip of the tooth, which is later filled by welding in place a small piece of metal. The tooth profile is made up of the arcs of two circles of radii equal to the pitch of the track and the centreline of the tooth-form is not perpendicular to the flat surface of the track shoe.

The hollow, central part of each track shoe (surrounding the centre of the track pin) is employed as an oil reservoir from which the track pin bearings are lubricated. This cavity is of limited volume compared with the size of the body of the track shoe casting, since it is blanked off from the hollow space inside the track shoe tooth. Replenishment of the lubricant is effected through a hole which faces upwards in the upper length of the track and which is plugged by a countersunk set-screw.

The face of the track shoe presented to the outside of the assembled track is cast as a lipped trough, to accommodate a rubber pad, through which the shoe makes contact with the road.

The track pins are located longitudinally by split cotter pins at their inner ends and by circular-section cotters at their outer ends. A flat on each cotter engages with a groove in the casting and thereby locks the track pin to the casting. The pins are otherwise a loose, running fit inside the forked members of the casting.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT.)

Track-shoe assemblies (continued).

The cotters taken from the vehicle in our possession were circular in section with flats near one end, as described above. That shown in the sectional view in Plate 8 appears to be of a slightly different form, however.

The inner races of the needle-roller bearings are a running fit on the track pins but are locked to the outer members of the forked casting and thereby to the track pins by the pronged lock-washers marked (7) in Plate 34. The prong of the lock-washer reposes in a hole in the casting. The outer races of the bearings are pressed into the castings. The inner races of the two bearings in each track shoe are separated by a shouldered distance piece which is a tight fit on both.

There are two oil seals to each track pin, i.e. one just outside each track pin bearing. The seals are all-rubber mouldings with the exception of the conventional, annular, coil spring holding the sealing element against the land. An extension of the inner bush of each needle-roller bearing serves as a land for the oil seal and the flange of the bush is machined to present a concave surface to the rubber sealing element. The seals are a push fit in the central member of the track shoe casting. It is probable that the function of the seals in preventing the ingress of foreign matter is more important than that of conserving the lubricant.

The rubber track shoe pads, shown in section in Plate 8, by which the shoes make contact with the ground, are secured to the track shoe castings by four tap bolts. The tap bolts engage with threaded ferrules which are welded to sheet-metal inserts, moulded inside each track pad. In the German specification of the ZGKW 3.t model, the track pads are referred to as type: "LDP".

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Dimensional Data.

(Scaled from vehicle except where marked x)

Driving-Sprocket Stub-Axle:	Pitch circle diameter of attaching flange bolts:	6.3"
	Diameter of attaching flange bolts:	0.6"
Final-Drive Gear-Wheel and Pinion:		
	No. of teeth on gear wheel:	71.
	No. of teeth on pinion:	14.
	Width of teeth:	2.3"
	Distance between centrelines of gear wheel and pinion:	7.5"
Sprocket Wheels:	Rim diameter:	20.3"
	Outside diameter of tyre: (This dimension is approximate as the tyre was in a partially worn condition).	22.4"
	Rim width (each):	2.2"
	Tyre tread width (each):	1.8"
	Pitch circle diameter of rollers:	23.2"
	Diameter of rollers:	2.0"
	Diameter of roller mounting pins:	0.8"
	Width of rollers:	2.0"
	Overall width across outside of sprocket wheel teeth:	3.3"
	Pitch circle diameter of sprocket wheel attaching studs:	7.2"
	Diameter of attaching studs:	0.56"
Bogie Wheels:	Rim diameter (both types):	20.4"
	Outside tyre diameter (both types): (This dimension is approximate as the tyre was in a partially worn condition).	22.5"

Dimensional Data (continued).

	Rim width (both types):	2.0"
	Tyre tread width (both types):	1.4"
	Overall width of widely spaced bogie assemblies (outside of rim of one wheel to outside of rim of mating wheel of pair):	11.5"
	Overall width of coupled bogie assemblies (outside of rim of one wheel to outside of rim of mating wheel of pair):	6.5"
	Outside diameter of track-tooth guide flanges (coupled bogies):	21.8"
	Gauge of sheet-metal of webs -	
	widely spaced bogies:	0.140"
	coupled bogies:	0.140"
	Diameter of lightening holes cut in webs -	
	widely spaced bogies:	3.5"
	coupled bogies:	2.9"
	Pitch circle diameter of hub-piece flange attaching bolts and rivets (widely spaced bogies):	4.8"
	Diameter of attaching studs (widely spaced bogies):	0.4"
	Pitch circle diameter of coupling rivets (coupled bogies):	7.8"
	Length of distance pieces carried upon coupling rivets (coupled bogies):	1.2"
Bogie Wheel-Carrier Arms:	Effective length (i.e. distance from centreline of wheel-carrying journals to centre-line of mounting journals):	11.8"
	Diameter of journals -	
	for inner mounting bearing:	2.165"
	for outer mounting bearing:	2.362"
	for inner wheel bearing:	1.968"
	for outer wheel bearing:	1.377"

Dimensional Data (continued).

Bogie-Suspension Torsion Bars:	Overall length:	47.0"
	Length of splines at each end:	1.9"
	Diameter of main length of torsion bar:	1.2"
	Approximate length at uniform section, 1.2" dia.:	42."
	Torque/deflection relationship:	see page 83.
Dimensions of Bogie-Suspension, Rubber Bumper Blocks:		2.8" x 2.1" x 1.9"
Bogie Shock-Absorbers (No.6 Bogies L.H. & R.H.):		
	Piston diameter:	2.1"
	Arm length:	6.4"
Idler-Wheel Assemblies:	All dimensions identical to those given above for the coupled-type bogie assemblies.	
Idler-Wheel-Carrier Arm:	Distance between centreline of wheel-carrying journals and centreline of mounting journals:	2.2"
	Distance between centreline of wheel-carrying journals and centreline of adjustment rod eye:	7.5"
Idler-Wheel Fulcrum Arm:	Effective length (i.e. distance between centreline of frame cross-member No.11 and centre-line of idler wheel mounting journals):	7.4"
Track Tension Shear Pins:	Effective diameter (i.e. diameter of ends):	0.31"
	Effective length (i.e. length of larger-diameter centre portion = distance between mounting forks =	0.6"

Dimensional Data (continued).

Idler-Wheel-Suspension Torsion Bars:

Total length:	22.3"
Length of splines at each end:	1.9"
Diameter of main length of torsion bar:	1.2"
Approximate length at uniform section, 1.2" dia.:	17.5"

Idler-Wheel Fulcrum-Arm-Mounting Bearings (Fabric-based plastic bushes):

Outer bearing:	3.9" internal diameter x 4.5" external diameter x 2.8" width.
Inner bearing - journal:	3.9" internal diameter x 4.5" external diameter x 1.8" width.
- side flanges:	3.9" internal diameter x 5.2" external diameter x 0.2" width.

Tracks:

Pitch:	140 m.m.* ≈ 5.5"
No. of links per assembled track - left-hand side:	55
right-hand side:	56
Track of tracks (i.e. distance between centreline of L.H. and centreline of R.H. tracks):	63.0" *
Extended length of assembled track - left-hand side:	303.2" *
right-hand side:	308.7" *
Overall width of each shoe:	11.2"
Diameter of track pin:	0.79"
Diameter of needle rollers of track pin bearings:	0.099"
Length of needle rollers of track pin bearings:	0.64"
Approximate area of ground contact of track-shoe rubber pad:	15 sq. in.

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Dimensional Data (continued).

Pressure on rubber track pads (calculated on basis of chassis fitted with troop-carrier body, laden) -

on hard surface:	42 lb/sq.in. *
on soft surface:	down to 7 lb/sq.in. *

Data Resulting from Experiment upon Parts from Vehicle.

Laboratory reports upon materials of construction:

Where examination of materials has been carried out, reference to the appropriate Laboratory reports has been made at the top of the sub-section dealing with the parts concerned.

Torque/deflection tests upon bogie and idler-wheel-suspension torsion-bars:

Tests were carried out upon two specimens of each type and a high degree of consistency was evident between the two sets of comparative results.

Average torque/deflection values were found to be:-

Bogie-suspension torsion bars:	73 lb.ft./degree.
Idler-suspension torsion bars:	166 lb.ft./degree.

Torque/deflection graphs, plotted from the test results upon the four specimens appear on pages 417 - 420.

A full report upon the torque/deflection tests which were carried out will be found in Vauxhall Motors Limited Experimental Report No.1218 pages 27 to 34 inclusive.

Pre-setting and fatigue-life investigations of bogie-suspension torsion bars:

Torque/deflection tests were carried out, involving comparable clockwise and anti-clockwise loading; observed values of torque and deflection at the limit of

DESIGN ANALYSIS OF CHASSIS - SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION (CONT)

Pre-setting and fatigue-life investigations of bogie-suspension torsion bars (continued).

proportionality of the same order under both conditions resulted in the conclusion that pre-setting of torsion bars is not employed.

A graph illustrating these results is reproduced on page 421.

Some fatigue tests of the bogie-suspension torsion bars were also carried out with the idea of giving some indication of the results of pre-setting and shotblasting upon bars of this type. Repeated stroking of the bars was effected through the maximum range considered possible on the vehicle, i.e. 0 - 36° deflection, corresponding with 0 to 43.5 tons/sq.in. stress range. Shotblasting and pre-setting techniques were based upon past experience of Vauxhall Motors and General Motors upon work of this kind.

A summary of the fatigue-test results has been given below, but it should be clearly emphasised here that the specimens tested were taken from the vehicle examined at the Works and that nothing was known of their past history as regards life, stressing or conditions of service. No final conclusions should, therefore, be drawn from the results given.

Condition:-	Average Life
As removed from vehicle (max. stress 97,000 lb/sq.in).	42,924 cycles.
Shotblast (max. stress 97,000 lb/sq.in).	185,258 cycles.
Pre-set 16° (max. stress 97,000 lb/sq.in).	100,741 cycles.
Pre-set 20° (max. stress 97,000 lb/sq.in)	53,533 cycles.
Shotblasted and then pre-set 22° (max. stress 96,200 lb/sq.in. due to smaller dia.)	496,779 cycles.

A full report upon the work of pre-setting and fatigue-life investigation which was carried out will be found by reference to Vauxhall Motors Limited, Experimental Report No.1218 pages 35 to 46 inclusive.

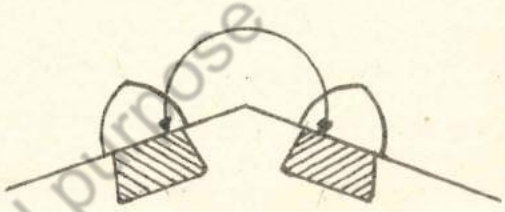
Flex-angle of track joints:

Values of the maximum and minimum possible angles between adjacent shoes of the track assembly during positive and negative flexing were measured upon three separate specimens and an average value determined; each specimen consisted of an assembly of two adjacent shoes, linked by a track pin and complete set of standard bearing parts.

Results were:-

Positive flex:	specimen (1)	129°	Negative flex:	specimen (1)	218°
	specimen (2)	131°		specimen (2)	219°
	specimen (3)	136°		specimen (3)	224°
	Average	132°		Average	220°

POSITIVE FLEX



NEGATIVE FLEX.

Velocity/load characteristics of No.6 bogie shock absorbers:

The shock absorbers were set up, in turn, on the shock absorber testing machine and tests were carried out in accordance with Vauxhall Motors Limited, Engineering Test Procedure, Passenger Chassis Section, Schedule No. R.4. The results of these tests are shown in the graph on page 412.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION.

Description of Design.

Transmission layout.

Included in: Layout diagram: Plate 1.
General photographic view: Plate 57.

Torque is transmitted from the engine to the driving sprockets through the clutch, gearbox, differential and final drive units respectively.

The gearbox is mounted in line with the power unit, but sufficiently rear of it to enable the differential unit to be situated transversely between the two. Short propellor shafts, parallel with the longitudinal axis of the frame, connect the clutch to the gearbox and the gearbox to the differential unit. The output shafts project transversely from either side of the differential and short propellor shafts link them to the final drive assemblies, which form part of the driving sprocket units.

Further details of the transmission will be found under the headings of the respective components.

Clutch assembly.

See SECTION 2 - POWER UNIT AND POWER-UNIT CONTROLS, page 22.

Gearbox assembly.

Included in: Layout diagrams: Plates 2 and 3.
Pictorial illustrations: Plates 21, 22 and 23.
General photographic views: Plates 67, 69, 70 and 71.

The general layout of the large, ten-speed, constant-mesh gearbox assembly will be seen from the diagram on Plate 2, and from the other reproductions referred to above.

The upper shafts of the gearbox are arranged to give four forward speeds and a reverse whilst it is possible to select two alternative gear trains of different ratios to link these shafts with the output shaft. The full range of the gearbox is thus eight forward ratios and two reverse.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Gearbox housing.

Included in: Layout diagram: Plate 2.
Pictorial illustration: Plate 21.
General photographic view: Plate 67.

The gearbox housing consists of two main castings, the vertical machined faces of which are clamped together, with no intermediate gasket, by long tap bolts. The plane of the centre joint thus formed includes the centrelines of the input and output shafts, and thereby facilitates assembly of the shafts, gears and bearings in the housing. A single dowel is provided for location of one of these main castings upon the other. There are two auxiliary castings, one housing the reverse gears and the other the selector rods and forks. Both are bolted to the right-hand half of the main housing. In addition, there are small castings for the end caps and mountings.

The large-diameter filler plug is located in the left-hand casting and there is a drain plug in the right-hand; both plugs are sealed, when in position, by circular steel washers. There are additional outlets in the left-hand casting, one for the speedometer drive and one for the high/low final gear ratio control. A breather in the form of a short brass tube is carried at the top of the right-hand casting.

Gearbox mountings.

Included in: Layout diagram: Plates 1 and 2.
Pictorial illustration: Plate 21.
General photographic view: Plate 75.

The gearbox assembly is three-point mounted from the frame, the two front mountings being carried upon frame cross-member No.6 and the single rear mounting upon cross-member No.8. The front mountings are situated at the ends of a transverse cast arm which also forms an end cap for the output shaft, whilst the single rear mounting is borne in a cast bracket, integral with the end-cap for the final-ratio shaft.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Gearbox mountings (continued).

All three mountings are of the same form and a section of the rear one is shown in Plate 2. It will be seen that the two rubber insulators of hollow, conical form, are sandwiched between the double-conical retainer and two appropriately shaped distance pieces, under the action of a single bolt, carrying a castellated nut and passing through all the above-mentioned parts and also through the fabricated, double-bent, sheet-metal brackets which are welded to the cross-member.

Gearbox shafts and gear-engagement sleeves.

Included in: Layout diagram: Plate 2.
Pictorial illustration: Plate 22.
General photographic views: Plates 68, 69 and 70.

There are six shafts in the gearbox which, for the purposes of this report only, have been named as follows:-

Input shaft	Included in the assembly shown at (1) in Plate 20.
Main shaft	Shown at (51) in Plate 22.
Lay shaft	" " (70) " " "
Reverse gear shaft	" " (28) " " "
Final ratio gear shaft	" " (36) " " "
Output shaft	" " (37) " " "

Input shaft: This is a very short shaft integral with the forked member of the rear universal joint of the propeller shaft from the clutch. It is carried by the main drive pinion, (59) in Plate 22, into which it is splined.

Main shaft: The main shaft is carried in the roller bearing shown at (52) in Plate 22, and the ball bearing at (57) in the same plate. Both these bearings are situated near the rear end of the shaft and the front end is located inside the main-drive pinion by a small parallel-roller bearing.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Gearbox shafts and gear-engagement sleeves.(continued).

The main shaft carries only the final-ratio gears, which are situated between its two main bearings. The first, second, third speed gears or the main drive pinion respectively may be locked to the shaft by movement of the two sliding gear-engagement sleeves which it carries. These sleeves are splined internally and externally, the internal splines mating constantly with the splines of the shaft and the external splines engaging, as required, with the internally splined bosses of the gear wheels. There is an annular groove around the centre of each of the gear-engagement sleeves to accommodate a striking fork.

Lay shaft: The first and second-speed layshaft gears are integral with the shaft and the main-drive and third-speed gears are splined to it, being separated by a tubular distance piece. The shaft is carried at its extreme ends and in the centre by two parallel-roller bearings and a ball bearing respectively.

Reverse-gear shaft: This shaft is carried at the front end in a parallel-roller bearing and at the rear end in a brass bush inside the hub of the loose reverse gear. The shaft is splined over the greater part of its length and carries the fast reverse gear and a sliding sleeve bearing dogs, which may be engaged with similar dogs on the forward face of the hub of the loose reverse gear.

Final ratio shaft: A large single-row ball bearing carries the front end of the shaft and the rear end is borne in a small parallel-roller bearing inside the boss of the rear final-ratio gear. The rear end of the shaft carries the internally and externally splined sliding sleeves, by which the alternative trains of final-ratio gears may be engaged, whilst the front, splined end links this shaft permanently with the output shaft.

Gearbox shafts and gear-engagement sleeves (continued).

Output shaft: The short output shaft is made in one piece with the forked member of the rear universal joint of the propeller shaft by which the gearbox is connected to the differential unit. It is rigidly splined to the forward end of the final ratio gear shaft and is, itself, carried in a single-row ball bearing at the front end of the gearbox housing. The speedometer-drive worm is carried along the short length of this shaft.

Gearbox gear wheels.

Included in: Layout diagram: Plate 2.
Pictorial illustration: Plate 22.
General photographic views: Plates 69 and 70.

All the gears are of a conventional design with helical teeth; they are well shown pictorially in Plate 22 and their functions in the layout diagram Plate 2.

All the gears have solid webs except the two largest-diameter final ratio gears, the webs of which are drilled for lightness.

In Plate 2, the manner in which the gears mesh with one another is very well shown. With reference to the reverse speed gear train shown upon this diagram, however, it might be worth while to point out that the loose reverse gear is in constant mesh with the rear and larger of the two final drive gears upon the main shaft. These gears are not shown in mesh in the diagram, as the Section, EF, is not entirely in one plane.

Gearbox bearings.

Included in: Layout diagram: Plate 2.
Pictorial illustration: Plate 22.
General photographic views: Plates 68, 69 and 70.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Gearbox bearings (continued).

The gearbox is very well provided with bearings, a total of 25 being employed in all. Parallel-roller and single-row ball bearings are favoured exclusively, with the exception of the one brass-bushed journal bearing for the reverse shaft, inside the loose reverse gear. The type, function and mounting of all the bearings is well shown in the sectional diagram, Plate 2.

It is worthy of note that only the layshaft gears, the final ratio gears on the main shaft, and the fixed reverse gear are splined to their respective shafts. All the remaining gears in the box are carried in their own bearings directly in the gearbox housing, and their mounting is completely independent of the shafts which pass through them. Two bearings are employed for each gear mounted in this manner and, with the exception of the front bearing on the main drive pinion, the extended bosses of the gear wheels also serve as the inner races of the bearings which carry them. In a similar manner, there is no separate outer race for the main-shaft steady bearing, inside the main-drive pinion. The brass bush in the hub of the loose reverse gear is lubricated by a drilling through the boss of the gear.

Longitudinal location of the end bearings is effected by caps, secured to the outside of the gearbox housing by tap bolts and packed with shims, whilst spring-steel rings, reposing in machined grooves in the gearbox castings, are employed for location of the intermediate bearings.

Gearbox oil seals.

Included in:	Layout diagram:	Plate 2.
	Pictorial illustrations:	Plates 21 and 22.
	General photographic views:	Plates 68 and 69.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Gearbox oil seals (continued).

Oil seals are pressed into the shaft end-covers of the gearbox housing where the input shaft enters and output shaft leaves the box. Both these seals are of the standardised pattern employed throughout the vehicle and described on page 49. with regard to the front hub oil seals.

The light sheet-metal oil deflector carried on the output shaft, and clearly visible in Plate 68, adjacent to the ball bearing carrying the shaft, relieves the output-shaft oil seal of some of its load.

Gearbox selectors.

Included in: Layout diagram: Plate 3.
Pictorial illustration: Plate 23.
General photographic views: Plates 67 and 71.

The selector box assembly is shown in section in Plate 3 and in pictorial view in Plate 71. It carries three selector forks by means of which the first, second, third, fourth and reverse gears are engaged. The selector forks are operated by the twisting and sliding action of the selector-box main control rod situated at the top of the box.

All the selector forks are of brass and are secured to the hardened-steel rods, upon which they are mounted, by small grub screws; the rods slide directly in the casting which forms the box and their location is controlled by the usual spring-loaded ball device (see diagram). The selector-box main control rod is mounted in flanged, brass-bushed bearings.

The striking fork operating the final-ratio-gear engagement is shown clearly in section, CD, of Plate 2. The spring-loaded ball reposes in either of two part-spherical indentations in the small, otherwise flat, machined face upon the outside of the gearbox-housing casting.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Gearbox controls.

Included in: Layout diagram: Plate 15.
Pictorial illustration: Plate 45.
General photographic view: Plate 67.

There are two separate gear-shift levers, one for engaging the first, second, third, fourth and reverse gears, and the other operating the alternative final-ratio gears. Both levers are mounted on the fabricated, welded and bolted sheet-metal structure shown at (57) in Plate 45. This structure is bolted to two right-angle brackets, welded to each side-member, and spans the gap between left and right-hand side-members, thereby bridging the differential unit. The function of this "bridge", as it might be termed by virtue of its shape, is to carry the three major manual controls, i.e. the hand-brake and the two gear-shift levers.

A welded, sheet-metal box is bolted to the top platform of the bridge and forms a gate for the lever controlling the four forward speeds and the reverse. The lever itself incorporates a ball near its lower end which is mounted in a brass-bushed socket, bolted to the underside of the top platform of the bridge, and shown in section in Plate 15. The slot of the gate corresponding with reverse gear is normally covered by a light flap, pivotted at one end. This flap is held closed by a coil spring surrounding its hinged pivot pin (see Plate 15), but can easily be opened when it is required to engage reverse gear by applying slight extra pressure to the gear shift lever.

There are only two positions of the lever, by which the alternative final-ratio gears are engaged, and the lever is accordingly mounted on a simple pivot pin carried at the rear of the manual controls bridge. It will be observed from Plate 67 that a substitute lever has been fitted to the vehicle which was in our possession; the form of the original control, however, will be seen from the plates reproduced from the German manuals.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Gearbox controls (continued).

The appropriate twisting and sliding motion, required for the engagement of any particular gear, is transmitted to the selector-box main control rod, from the extreme lower end of the gear-shift lever, through the double-universally jointed control rod clearly visible in Plate 67. The end of this shaft, which projects beneath the bridge is connected to a pivot pin carried in the boss at the extreme lower end of the gear-shift lever through a forked, bent crank.

The lower end of the final-ratio-engagement gear-shift lever is linked directly to the crank on the side of the gearbox, which operates the striking fork, by means of the long, bent connecting-rod visible in Plates 1 and 57.

Differential assembly.

Included in: Layout diagram: Plate 4.
Pictorial illustrations: Plates 24, 25 and 26.
General photographic views: Plates 72, 73, 74, 83 and 84.

A spur-wheel differential is employed and the unit includes a crown wheel and pinion, by means of which the drive is transmitted from the longitudinal axis, in which the engine and gearbox lie, to the transverse axis required by the final-drive units. The layout is shown in Plate 4, from which the mode of operation will be apparent. In the course of straight-ahead running, the crown wheel, the differential carrier and the six shafts, pinions and gear wheels which it carries, the steering brake-drums and the brake-drum-mounting sleeves, together with the output shafts and output-shaft gears, all revolve as one unit, with the same angular velocity, about the centreline of the output shafts. Upon application of one of the steering brakes, however, the differential-carrier gears on the same side as the drum, to which brake application is made, being in constant engagement with the teeth of the brake-drum-mounting sleeve, will commence to rotate about their own axes, and this rotational motion will be transmitted through the differential pinions to the output-shaft

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Differential assembly (continued).

differential gear wheels, so that equal and opposite angular velocities will be imparted to the left-hand and right-hand shafts respectively and superimposed upon any common velocity with which they may already be moving. As pointed out in Section 7, under the heading "Layout and action of steering", the linkage to the steering brakes, and the adjustment required of this, is such, that the curve described, due to the relative reduction in speed of one track-driving sprocket and the equal increase in speed of the other, is in unison with that demanded by the angular deflection of the front road wheels.

The individual units of the differential assembly have been dealt with in greater detail below.

Differential housing.

Included in: Layout diagram: Plate 4.

Pictorial illustrations: Plates 24, 25 and 26, and pages 34[illegible] - 35[illegible] of the Metallurgical Report.

General photographic views: Plates 72 and 83.

Metallurgical Report: Pages 344 - 355.

The major part of the differential housing is cast in two halves, which are shown at (2) and (3) in Plate 24. The machined faces of these castings are clamped together by ten bolts and nuts, without the use of any intermediate packing material; the joint thus formed, lies in a plane which is approximately horizontal, and which includes the two principal axes of the rotating parts of the differential unit, thus facilitating assembly of these parts into the housing. The housing is completed by three end-cover-plates held in position by tap bolts and shown at (50) and (61) in Plates 25 and 26 respectively.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Differential housing (continued).

A large drain plug is provided in the lower, main casting of the housing and in the upper casting there is a filler plug with extended neck and cap incorporating a dip stick. At the top of the housing is a small combined cover-plate and breather-tube assembly, held in position by four set-screws. The above accessories are well shown in the sectional views on Plate 4.

Differential-unit mounting.

Included in: Layout diagrams: Plates 1 and 4.
Pictorial illustration: Plate 24.
General photographic views: Plates 72 and 83.

The housing of the differential unit is four-point, flexibly mounted from frame cross-members No's 4 and 5, two mountings being situated on the forward member of the two and two mountings on the rear.

The four mountings are alike and are of the double-conical-rubber-insulator type, with a single, vertical clamping and anchorage bolt, exactly similar to those employed for the gearbox. This type of mounting has been described under the heading "Gearbox mountings" on page 87. As in the case of the gearbox, the double-coned retainers are integral with the casting of the housing. Those for the front mountings are carried on the forward edge of the upper casting of the main housing and those for the rear mountings on either side of the pinion tube of the lower casting.

Sheet-metal brackets are welded to No.5 cross-member to support the rear mountings but those at the front are carried on solid packing blocks, welded to No.4 cross-member, and tapped to accommodate the anchorage bolts. Examples of both front and rear mountings are shown in section on Plate 4.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Differential carrier.

Included in:	Layout diagram:	Plate 4.
	Pictorial illustrations:	Plate 25, and pages 359 - 367 of Metallurgical Report.
	General photographic views:	Plates 73 and 83.
	Metallurgical Report:	Pages 356 - 371

The differential carrier is made up of three main components, the central casting, (17) in Plate 25, and the two end-pieces which are forgings, shown at (27) in the same plate. The three parts are clamped together to form one unit, along with the crown wheel, which is inserted between the central casting and the right-hand end forging, as shown in the sectional diagram. Clamping is effected by six, long, hexagon-headed bolts, carrying castellated nuts locked by split pins. These bolts are machined to a dumb-bell form, so that lengths at each end, which are of greater diameter, are a good fit in the holes of the parts which they join.

The centre casting carries two large-diameter, flanged, phosphur-bronze bushes in which the bosses of the output-shaft differential gear wheels are mounted in the assembled unit. Smaller flanged bushes of the same material are pressed into the main flanges of the forged end-pieces to carry the differential-pinion shafts. It will be observed from the illustrations that two different bushes are employed in these positions, the shorter ones being used at the ends of the shafts remote from the gear wheels which they carry, to permit of accommodation of a longitudinal retaining device for the shaft.

Large, flanged, brass or phosphur-bronze bushes, (25) in Plate 25, are pressed into the centre bores of the end-pieces and serve to carry the brake-drum-mounting sleeves when the unit is assembled.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Differential shafts.

Included in: Layout diagram: Plate 4.
Pictorial illustration: Plate 25.
General photographic views: Plates 73 and 74.

The two output shafts of the differential unit are identically similar and each is splined into one of the output-shaft gear wheels at the inner end, and is flanged for attachment to the universal coupling at the outer end. The shafts are shown at (20) in Plate 25.

The spiral-bevel-pinion shaft and the differential pinion shafts are integral with the pinions which they carry, vide (41), (33) and (33a) respectively in Plate 25. The differential-pinion shafts are located by the insertion of a distance piece between the pinion and the flanged face of the bearing bush at one end and of a circlip and plain washer in the flange of the carrier end-piece at the other.

Crown wheel and pinion.

Included in: Layout diagram: Plate 4.
Pictorial illustration: Plate 25, and pages 374 and 377, of Metallurgical Report.
General photographic views: Plates 73, 74 and 83.
Metallurgical Report: Pages 372 - 379.

The spiral bevel crown wheel and pinion are well shown in the diagrams and photographs referred to above. The crown wheel is mounted upon the six, differential-carrier bolts, between the centre casting and the right-hand end-piece, as referred to above. Mounting of the pinion has been made the subject of the next paragraph.

Pinion mounting and bearings.

Included in: Layout diagram: Plate 4
Pictorial illustration: Plate 25.
General photographic views: Plates 72, 74 and 83.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Pinion mounting and bearings (continued).

The pinion is carried in a single-row roller bearing and a double-row ball bearing, the two bearings being pressed on the pinion shaft and separated by a hollow, cast, frustroidal distance-piece. The outer races of the two bearings are pressed into the flanged tube, (47) in Plate 25, and the whole assembly included in the tube, is assembled into the differential housing as a single unit. The flange of this tube is secured to the differential housing by ten tap bolts, and shims are inserted between the machined, end face of the housing and the underside of the flange of the tube, to give correct adjustment between the teeth of the pinion and the crown wheel. These shims are drilled to permit the above-mentioned, ten tap bolts to pass through them, and an end cover-plate, housing an oil seal is also attached by the same bolts.

Differential spur gears and pinions.

Included in: Layout diagram: Plate 4.

Pictorial illustration: Plate 25, and page 382 of Metallurgical Report.

General photographic views: Plates 73 and 83.

Metallurgical Reports: Pages 380 - 384

In addition to the crown wheel and pinion, the gears of the differential unit include the six differential pinions, which are integral with the shafts upon which they are mounted in the carrier, the six differential gear wheels, tapered, keyed and nutted upon these shafts, and the two output-shaft gears which are splined on the output shafts and the bosses of which are borne in the phosphur-bronze bushes of the central casting of the differential carrier. All the above are straight-toothed gears and are amply illustrated by the reproductions referred to at the top of the paragraph.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Steering-brake-drum mounting sleeves.

Included in: Layout diagram: Plate 4.
Pictorial illustration: Plate 25.
General photographic views: Plates 73 and 84.
Metallurgical Report: Pages 388 - 392.

The steering brake drums are borne upon sleeves which are flanged at one end to carry the brake drums and upon which teeth have been cut at the opposite end, to engage with the teeth of the differential-carrier gears. These sleeves are carried in the brass bushes, pressed into the main bores of the differential carrier, the inside bores of the sleeves in turn carry brass bushes to permit free rotation upon the output shaft. These sleeves may turn, therefore, independently of both the differential carrier and the output shafts; this condition is fulfilled when the vehicle is describing a curve due to application of one of the steering brakes. The form of the brake-drum sleeve can be seen at (21) in Plate 25.

Differential-unit bearings.

Included in: Layout diagram: Plate 4.
Pictorial illustration: Plate 25.
General photographic view: Plate 74.

The single-row roller and double-row ball bearing, carrying the spiral bevel pinion, are shown at (42) and (44) in Plate 25, and are also clearly illustrated in the sectional diagram and in Plate 74.

There are two other rolling-friction bearings in the assembly, namely the two large-diameter ball bearings which carry the differential carrier in the main housing. These are conventional single-row ball bearings and are shown at (29) in Plate 25.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Differential-unit bearings (continued).

The remaining bearings of the assembly come into operation, only when the vehicle is not travelling upon a straight course, and brass or phosphur-bronze-bushed, journal bearings are employed. All these bearings are clearly shown in the sectional diagram and have already been mentioned under the headings of the various components into which they are pressed.

The bearings of the short, differential-pinion shafts are presumably adequately lubricated by splash, as no individual oil ways are provided. There are two diametrically opposed grooves in the bushes for oil retention, however.

Lubrication of the two sets of journal bearings, by means of which the differential carrier is mounted on the brake-drum driving sleeves and by which these sleeves are, in turn, mounted upon the main output shafts, is of interest, however. Two four-scooped, internally grooved rings, acting as oil ducts, are carried, one on the boss of each differential-carrier end-piece, between the inner race of the bearings, upon which the carrier is borne in the housing, and the circular nut, by which the inner race of the bearing is held against the shoulder of the carrier end-piece. The bosses and the bushes are suitably drilled and grooved to make full use of the lubricant scooped into the circular oil duct. There are two, diametrically opposed, full-length grooves in each of the smaller bushes, whilst the larger bushes have four such grooves, spaced at 90°.

An oil-way is drilled in the central casting of the differential carrier to aid the supply of lubricant to the working surfaces of the two centre bearings in which the differential output shaft gears are borne.

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Differential-unit oil seals.

Included in: Layout diagram: Plate 4.
Pictorial illustrations: Plates 25 and 26.
General photographic view: Plate 74.

Conventional oil seals, of the type described with reference to the front-hub oil seals on page 49 , are used to prevent egress of oil along the output shafts, the brake drum mounting sleeves and the spiral-bevel-pinion shaft. The seals for these purposes are shown at (22), (54) and (51) in Plates 25 and 26, and they are pressed into the brake-drum-mounting sleeves and the three, circular, end cover-plates of the differential housing respectively.

Steering brakes and drums.

See SECTION 7 - STEERING AND BRAKES, page 114.

Final drive units.

The final drive units form part of the driving sprocket units, reference to which will be found under SECTION 5 - TRACK-LAYING UNITS AND REAR SUSPENSION, pages 58 to 85.

Propeller shafts.

Included in: Layout diagram: Plates 1 and 2.
Pictorial illustration: Plate 20.
General photographic views: Plates 76 and 82.

Four, short, universally jointed propeller shafts are incorporated in the transmission of the vehicle. The three designs employed are illustrated in Plate 20. Referring to this plate, that at (1) links the clutch with the gearbox, that at (3) links the gearbox with the differential unit and the type shown at (5), of which there are two, is designed to couple each of the differential, output shafts to its appropriate final-drive unit. It will be seen that the shafts, connecting the gearbox with the

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Propeller shafts (continued).

differential unit and the differential unit with the final-drive units, are each no more than a pair of coupled universal joints. A hollow shaft, with the universal joints welded to the ends, is employed for transmitting the drive from the clutch to the gearbox, however.

The universal joints vary in size but are all of the same conventional design, incorporating needle-roller bearings. A partially dismantled joint of one of the couplings, linking the differential to the final-drive unit, taken from the vehicle which was in our possession, is shown in Plate 76. This photograph illustrates the construction of the joints, in which the cylindrical needle-roller retainers are clamped to the main castings of the joint by small bearing caps, using two tap bolts. Plain, steel washers are a good fit between the centre castings and the open end of each needle-roller retainer.

The centre-piece of each joint is fitted with a grease nipple and is suitably drilled to convey the lubricant to the bearings.

Dimensional Data.

(Scaled from vehicle except where marked *)

TRANSMISSION RATIOS (GEARBOX AND OVERALL):-

GEARSHIFT LEVER POSITIONS:-				
1st to 4th & Reverse Speed Lever:-	FINAL-RATIO LEVER:-			
	LOW		HIGH	
	Engine to G'Box Output-Shaft Ratio.	Engine to Driving-Sprocket Ratio	Engine to G'Box Output-Shaft Ratio	Engine to Driving-Sprocket Ratio.
First	8.63	84.64	3.47	34.04
Second	4.47	43.80	1.80	17.61
Third	2.51	24.58	1.01	9.88
Fourth	1.58	15.46	0.63	6.22
Reverse	9.25	90.71	3.72	36.48

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Dimensional Data (continued).

Gearbox:-

Number of teeth of gear-wheels -

Main drive pinion:	22
Main-shaft 3rd-speed gear:	29
Main-shaft 2nd-speed gear:	38
Main-shaft 1st-speed gear:	47
Lay-shaft main-drive gear:	41
Lay-shaft 3rd-speed gear:	34
Lay-shaft 2nd-speed gear:	25
Lay-shaft 1st-speed gear:	16
Reverse-shaft fast gear:	43
Reverse-shaft loose gear:	35
Main-shaft low-final-ratio gear:	26
Main-shaft high-final-ratio gear:	41
Final-ratio-shaft low-final-ratio gear:	41
Final-ratio-shaft high-final-ratio gear:	26

Distances between shaft centrelines -

Input shaft)) and Lay shaft: Main shaft)	3.75"
Lay shaft and reverse shaft:	3.40"
Reverse shaft and main shaft:	5.98"
Main shaft and (Final-ratio shaft) ( ) (Output shaft)	5.44"

Dimensional Data (continued).

Lay shaft and (Final-ratio shaft / Output shaft)	6.53"
Reverse shaft and (Final-ratio shaft / Output shaft)	5.44"

Bearing sizes -

Input shaft, forward, (roller):	1.769" x 3.350" x 0.905"
Input shaft, rear, (roller):	2.166" x 3.350" x 0.905"
Main shaft, forward, steady, (roller):	0.670" x 1.339" x 0.630"
Main shaft, intermediate (roller):	2.301" x 3.935" x 0.985"
Main shaft, rear (ball):	1.179" x 3.540" x 0.905"
Lay shaft, forward (ball):	1.377" x 2.150" x 0.825"
Lay shaft, intermediate (roller):	1.968" x 3.151" x 0.905"
Lay shaft, rear (roller):	1.383" x 3.151" x 1.220"
Reverse shaft, forward:	1.723" x 2.833" x 0.905"
Final-ratio shaft, rear, steady (roller):	0.985" x 1.722" x 0.590"
Final-ratio shaft, front (ball):	1.969" x 4.330" x 1.060"
Output shaft, front (ball):	2.366" x 4.330" x 0.868"
Main-shaft 3rd-speed-gear, forward (roller):	2.166" x 3.350" x 0.905"
Main-shaft 3rd-speed-gear, rear; Main-shaft 2nd-speed-gear, forward; Main-shaft 2nd-speed-gear, rear; Main-shaft 1st-speed-gear, forward; Main-shaft 1st-speed-gear, rear (roller):	2.617" x 3.935" x 0.824"

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Dimensional Data (continued).

Loose-reverse gear forward)		ø
)	(roller):	2.166" x 3.350" x 0.905"
Loose-reverse gear rear)		
Final-ratio shaft high-gear, forward)		
)		
Final-ratio shaft high-gear, rear)		
)	(ball)	2.463" x 4.923" x 0.945"
Final-ratio shaft low-gear, forward)		
)		
Final-ratio shaft low-gear, rear)		

ø Dimensions marked thus represent the diameters of the inner path of contact of the rollers.

ǂ Dimensions marked thus represent the diameters of the outer path of contact of the rollers.

Differential unit:

Number of teeth of gear wheels, pinions, etc. -

Spiral bevel pinion:	15
Spiral bevel gear:	29
Output-shaft gears:	45
Differential pinions:	12
Differential-pinion-shaft gears:	33
Brake-drum-mounting sleeves:	24

Distances between shaft centrelines -

Pinion shafts and output shafts:	6.06"

Final-drive units:

See SECTION 5, pages 59 to 61.

Oil capacities:

Gearbox:	1.32 gallons ж
Differential unit:	0.77 gallons ж
Final-drive units:	0.24 gallons each ж

DESIGN ANALYSIS OF CHASSIS - SECTION 6 - TRANSMISSION (CONTINUED).

Data Obtained by Experiment upon Parts from Vehicle.

Laboratory reports upon materials of construction:

Where examination of materials has been carried out, reference to the appropriate Laboratory reports has been made at the top of the sub-section dealing with the parts concerned.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES.

General Design.

Layout and action of steering.

Included in: Layout diagrams: Plates 4, 9, 10, 13 and 14.

The vehicle is steered by the combined action of turning the front road wheels and of increasing the velocity of the track driving sprocket, and consequently of the track, on the outside of the curve which the vehicle is required to describe, relative to that on the inside. Steering of the front wheels is effected through a conventional system of mechanical links. The speed of the outer driving sprocket is increased and that of the inner sprocket equally reduced, relative to the corresponding speed for a straight course, by means of the differential unit and the steering brakes.

Front-wheel and track steering are controlled concurrently from the steering wheel, but the mechanical linkage is such, that track steering does not become effective until the steering wheel has been turned from the position, corresponding to which the front road wheels are set upon a straight course, through a definite angle, which is pre-determined but variable by adjustment. Thus, for slight variations from a straight path and for large-radius curves, steering is by deflection of the front wheels only, and the action of the differential is simple that which would be expected of a unit of this kind. The steering brakes come into operation for smaller-radius curves, but the design is such that with correct adjustment the transition from a large-radius curve to one of smaller radius is smooth and controllable.

The layout of the steering column assembly, including column, upper and lower steering boxes and steering wheel, is shown in Plate 10. The chassis which was examined was intended to accommodate an armoured body and the restricted shape of this presumably accounts for the unusual rake of the steering wheel requiring the addition of the upper steering box incorporating bevel gears. The conventional mechanism comprising drop-arm, drag link, third arm, tie-rod and left-hand and right-hand steering arms, can be seen in Plates 1 and 9. The layout of the mechanical linkage to the steering

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Layout and action of steering (continued).

brakes is as shown in Plates 13 and 14 and reference to the differential unit will be found in SECTION 6 - TRANSMISSION, pages 94 to 102. The principal components of the steering mechanism have been described below under their respective headings.

Steering wheel.

Included in: Layout diagram: Plate 10.
Pictorial illustration: Plate 41.
General photographic views: Plates 67 and 77.

The steering wheel is typical of the design associated with road-vehicles and has four spokes. Hub, spokes and rim are steel and the whole is covered in vulcanite-like material. The wheel is tapered, keyed and nutted to the end of the short shaft upon which it is carried and access to this nut is obtainable by removal of the light-alloy centre-cap, secured to the boss of the steering wheel by three countersunk screws.

Upper steering box assembly.

Included in: Layout diagram: Plate 10.
Pictorial illustration: Plate 41.
General photographic view: Plate 77.

The upper steering box has apparently been introduced into the design of Model 251 to give the required reverse rake of the steering wheel. It incorporates two bevel gears which give a slight increase in the velocity-ratio of the steering mechanism.

Two castings form the housing of this steering box and are clamped together by seven nuts and bolts. In this respect, the housing is similar to those of the gearbox and differential unit, since the contacting machined faces form a joint, with no intermediate gasket, and in the plane of which lie the rotating parts of the assembly. The housing is cast in the form of a right-angle bracket at the top and by means of this it is attached by six bolts to the rear and underside of the dash panel. A grease nipple is tapped into one side of the housing.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Upper steering box assembly (continued).

The bevel gears are integral with the short shafts, upon which they are mounted, and at the opposite end to the gears, one of these shafts carries the steering wheel and the other the steering-column universal joint. The manner in which the bevel gears and shafts are mounted in the housing in double-flanged, brass bushes will be apparent from the sectional diagram.

Secured to the face of the upper steering box housing adjoining the steering wheel, is the device known as the steering indicator which is described below.

Steering indicator.

Included in: Layout diagram: Plate 10.
Pictorial illustration: Plate 41.
General photographic view: Plate 77.

The purpose of the steering indicator is to show the driver, by means of a pointer passing over a scale, the precise lock at which the front wheels are turned.

The steering-box housing is recessed, where it faces the steering wheel, and the depression formed is covered by a small, cast cap of similar shape, attached by five countersunk set-screws. Within the housing thus formed are the gears which operate the pointer of the indicator. These comprise a large-diameter worm on the main shaft, engaging with a small pinion on an oblique intermediate shaft, which also carries a smaller worm engaging, in turn, with another pinion on the spindle upon which the pointer is mounted. The pointer is thus driven from the steering-wheel shaft through two worm and pinion trains. The layout of the gears and intermediate shaft are shown in the inset diagram representing section, CD, on Plate 10.

Both the pointer and the scale were missing from the vehicle which came into our possession and details of these parts are consequently not known.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Lower steering box assembly

Included in: Layout diagram: Plate 10
Pictorial illustration: Plate 41
General photographic view: Plate 79

The lower steering box assembly fulfils the function usually associated with a steering box in a conventional steering layout, i.e. that of converting the rotary motion and torque of the steering column to similar motion, but of smaller amplitude and greater torque, at the cross-shaft upon which the drop-arm is carried.

A worm-and-nut type of steering box is employed, sectional views of which appear on Plate 10; the motion of the nut is transmitted to the drop-arm shaft through the double-armed crank.

The steering box housing is made up of three castings, the main case shown at (1) in Plate 41, the top cover at (2), and the end cover plate at (4) in the same plate. The characteristic form of the main-case casting will be seen in the sectional diagram showing the right-angle bracket by which it is secured to the side-member of the frame and the deep web with three strengthening ribs between the box and the bracket. The top cover is attached by six tap bolts and the centreline of the drop-arm shaft lies in the plane of the joint between this cover and the main case. The end cover is also attached by tap bolts and gaskets are not employed in either case. There is a filler plug in the top cover but no drain plug is included in the housing.

The worm is an integral part of the steering column and is carried in the main case in two, single-row, ball bearings of a type designed to bear some measure of combined radial and axial load, (see sectional diagram). The lower bearing is located against the end cover-plate, which is held in position by four set-screws, and the upper one by the threaded sleeve, passing round the column and locked by a large nut.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Lower steering box assembly (continued).

The nut with which the worm engages is shown at (6) in Plate 41, and the slotted, circular bearing-pieces, marked (7), with which the double crank of the drop-arm shaft is mated, are an extremely good running fit in recesses bored in either side of the nut. Both the nut and the bearing-pieces are of hardened steel. Rotation of the nut relative to the steering box housing is prevented by two machined slides, projecting from the inner surface of the housing, upon which the nut bears lightly.

The drop-arm shaft and the double-armed crank, which engages with the nut assembly, are a single part and apparently a drop forging. The crank and shaft is carried in two brass bushes which are held in position by circular nuts and prevented from rotating by dowels. The shaft projects from both sides of the box, and at one end carries the long drop-arm, connected to the drag-link through which the front wheels are steered, whilst at the other end, a shorter drop-arm is carried, and is linked ultimately to the steering brakes. Both arms are attached by splines and castellated nuts locked by split pins.

Steering column.

Included in: Layout diagram: Plates 1 and 10

Pictorial illustration: Plate 41

General photographic views: Plates 77 and 79

The steering column includes the worm for the lower steering box and the whole is apparently machined from the solid bar.

The column is carried in the steering box in two single-row, semi-thrust, ball bearings, situated one at each end of the worm; at the upper end it is secured to the universal coupling by a keyed, tapered and nutted joint.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Steering-column universal coupling.

Included in: Layout diagram: Plate 10
Pictorial illustration: Plate 41
General photographic view: Plate 77

The universal coupling, at the top of the steering column, links the latter to the shaft projecting downwards from the upper steering box, and accommodates any mis-alignment between these two rigidly mounted shafts. The coupling consists of a single, thick, rubberized-fabric disc held between two, three-pronged spiders by six bolts and nuts of about $\frac{3}{8}$" diameter. The spiders are attached to the shafts by tapered and keyed joints closed by nuts.

Front-wheel-steering drag-link.

Included in: Layout diagram: Plate 1
Pictorial illustration: Plate 41
General photographic view: Plate 61

The steering drag-link is of conventional form with ball-joints at either end. It is a hollow rod of construction similar to the steering tie-rod, and its length is adjustable by means of a similar threaded-socket device, locked by two clamp bolts. The same ball-joint end-assemblies appear to be used for the drag-link as for the tie-rod.

It will be observed that a bent drag-link is shown in the plates reproduced from the German manuals, 1 and 41, whilst that, taken from the vehicle which came into our possession, was a plain, straight rod.

Steering arms.

See SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION, page 47

Steering tie rod.

See SECTION 4 - FRONT AXLE ASSEMBLY AND FRONT SUSPENSION, page 48.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Steering brake drums.

Included in: Layout diagram: Plate 4.
Pictorial illustrations: Plates 24 and 26.
General photographic views: Plates 72 and 82.

The steering brake drums on the vehicle which was examined were of general shape and approximate dimensions similar to those shown in the sectional diagram on Plate 4, but the flange and web of each drum were separate parts as shown at (60) and (61) respectively in Plate 26. Six tap bolts hold the two parts together; the bolts pass through clearance holes in the flanged rim of the drum and are anchored in tapped holes in the web.

Steering brake assemblies.

Included in: Layout diagram: Plates 4 and 14.
Pictorial illustrations: Plates 24 and 26.
General photographic views: Plates 72, 83 and 84.
Metallurgical Report (linings and drums): Pages 393 - 405.

Conventional-design brakes of fairly light construction are employed for operation of the track steering.

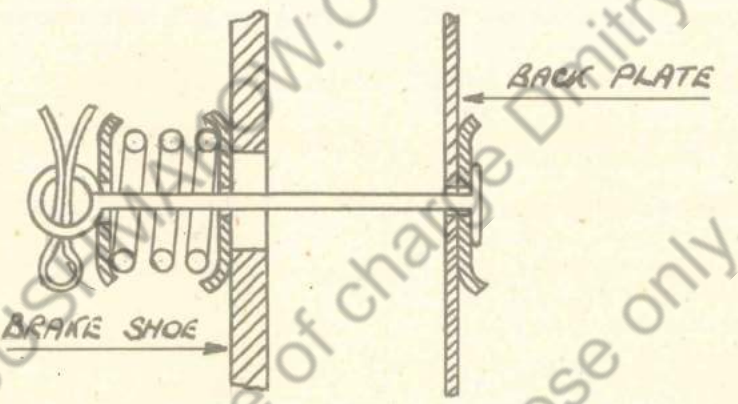
The back plates are secured to the end covers of the differential unit by eight tap bolts of about 5/16" diameter. The shoe construction is very light and a conventional T-section is formed from thin-gauge, flat, sheet-metal segments and wrapped sheet-metal plates, which are welded together over lengths of approximately one inch at the ends of the wrapped plates only.

The shoes are mounted at the top on a large bolt, of special design, secured to the back plate; the forked upper ends of the shoes are supported against this bolt, between a boss formed upon it adjacent to the back plate, and a large plain washer carried at the end of the bolt. The outer end of the bolt is of rectangular section and relative

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Steering brake assemblies (continued).

rotation of the plain washer, which has a rectangular hole, is thus prevented. The washer is held in position by a large split pin. The brake shoes are supported against one another at their lower ends by use of a narrow, flanged reel, fitting between the forks of the two shoes. Each shoe is flexibly pinned to the back plate, slightly below the mid-point of its length, by a pin-and-coil-spring assembly of a conventional form, as shown.



Flat-topped impressions have been pressed into the back plates so that contact between the shoes and the back plates is made at three points only for each shoe, i.e. at the centre and at each end.

The brake shoes are operated by a cam and dual-lever mechanism. The brake cable is attached to one end of the primary lever, which is pivotted to the back plate at the opposite end. The secondary lever is pivotted upon the large-diameter bolt, which also supports the upper ends of the brake shoes and a projection upon this lever serves as a double-contact cam by means of which the shoes are separated. Linkage between the primary and secondary levers is effected by a pin, which is rigidly attached to the primary and slides along the edge of the secondary lever. The closing action of the shoes is good, three coil tension springs being employed for this purpose.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Steering brake assemblies (continued).

One of these is arranged horizontally across the bottom of the shoes and linking one shoe with the other, the line of action being approximately 1¼" above the fulcrum point. The two shorter springs are fitted obliquely at the top of the brake between the individual shoes and the washer on the top-mounting bolt.

The material of the linings was examined by our Laboratory and their report will be found on page 353 et seq. The linings are secured to the shoes by steel rivets, arranged in pairs transversally across the lining width. The leading and trailing brake shoes are apparently identical, but a longer lining is fitted to the trailing shoe than to the leading. Both leading and trailing-shoe linings are tapered at their leading and trailing edges. The linings of the vehicle inspected had suffered some wear but their thickness had obviously never been very great and that of leading and trailing shoes was apparently equal.

The steering-brake cables are operated from cranks on the steering-brake cross-shaft, which, in turn, is rotated by a mechanical linkage from the right-hand drop-arm of the lower steering box. Forked pieces are swaged to the brake ends of the cables and permit their attachment to the primary operating levers, whilst, at the opposite ends forked attachments are fitted in threaded sockets, thereby enabling the effective lengths of the cables to be adjusted. Adjustment is locked by means of nuts on either side of the moving pieces. The cable casings are anchored by the two brackets, shown at (8) and (9) in Plate 24, to the pinion housing of the differential unit. Conventional grease nipples, situated mid-way along the length of each cable, are visible in the same plate.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Steering-brake-control cross-shaft, cranks and collars.

Included in: Layout diagrams: Plates 13 and 14

Pictorial illustration: Plate 42

General photographic views: Plates 67, 81 and 82

The cross-shaft, carrying the cranks from which immediate operation of the steering brakes is effected, is situated rear of the differential and just above the centre-line of this unit. The cross-shaft and its position in the assembled chassis can be seen in Plate 82.

Five cranks and two collars are carried on the cross-shaft and are shown in their order from left to right across the shaft at (118), (106), (112), (110), (107) and (106) respectively in Plate 42.

The order and functions of these cranks and collars have been set out below and, for the purposes of this description, they have been designated Links No's 1 - 7, from left to right across the shaft.

Link No.1: A crank; keyed to the shaft and connected ultimately to the steering box, thus providing the means whereby rotary motion is imparted to the shaft.

Link No.2: A tappet-carrying collar; keyed to the shaft and operating the left-hand steering brake, in conjunction with Link No.3

Link No.3: A crank; mounted freely on the shaft and connected by cable to the shoe-operating levers of the left-hand steering brake.

Link No.4: A combined tappet-carrying collar and hand-brake connection crank; mounted freely on the shaft and operating the left-hand steering-brake in conjunction with Link No.3; it incorporates an additional arm which is linked to the trailer-brake operating valve.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Steering-brake-control cross-shaft, cranks and collars (continued).

Link No.5: Similar combined tappet-carrying collar and hand-brake connection crank; mounted freely on the shaft and operating the right-hand steering-brake in conjunction with Link No.6.

Link No.6: A crank; mounted freely on the shaft and connected by cable to the shoe-operating levers of the right-hand steering-brake.

Link No.7: A tappet-carrying collar; keyed to the shaft and operating the right-hand steering-brake, in conjunction with Link No.6.

A brief indication of the operation of the steering-brake-control cross-shaft and the cranks and collars which it carries has been given below.

The cross-shaft is turned throughout the whole of the movement of the steering wheel by virtue of the connection of the latter by continuous mechanical links to the crank described above as Link No.1. The links referred to as tappet-carrying collars, are collars incorporating a projection in which is mounted a hexagon-headed set-screw in such a position that its centreline is at right angles to that of the shaft but does not intersect it. At a given deflection of the steering linkage or hand-brake lever, adjustable by varying the position of the set-screw, the tip of the latter impinges upon a flat face incorporated in the boss of each of the cranks carrying the brake cables, (Links No's 3 and 6 above), and further deflection in the same direction results in simultaneous movement of the collar and adjacent crank in that direction. The position of the set-screw in its threaded mounting is locked by means of a nut. The flat faces incorporated in the bosses of cranks No's 3 and 6 are each wide enough to accommodate the tappets borne in the collars on either side.

To enable the right-hand brake to be brought into action upon rotation of the shaft in one direction from the datum position, and the left-hand one, upon rotation in the

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Steering-brake-control cross-shaft, cranks and collars (continued).

opposite direction, the right-hand crank normally projects upwards from the shaft and the left-hand one, downwards. Left-hand and right-hand hand-brake cranks are arranged in the reverse manner.

Anchorage to the cross-shaft of those collars and cranks, stated above to be keyed to the shaft, is effected by clamp bolts, fitted in semi-split bosses; radiused grooves are milled in the shaft and the clamp bolts engage with these to prevent relative rotation between the boss and the shaft. The rotating bosses are brass-bushed and each carry an independent grease nipple. The cross-shaft itself is hollow with solid welded ends; it is supported at its ends in brass bushes borne in two large trunnions.

Steering-brake-cross-shaft mounting trunnions.

Included in: Layout diagram: Plate 14
Pictorial illustration: Plate 35
General photographic view: Plate 81

The large triangular trunnions supporting the steering brake control cross-shaft are of fabricated, sheet-metal construction, punched with large holes for lightness and welded to frame cross-members No's 5 and 6. These trunnions each carry a brass bush which serves as a bearing for the cross-shaft and the shaft and bushes are assembled into the trunnion from the right-hand end. The whole assembly is thus held in position by an end cover-plate attached to the right-hand trunnion by a single set-screw.

Steering-brake-control main push-and-pull rod.

Included in: Layout diagrams: Plates 13 and 14
Pictorial illustration: Plate 42
General photographic view: Plate 82

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Steering-brake-control main push-and-pull rod (continued).

The main push-and-pull rod serves to link the right-hand drop-arm of the lower steering-box shaft to an intermediate crank carried on the left-hand cross-shaft-support trunnion, which is, in turn, linked to the crank rigidly secured to the extreme left-hand end of the cross-shaft. The main length of the push-and-pull rod is hollow and incorporates a double set to permit of its accommodation between the various controls and other components in the neighbourhood of the scuttle. It is forked at either end to facilitate its attachment to the cranks which is effected by conventional, freely pivotted joints.

The salient feature of the link, however, is the spring-and-cylinder device which permits of a certain measure of lost motion. This assembly is well shown in the sectional and exploded views of Plates 13 and 42 respectively, and no further explanation is required. It will be appreciated that this lost motion device is effective, to an equal extent, in both tension and compression, since the force transmitted will be absorbed by the same coil spring in each case. The assembly from the vehicle in our possession was load/deflection tested and the results will be found on page 158.

Steering-brake-control, intermediate crank and linkage.

Included in: Layout diagram: Plate 13
Pictorial illustration: Plate 42
General photographic views: Plates 81 and 82

Completing the linkage, between the right-hand drop-arm of the lower steering box assembly and the steering-brake-control cross-shaft, is the bell-crank and double-forked rod shown at the right-hand side of the diagram on Plate 13. Through this linkage, the design of which will be apparent from the illustration, the main push-and-pull rod operates the extreme left-hand crank, Link No.1, of the steering-brake-control cross-shaft. Plain, pin joints are employed for the forked link and are locked by split pins. There are brass-bushed bearings for the short shaft upon which the bell-

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Steering-brake-control, intermediate crank and linkage (continued).

crank is carried. These are mounted on either side of the bell-crank, one in the left-hand trunnion and one in an additional bracket also welded to No.6 cross-member. The bearings and shaft are assembled from the right-hand side into the brackets which carry them, in a similar manner to that required for the steering-brake-control cross-shaft. A similar end-retaining plate, secured to the right-hand bracket by a single tap bolt, is also employed.

Braking system.

Included in: Layout diagrams: Plates 5, 12, 15 and 16

Pictorial illustrations: Plates 27, 29, 44, 45 and 46

The main brakes of the vehicle are located inside the driving sprocket wheels and are operated from the foot pedal through a compressed-air system. The vehicle is also provided with a hand-brake control; this is mechanically linked to the steering brakes, the design and operation of which have been described earlier in this section, see page 114 et seq. Provision is made on both foot and hand systems for co-ordinated application of the brakes of a trailer suitably equipped.

Main-brake assemblies.

Included in: Layout diagram: Plate 5

Pictorial illustration: Plate 29

General photographic views: Plates 80 and 85

Metallurgical Report (linings only): Pages 240 249 and 395 396

The component parts of each main-brake assembly are well shown in Plate 29, and the drum, which is part of the driving-sprocket casting, in Plate 27. The general design of the brake units is similar to that of the steering brakes described on pages 114 to 116; the diameter is slightly larger, however, and the shoe-operating-link mechanism is slightly different.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Main-brake assemblies (continued).

The flange plate is of fairly heavy-gauge sheet-metal and is bolted to the final-drive gear-case cover by eight tap bolts. The shoes are each formed from two sheet-metal sections welded together, at the ends only, in the manner employed in the construction of the steering-brake shoes. The linings are also of similar form, attached to the shoes by steel rivets arranged in pairs across the lining width; the linings are generously chamfered at both leading and trailing edges. A longer lining segment is employed for the trailing shoe than for the leading.

The primary lever of the shoe-operating mechanism, (46) in Plate 29, is pivotted upon its brass-bushed bearing on the special bolt secured to the back plate, which also acts as the stop against which the lower ends of the brake shoes (upper in Plate 29) are supported when the brake is not applied. At the lower ends, the leading shoe carries a fork, attached by three rivets, upon which is mounted a roller, whilst the trailing shoe carries a freely pivotted lever, incorporating a stop, which bears upon the roller of the leading shoe. Actuation of this lever, which is effected by a fixed pin, projecting from the primary, shoe-operating lever, results in separation of the upper ends of the brake shoes. The shoes are normally closed by three, coil, tension springs, which can be seen in Plate 29; two springs are fitted in parallel across the upper ends of the shoes.

An interesting auxiliary to the shoe-operating mechanism is the hinged lever shown at (52) in Plate 29, with which an additional pin on the primary lever engages and thereby applies supplementary pressure to the trailing shoe near its mid point. The hinged lever is pivotted from the back-plate and the hinge, which is spring-loaded, accommodates any movement of the primary lever which would otherwise result in excessive application of pressure through this auxiliary mechanism. The auxiliary lever bears upon a hardened-steel plate, welded to the inside of the brake shoe. The mechanism described

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Main-brake assemblies (continued).

above can be seen in Plate 85 which shows the main-brake back plate assembly with brake shoes and secondary operating lever removed.

Brake pedal and linkage to operating valves.

Included in: Layout diagram: Plate 12

Pictorial illustration: Plate 44

There is a conventional brake pedal and the linkage of rods and cranks to the operating valves for both the main and trailer brake systems is shown in Plate 12. The brake pedal pivots upon the same pin as is used for the clutch pedal, this pin being mounted in a bracket welded to and projecting rearwards from frame cross-member No.4. The intermediate-crank pivot pin is held in a bracket secured to cross-member No.5. Both these pivot pins carry a grease nipple in one end. The double-forked rods, linking the lower end of the brake pedal with the intermediate crank, and the intermediate crank with the main-brake-valve-operating lever, although indicated by different numbers, i.e. (38) and (42), in Plate 44, are the same length and appear to be interchangeable.

Design and adjustment of the linkage are such that the trailer-brake system is put in operation before the main-brake system.

The compressed-air system.

Included in: Layout diagram: Plate 16

Pictorial illustration: Plate 46

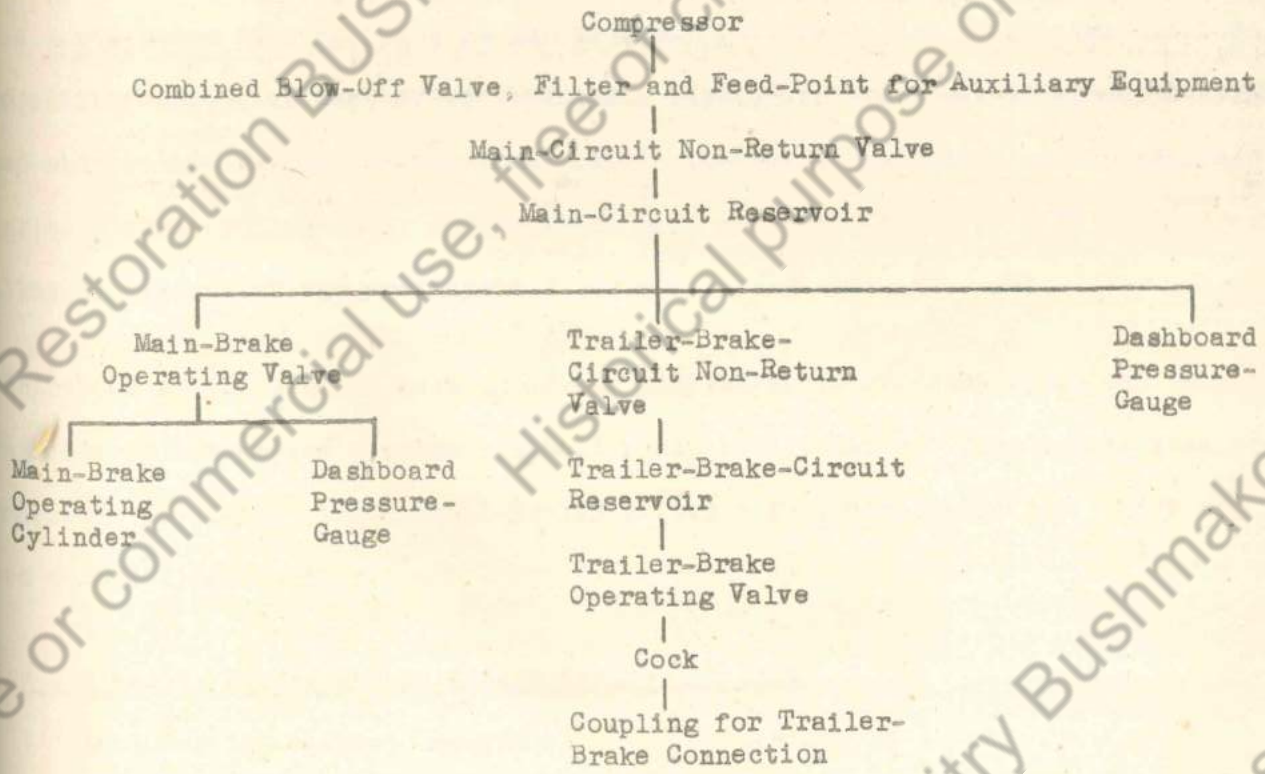
The main brakes are applied by the action of air pressure upon the piston of the operating cylinder; the piston is connected by mechanical linkage to the brake cables. The cylinder is normally under atmospheric pressure, but a release valve is opened, upon depression of the foot pedal, and the operating cylinder is thereby included in the compressed-air circuit. When the braking system of the vehicle is connected to

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

The compressed-air system (continued).

that of a trailer, suitably equipped, the trailer brakes will normally be included in the circuit and the shoes will be held clear of the drums by the air pressure. The trailer brakes are thus applied by releasing the pressure, and the valve, by means of which this is effected, is linked to both hand and foot controls. Air is supplied to the system under pressure by a compressor, driven by the engine, and the requisite pressure is maintained in the system at all times when the engine is running, by the combined action of the compressor and of a spring-loaded blow-off valve. Two reservoirs are included in the system to increase the capacity.

The circuit is shown diagrammatically and pictorially on Plates 16 and 46, respectively, and the sequence of the various units in the circuit has been tabulated below in order to clarify the nomenclature employed in this report.



DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

The compressed-air system (continued).

A feature of interest which is common to most of the above units, in which it can be applied, is the use of light alloy castings for the housings. Such castings are employed for the combined blow-off valve, filter and auxiliary feed-point, the main-circuit non-return valve, the main-brake operating valve, the trailer-brake-circuit non-return valve and the trailer-brake operating valve, in conjunction with steel unions, brass valve-seats, sockets, cocks, bushes etc., and cast-iron caps.

Air compressor.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46
General photographic views: Plates 86 and 87

A single-cylinder, reciprocating compressor is employed and is well shown in the photographs, Plates 86 and 87. It will be seen that the crankcase of the compressor is a three-piece casting, open at the bottom; this is bolted to a large, hollow projection, formed as part of the crankcase casting of the power unit, on the right-hand side of the engine, at the front end. The small crankshaft of the compressor carries a large pulley wheel at the front end, which is driven by a "V"-belt from a pulley on the end of the crankshaft.

Lubrication of the big-end bearing of the compressor is effected by splash from the crankcase of the engine through the hollow support. The air feed to the head of the compressor is fitted with a metal-packed filter with a detachable top, which can be seen in the illustrations.

Blow-off valve, filter and auxiliary feed point unit.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46
General photographic view: Plate 90

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Blow-off valve, filter and auxiliary feed point unit (continued).

This unit fulfils the combined functions of regulating the pressure of the air supplied to the system from the compressor, of filtering this supply, and of acting as a feed-point from which compressed air may be drawn for any auxiliary requirements such as tyre inflation etc.

The assembly is situated beneath the bonnet, beside the engine, and is bolted to a bracket from the right-hand side-member. The design of the unit will be apparent from Plate 90. The entry from the compressor communicates directly with the outer chamber of the barrel containing the steel-swarf filtering medium. A steel tube, drilled with holes at its lower end, passes through the centre of the filter chamber, and through this, filtered air is led to the cock, by means of which the auxiliary feed-point can be included in, or excluded from, the circuit. The cock is intended to control only the auxiliary feed-point, and permits of direct communication of the braking system with the filtered air supply in either of the two positions. The end of the cock is drilled so that the blow-off valve, situated in the top of the unit, is also always included in the circuit. The pressure maintained in the circuit when the engine is running and no brake application is being made, will be that at which this valve is designed to blow-off. The valve on the vehicle examined bore the stamped impression, "11 Kgm per Sq.Cm." (11 Kgm/Sq.Cm. is approximately equivalent to 157 lb/sq.in.).

Removal of the finger-grip cap in the centre of the main lower end-cap of the filter chamber, reveals a small-bore outlet, presumably intended for draining water from the system.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Main-circuit non-return valve.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46
General photographic view: Plate 91

The main-circuit non-return valve unit is bolted to the right-hand side-member, mid-way between cross-members No's 5 and 6; it is designed to prevent loss of pressure under normal circumstances from the braking side of the system to the compressor side, should the latter become less than the former, but also to relieve the pressure on both sides should it for any reason become excessive.

Referring to Plate 91, the entry from the compressor side, via the filter unit described above, is into Chamber 1, which communicates directly with Chamber 2. Chamber 2 is separated from Chamber 3, and Chamber 4 from Chamber 1, by spring-loaded, disc valves, which are arranged to open under fluid pressure to permit air to pass from Chamber 2 to Chamber 3, and from Chamber 4 to Chamber 1, but not in the reverse direction in either case. Very light springs are employed for the closure of these valves. The exit communicates with Chamber 3, and in the normal course of events, the passage of air is thus from Chamber 1 to Chamber 2, through the one-way valve from Chamber 2 to Chamber 3, and out through the exit to the pipe-line leading to the reservoir.

The two holes, visible in the outer face of the diaphragm-valve housing, are passages leading to Chamber 3, whilst the centre hole of this valve communicates with Chamber 4. Chamber 4 contains a spring-loaded plunger, incorporating a projection by means of which the valve separating this chamber from No.1 is opened upon depression of the plunger. In Chamber 4, beneath the plunger, is an outlet to the exhaust. Thus air in Chamber 3 above a pre-determined pressure will find its way through the diaphragm valve into Chamber 4, whereupon it will depress the plunger, which, in turn, will open the valve communicating with Chamber 1, and air from the compressor will pass out to the exhaust.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Main-circuit non-return valve (continued).

There is a brass orifice of very fine bore, connecting Chamber 4 with the exhaust, which ultimately relieves the pressure on that side of the system.

The exhaust is situated on the side of the unit remote from the face shown normally in the photograph; it consists of a cylindrical housing, in which steel swarf is packed between fine-mesh gauzes. The design of the diaphragm, relief valve can be seen in Plate 91. The diaphragm is of very thin-gauge, brass sheet; it seats peripherally upon a grease-proof paper washer and is covered by a thin, fibre washer of the same diameter. Above the fibre washer is the cast-iron disc which carries the load of the spring.

Main-circuit reservoir.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46
General photographic view: Plate 57

The main-circuit reservoir is a sheet-metal tank made up in three parts with welded seams, as shown at (14) in Plate 46. It is carried solidly upon cross-members No's 7 and 8 of the frame by right-angle brackets, welded to the ends of the tank. Inlet and outlet are at opposite ends of the tank and the unions are held in position by nuts; a drain plug is included at the bottom of the tank.

Main-brake operating-valve assembly.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46
General photographic view: Plate 92

This unit incorporates two valves, an inlet and an exhaust; the former is opened upon depression of the foot-brake pedal and thereby exposes the piston of the main-brake operating cylinder to the pressure of the system; the exhaust valve opens when the pedal returns to its normal position and releases the pressure by which the brakes

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED):

Main-brake operating-valve assembly (continued).

were applied.

An exploded view of the unit appears on Plate 92, from which the functions of the various parts will be appreciated. The lever, shown in the top, left-hand corner of the plate, is pivotted at its centre boss to the forked rod by the pin shown; the upper end of the lever is connected ultimately to the foot-brake pedal by a system of links, attached by a pin, passing through the uppermost hole, whilst the lower end makes contact with a steel ball, mounted on the plunger which is carried in the main cylinder of the unit. It will be seen that a definite and pre-determined depression of the plunger in the cylinder results in closure of the exhaust valve, followed immediately, but not until exhaust valve closure is complete, by opening of the inlet valve. It will also be observed, that the two coil springs, one bearing upon the plunger, and one bearing upon the inlet-valve disc and resisting depression of the plunger, are balanced against the two larger, coil springs, housed in the upper cylinder of the unit. Cursory examination of the dimensions of the assembly revealed that the spring, bearing upon the inner face of the plunger, must be almost fully compressed before exhaust-valve closure takes place, but in spite of this, it is difficult to imagine that there can be very much deflection of the upper springs before the inlet valve is fully opened.

The disc valves, employed for inlet and exhaust, are rubber faced, and the sealing element of the plunger is of leather.

Main-brake operating-cylinder assembly.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46
General photographic view: Plate 93

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Main-brake operating-cylinder assembly (continued).

An exploded view is shown on Plate 93 of the operating-cylinder-and-piston assembly, by means of which the pressure in the compressed-air system is converted to force in the mechanical, brake-operating linkage.

The assembly, which is mounted upon No.6 cross-member, consists only of a cylinder, piston and cylinder-head, together with a large, coil spring, which separates the piston from the head, and thus resists any depression of the former. The cylinder is of fairly light-gauge material (approximately 3/32" thick), and the head is attached by means of six studs and a circular ring, drilled to accommodate the studs. Communication with the air-pressure system is by a union, welded to the end of the cylinder opposite to the head. The piston is a fabricated, sheet-metal assembly, faced circumferentially with leather to effect a seal against the cylinder walls.

Trailer-brake-circuit non-return-valve unit.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46
General photographic view: Plate 94

This unit is bolted to the lower flange of the right-hand side-member, just rear of No.10 frame cross-member, and prevents return of air from the trailer brake side of the system. There are two valves, one of the diaphragm and the other of the ball type; both are arranged to open under pressure of air from the entry side, and provide alternative passages through the unit.

An exploded view will be found upon Plate 94, from which the operation will be self-explanatory. The lower passage of the unit was cut in two and the section is shown at the bottom of the above plate. The diaphragm valve is of similar design and size, to that incorporated in the main-circuit non-return-valve unit, a thin, brass diaphragm, covered by a fibre washer of the same diameter being employed. A very light spring is used for closure of the ball valve which presumably takes the greater flow of the two.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Trailer-brake-circuit reservoir.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46
General photographic views: Plates 57 and 58

The reservoir in the trailer brake system is of larger capacity than that included in the main circuit and serving both branches of the system, but is of precisely similar design and construction. The circumferential, welded joints between the pressed ends and the cylindrical centre portion are visible in the illustrations. Unions are secured to the ends by nuts and there is a drain plug at the bottom.

The reservoir is carried in a cradle formed by two sheet-metal strips, spanning the gap between frame cross-members No's 11 and 12, and is secured in position by two straps of lighter section, anchored to the same cross-members.

Trailer-brake circuit operating valve unit.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46
General photographic views: Plates 88, 89 and 95

The trailer-brake shoes are held clear of the drums by the air pressure in the system, and consequently the function of the trailer-brake-operating valve is the progressive release of this pressure, upon application of either the hand or foot brakes of the vehicle.

The mode of operation of the valves will be apparent from a study of the exploded pictorial view on Plate 95. The fork, shown in the top, left-hand corner of this plate, is mechanically linked to both the foot-brake pedal and the hand-brake lever, in such a manner, that air is released through this unit, and the trailer brakes thereby applied, before the brakes on the tractor come into effect.

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Trailer-brake circuit operating valve unit (continued).

Both disc valves are rubber faced, but a leather sealing element is employed upon the plunger. The inner, coil spring, carried on the bolt connected to the striking fork, is balanced against the outer spring, surrounding the plunger assembly, to give progressive opening of the valve.

Trailer-brake cock.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46

A cock is inserted in the line, between the operating valve and the trailer coupling, to prevent loss of pressure when no trailer is drawn. A simple two-position cock is employed which may be set either to the open or the closed position by the permanently attached lever. The centre-piece and bush are brass and the housing is a ferrous casting.

Trailer-brake connection.

Included in: Layout diagram: Plate 16
Pictorial illustration: Plate 46

The adaptor, by means of which the compressed-air braking system of the tractor is coupled to that of the trailer, can be seen in the two reproductions, referred to above, taken from German manuals, but there was no such fitting upon the vehicle which came into our possession and consequently no further details are known.

Dashboard pressure-gauges.

Included in: Pictorial illustration: Plate 52

A dual-needle instrument is fitted to the dashboard to record the pressures in the system at the reservoir in the main-circuit and at the main-brake-operating cylinder. Reference to the instrument will be found in SECTION 8 - ELECTRICAL SYSTEM AND INSTRUMENTS. Pipe-lines are taken to the dashboard from the four-way union rear of

Dashboard pressure-gauges (continued).

the main circuit reservoir, and from the outlet of the main-brake-operating valve respectively.

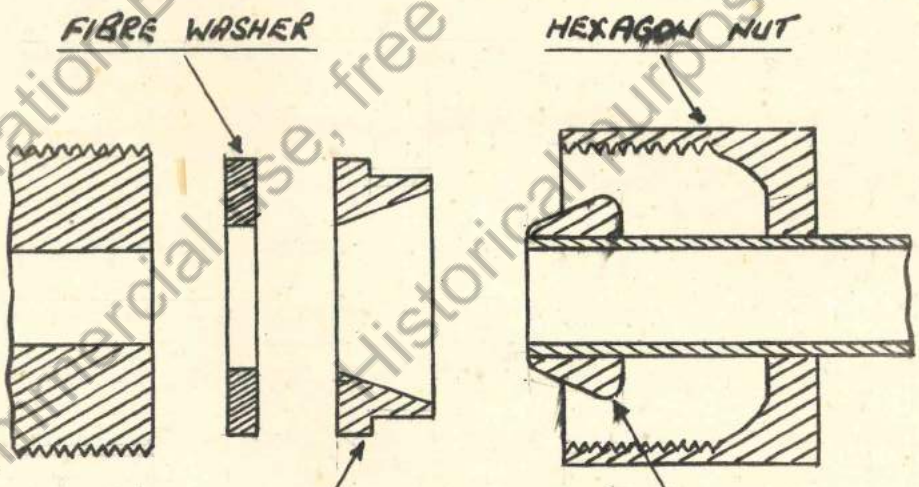
Pipe-lines and unions of the compressed air system.

Included in: Layout diagram: Plate 16

Pictorial illustration: Plate 46

With the exception of the leads to the dashboard pressure-gauges, steel pipes of about 7/16" diameter internal bore are used throughout the system; the pressure-gauge leads have a considerably smaller bore.

The unions employed at junctions, and for connection of the pipe-lines to the various units, are all of the same design, which is illustrated in the diagram below.



DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Main-brake operating linkage.

Included in: Layout diagram: Plate 12
Pictorial illustration: Plate 44
General photographic view: Plate 67

The main-brake operating cylinder is arranged to apply both brakes concurrently through the main-brake operating cross-shaft. The system of cranks and connecting rods employed will be seen in the diagram on Plate 12. The cross-shaft lies parallel with cross-members 6 and 7 and is situated between them; it is borne in end-bearing castings bolted to the side-members. The three cranks are rigidly secured to the shaft by clamp bolts fitted in their semi-split bosses and engaging with small, radiused grooves, milled in the shaft. Straight rods link the two outer cranks on the cross-shaft with the brake-operating cables and the ends of the cable casings are secured each by two bolts to brackets, welded to the top flanges of the frame side-member.

Hand-brake lever and linkage.

Included in: Layout diagrams: Plates 14 and 15
Pictorial illustration: Plate 45
General photographic views: Plates 67 and 88

The hand-brake lever is well shown in Plate 15; it is mounted on a single, pivot pin on the bridge, which also carries the two gear-shift levers. A spring-loaded pawl is carried at the lower end of the hand-brake lever and engages with a toothed-quadrant, bolted to the vertical member of the bridge. The pawl may be released by a conventional, bent lever, attached to the hand-grip (see diagram).

Flexible cables connect the cranks of the steering-brake cross-shaft, designated, Links No's 4 and 5, (see pages 117/8), to opposite ends of a horizontal balance-bar, whilst the lower end of the hand-brake lever is connected directly to the mid-point

Hand-brake lever and linkage (continued).

of this bar by a short rod, forked at both ends. Operation of the hand-brake lever thus results in application of both steering brakes concurrently and with equal forces. Link No.4 of the steering brake cross-shaft is a bell-crank, one arm of which is connected by a cable through a coil, tension spring to the trailer-brake operating valve unit; the design of the connection is such that application of the trailer brakes precedes that of the brakes of the tractor.

The above linkage is clearly shown in the diagrams on Plates 14 and 15.

Dimensional Data.

(Scaled from vehicle except where marked with x)

Steering Wheel:	Outside diameter:	17.6"
Upper Steering Box:		
	No. of teeth of bevel gears -	
	steering-wheel-shaft gear:	14
	steering-column gear:	18
Steering Column and Lower Steering Box:		
	Outside diameter of column:	1.2"
	Outside diameter of worm teeth:	1.8"
	Internal diameter of worm teeth:	1.3"
	Pitch of worm:	0.38"
	Effective lengths of cranks at mid-stroke:	2.5"
	Effective length of drop-arms -	
	L.H. (operating steering of front wheels):	8.8"
	R.H. (operating track steering):	4.7"

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Dimensional Data (continued).

Effective radius at which steering third arm acts:		7.5"
Overall leverage ratio - steering drop-arm shaft to steering-brake-control cross-shaft:		1.65:1
Effective length of cranks upon steering brake control cross-shaft by means of which the brakes are operated:		2.7"
Steering Brakes:		
	Internal drum diameter:	9.1"
	Leverage ratio of shoe-operating mechanism -	
	leading shoe:	5.3:1
	trailing shoe:	6.0:1
	Distance from centreline of brake assembly to lines of action of effective "cam-tip" forces -	
	leading shoe:	4.4"
	trailing shoe:	2.7"
	Circumferential length of liners -	
	trailing:	9.9"
	leading:	7.5"
	Width of liners:	1.9"
Main Brakes:	Internal drum diameter:	17.3"
	Leverage ratio of shoe-operating mechanism -	
	leading shoe:	4.4:1
	trailing shoe:	2.6:1
	Distance from centreline of brake assy. to lines of action of effective "cam-tip" forces -	
	leading shoe:	5.5"
	trailing shoe:	7.9"

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Dimensional Data (continued).

Circumferential length of liners -	
leading:	14.2"
trailing:	18.1"
Width of liners:	3.1"
Length of cranks on main-brake control cross-shaft -	
Crank linked to operating cylinder:	5.92"
Cranks linked to brakes:	3.42"
Hand-brake leverage ratio (centre of grip to cable attachment):	5.25:1
Length of hand-brake connection cranks on cross-shaft:	4.9"
Compressed-Air System:	
Brake-operating-piston diameter:	3.9"
External diameter of brake pipes:	0.57"
Internal diameter of brake pipes:	0.46"

Data Resulting from Experiment upon Parts from Vehicle.

Laboratory reports upon materials of construction:

Where examination of materials has been carried out, reference to the appropriate Laboratory reports has been made at the top of the sub-section dealing with the parts concerned.

Investigation of design of coil spring from steering-brake-control main push-and-pull rod:

The spring was removed from its housing and the following design particulars were noted:-

DESIGN ANALYSIS OF CHASSIS - SECTION 7 - STEERING AND BRAKES (CONTINUED).

Data Resulting from Experiment upon Parts from Vehicle (continued).

Free height:	4.53"
Solid height:	2.38"
Solid load:	280 lbs. wt.
Load at 1" deflection:	120 lbs. wt.
Load at 1.5" deflection:	183 lbs. wt.
Estimated rate:	124 lbs/in.
Length, when assembled in push-and-pull rod:	4.25"
Estimated preload when assembled in push-and-pull rod:	35 lbs. wt.
Outside dia. of spring:	1.86"
Inside dia. of spring:	1.44"
Diameter of wire:	0.21"
Total number of coils:	$9\frac{3}{4}$ approx.
Number of working coils:	8

DESIGN ANALYSIS OF CHASSIS - SECTION 8 - ELECTRICAL SYSTEM AND INSTRUMENTS.

General Design.

Electrical system layout.

Included in: Pictorial illustrations: Plates 52 and 53

Ignition is by the Bosch rotating-magnet-type magneto mounted on the R.H. side of the engine and driven from the idler shaft of the timing-gear train. The sparking plugs are enclosed beneath a cover, attached by two thumb screws and the plug leads are encased in a single, metal-covered, flexible cable, linking the magneto to the sparking-plug cover; all these parts can be clearly seen in the photograph taken from a report upon a ZGKW 1t vehicle, Plate 98. Further reference to the magneto will be found in the report upon the power unit by our Engine Section, page 21.

Current for all other requirements, which include starting, lighting, horn, etc., is supplied from a single, 12-volt accumulator, housed in the frame between the gearbox and the petrol tank. The battery is replenished by a dynamo, driven from the engine.

Information, regarding the electrical equipment powered by the battery, is largely restricted to that apparent from Plates 52 and 53. No electrical circuit diagram was included in any of the German manuals from which other illustrations in this report have been reproduced. Moreover the vehicle which came into our possession was a bare chassis, and even as such the electrical equipment was in a depleted state. On this vehicle there were thus no major electrical accessories, apart from the starter, and of the circuit, there remained only two, metal-covered, flexible cables of fairly large diameter, extending from the battery, along the L.H. side-member as far as the scuttle, from which point it appeared that a number of smaller leads had originally been tapped.

Some further details of the main items involved in the electrical system have been set out below under their respective headings.

DESIGN ANALYSIS OF CHASSIS - SECTION 8 - ELECTRICAL SYSTEM AND INSTRUMENTS (CONTINUED).

Battery.

Included in: Layout diagram: Plate 1
Pictorial illustration: Plate 53
General photographic view: Plate 57

The battery is apparently a conventional, six-cell, 12-volt, lead-plate/sulphuric-acid accumulator and is shown at (48) in Plate 53. It is housed in a battery box situated, rear of the gearbox and just in front of the petrol tank. The original battery had been removed from the vehicle which was examined, and that visible in the general photographic view is an English replacement.

Battery box.

Included in: Layout diagram: Plate 1
Pictorial illustration: Plate 53
General photographic view: Plate 88

The battery box is mounted on the frame adjacent to L.H. side-member; it is attached to cross-members 8 and 9 at the inner end, and to the L.H. side-member at the outer end, by brackets welded to the members in both cases.

The design of the battery box will be seen from the illustration at the top of Plate 53, from which it would appear that the battery is completely enclosed. All the parts shown in this plate were not present on the vehicle which came into our possession, however.

Battery cables.

Included in: Pictorial illustration: Plate 53
General photographic view: Plate 88

Flexible, metal-covered cables, adequately clipped to the rigid fixtures which they adjoin, appear to be employed throughout. Two, such cables remained on the vehicle which came into our possession, and extended, from the battery, along the L.H. side-

DESIGN ANALYSIS OF CHASSIS - SECTION 8 - ELECTRICAL SYSTEM AND INSTRUMENTS (CONTINUED).

Battery cables (continued).

member to the scuttle, where a junction to smaller leads had apparently been made by a T-piece.

The earthing cable, which is anchored to No.9 cross-member, is shown at (67) in Plate 53.

Dynamo.

Included in: Layout diagram: Plate 1

Pictorial illustrations: Plates 19 and 97

The dynamo is mounted at the front of the engine on the L.H. side and is driven by a V-belt from the front pulley of the crankshaft. It is stated in one German manual to be a 130-watt unit of the RCK type, driven at 1.2 times engine speed. The unit, from the vehicle which was examined, appeared, externally, to be of conventional design and consequently was not dismantled.

Starter.

Included in: Layout diagram: Plate 1

Pictorial illustrations: Plates 19 and 97.

The electric starter, powered by the battery, is mounted also on the L.H. side of the engine and is visible in Plate 19. It engages with the flywheel, when in use, by means of a pinion. The starter also appeared to be a unit of conventional design from the outside, and was not dismantled.

Lighting and other electrical accessories.

As mentioned earlier in this section, information, regarding the electrical accessories of the ZGKW 3t, model 251, is at present restricted to that which is apparent from a study of Plate 52.

DESIGN ANALYSIS OF CHASSIS - SECTION 8 - ELECTRICAL SYSTEM AND INSTRUMENTS (CONTINUED).

Instruments.

Included in: Pictorial illustration: Plate 52

General photographic view: Plate 67

The instruments are carried on the dash-panel in the usual manner, and include oil-pressure gauge, ammeter, revolution counter, cooling-water-temperature recorder, pressure-gauge for the air-brake system and a tachograph by means of which permanent records of journeys are plotted on a time/distance basis.

Of these instruments, only the air-brake pressure-gauge and ammeter remained on the vehicle which was examined at the Works, and the only illustrative matter, relating to the instruments, which could be found in German manuals, is reproduced as Plate 52. The positions of all the instruments or details of their design are, therefore, not known. Plate 67 shows the dashboard, of the vehicle which was examined at the Works, in the condition as received, with the exception of the British oil-pressure gauge, which had been fitted in the aperture at the extreme L.H. side of the dash. From a study of the instruments fitted and the remaining apertures, it would appear that the order of location of the instruments from left to right is that in which they are listed above.

Plate 52 was reproduced from one of the German manuals, and the instruments, referred to at the beginning of this section, can be traced upon it and are believed to be:-

(1) cooling-water-temperature recorder

(15) revolution counter

(19) ammeter

(20) oil-pressure gauge

(25) air-brake pressure-gauge

DESIGN ANALYSIS OF CHASSIS - SECTION 8 - ELECTRICAL SYSTEM AND INSTRUMENTS (CONTINUED).

Instruments (continued).

No tachometer is shown upon this plate, but it is fairly certain that one is normally fitted, since documentary evidence of German origin, which has been inspected, would appear to indicate that such instruments are employed throughout the Zugkraftwagen series of vehicles, and reference is made to a tachometer in the operating instructions of the 3t model which are included in this report. It is probable that the instrument was bolted to the dashboard at the extreme R.H. end. One of these instruments taken from a 5t vehicle was examined at the Works. It included a kilometer recorder and a needle, indicating road-speed in kilometres-per-hour, together with a red, warning light, which was arranged to illuminate when this speed became excessive; the remaining parts of this instrument were missing, but from certain German manuals which have been studied, it would appear that a time clock and an autographic recorder are included, by means of which trip mileages, journey and waiting times may be recorded.

The air-brake pressure-gauge is a dual-needle instrument and indicates the pressures in the system both at the reservoir of the main circuit and at the main-brake operating cylinder.

The remaining instruments would appear to conform to conventional designs.

Also carried on the dashboard, are the ignition switch, starter button, light switch, trafficator control etc. Such details as are known with regard to these parts are shown in Plates 52 and 67.

Dashboard and scuttle.

Included in:	Layout diagrams:	Plates 1 and 11
	Pictorial illustration:	Plate 49
	General photographic view:	Plate 67

DESIGN ANALYSIS OF CHASSIS - SECTION 8 - ELECTRICAL SYSTEM AND INSTRUMENTS (CONTINUED).

Dashboard and scuttle (continued).

The sheet-metal dashboard and scuttle structure, upon which the instruments, steering wheel and minor controls are mounted is shown in Plate 49. It is a fabricated assembly, of the rather complex design shown, and the sheet-metal components are joined mainly by rivets. The whole assembly is bolted to the upper flanges of the side-members.

Dimensional Data.

Data Resulting from Experiment upon Parts from Vehicle.

) No observations of this kind were made with regard to the Electrical System or Instruments.

SERVICE, REPAIR AND MAINTENANCE.

Plates 55 and 56 have been reproduced from a parts list appertaining to the ZGKW 3t, model 251, and shows some auxiliary equipment which is presumably stowed on the vehicle. Full details of the tools and spares which are intended to be carried are not known, however.

A copy of a German instruction manual (less illustrations) relating to a ZGKW 3t type of vehicle with open, troop-carrier body, was inspected at the Works and a translation of the operating, maintenance and repair instructions contained therein is reproduced below:-

"SERVICE INSTRUCTIONS.

"WORKING OF VEHICLE:

"(a) Preparations for the journey.

"Before commencing a journey the following work has to be carried out:-

1. The fuel provisions in both tanks are to be examined.

2. The water level in the radiator is to be examined.

3. The oil level in the engine has to be examined with a measure.

4. The pressure of the tyres is to be tested.

5. The tension of the tracks must be tested. The track must, on an even road, pass over the first and last running wheels without touching them, and rest on the other wheels.

6. Particularly in cold weather, the air container of the pneumatic brake is to be emptied of water by the drain screw.

"The speed recorder is to be made ready daily before the vehicle is used, in the following manner:-

(a) Open the apparatus (turn key to the left).

(b) Turn the milled holding ring of the spring clamp to the left and take the recording disc out.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"(c) Wind the clock steadily by turning the milled ring to the left.

(d) Adjust the hands of the clock by turning the milled disc in the left upper corner of the clock.

(e) Insert the recording disc. It is inserted in such manner that it lies at the exterior margin below the red tongue. In the margin of the disc a time-piece is found. The disc is to be turned so that the tip of the red tongue points at the respective time of the day. Then the spring clamp is replaced and the ring is turned to the right. When doing so, care has to be taken that the recording disc is not shifted. Minor corrections can be carried out even after fastening the spring clamp.

(f) Adjust the daily kilometre recorder at "0" by turning the adjusting 0 button in the direction indicated by the arrow and close the lid.

"(b) Starting of engine.

"Before the engine is started, the following points have to be observed:-

1. Gear control lever of the main gear to be put into neutral.

2. Fuel tap to be opened; fuel pump to be filled from the auxiliary tank by dropping petrol.

3. Ignition to be switched on.

4. Starting carburettor to be operated without supplying gas by handle or pedal gas lever. Starter button to be pressed. When the engine is cold, the clutch must be disengaged before the electric starter is operated and the starting to be assisted by turning the crank. After the engine has started, the starting carburettor must be switched off immediately (release the starting button). The three way cock is to be switched over to the main tank.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"(c) Service instructions before and during the journey.

1. Before commencing to drive, let the engine first run warm for a few minutes, at a low number of revolutions (about 1000 revolutions per minute), until the cooling water has reached a temperature of 50° centigrades.

2. Watch the temperature of the cooling water. Open the flap-wall of the radiator when the engine is hot, close it when the engine is cold. The most favourable temperature is between 80° and 85° centigrade.

3. Watch the oil-pressure indicator. Whilst the car is working, the pressure should not fall below 1 atmosphere, absolute pressure. When the oil pressure diminishes or when no pressure at all is indicated, danger is imminent and the defect must be eliminated before continuing the journey.

4. If the vehicle is driven daily, the filter packing has to be squeezed once daily by means of the cross-bar fitted to the filter.

After the engine has been at rest for days, this cleansing operation has to be repeated several times.

5. During the journey watch the revolution indicator; the engine must not run at more than 2800 revolutions per minute.

6. The brake pressure must not exceed 5 atmospheres, absolute pressure.

7. The tap for filling of tyres is to be examined frequently as to its correct position. (This applies only to vehicles in which the tyre-filling bottle is arranged in the driver's cab).

8. The reduction gear lever must be let in correctly.

"(d) Stopping of engine and vehicle.

"The engine is stopped by switching off the ignition.

"The fuel taps are to be shut.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"After each journey the bolts, supports and rubber pads of the caterpillar tracks are to be examined and, in so far as may be necessary, to be repaired or replaced.

"If no frost-protective agent is mixed with the cooling water, the latter should be drained when there is a risk of frost.

"INSTRUCTIONS FOR DRIVING:

"(a) Gear Control.

"The open-country gear must not be put in unless the vehicle is at rest. When the road gear is used, the lever must be moved forward, when the open-country gear is used: backward. The transmission gear is to be changed in the usual manner, by disengaging the clutch in accordance with the gear-shift diagram. When changing up, push the clutch out completely. When changing down, push the clutch out twice, half way only, and accelerate intermediately.

"For changing over to the reverse gear, press the lever to the left and backward and then move it straight to the front.

"Drive downhill in the same gear and with the same speed as uphill. The gear which in each case is suitable to the respective slope is to be put in, not during, but before entering any considerable slope (uphill or downhill) as otherwise the load train, going uphill, would immediately stop when the clutch is disengaged, whilst, going downhill, it would accelerate so much that gears could no longer be changed and the brakes alone would hold the train.

"(b) Brakes.

"The hand-brake acts through the brake-rods on the steering-brakes and thus through the steering mechanism on the caterpillar tracks of the vehicle. Any incorrect use of the hand-brake during the journey may cause considerable damage to the steering gear and, moreover, divert the vehicle from its direction.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"THE HAND-BRAKE IS THEREFORE TO BE USED AS A PARKING BRAKE ONLY AND TO BE APPLIED SLOWLY, BUT FIRMLY, AFTER THE VEHICLE HAS STOPPED.

"The driver of a tractor must be so familiar with the effect of the hand-brake that he DOES NOT OPERATE THE HAND-BRAKE WHILST DRIVING, even in the event of sudden emergencies. Only in one special case, i.e. when the tractor, driven with a trailer fitted with a pneumatic brake, is skidding; then the trailer alone may be affected by the hand-brake being carefully applied, as far as mid position, and the skidding of the tractor may thereby be controlled.

"(c) Driving on the road.

"Drive carefully inside towns and villages, over bridges, on a slippery track and on bends.

"In order to have a better control of the vehicle and to avoid abrupt application of the brakes in any circumstances, gas must be cut down in good time and a lower gear put in, before passing any dangerous spot.

"On journeys in convoy, the intervals between vehicles must be as many metres as the driving speed is kilometres-per-hour.

"(d) Driving in open country.

"Driving obliquely on a slope and turning of the steering wheel on a slope should be avoided as much as possible.

"When, at the crests of hill-tops or in similar conditions of the ground, the front wheels have lifted themselves considerably from the ground, then the car must be controlled carefully in order to avoid too rapid a falling forward, which might cause damage to the front axle. Ditches are best crossed in an oblique direction. On bends in the open country the driving should be slow in order to reduce the danger of the tracks coming off the wheels.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"When the vehicle is parked on a slope for any length of time, it should always be secured by putting stones or logs underneath. The best method of commencing the driving on a steep slope is to protect the vehicle, by stones or logs, from rolling downward and then to release the hand-brake.

"During the driving obliquely on steep slopes, the track on the lower side can easily come off the wheels. In such cases it should be attempted to make the track run on the wheels again by turning the steering-wheel in the direction of the uphill slope and by slow driving in reverse.

"When driving in reverse, particularly on loose ground, foreign bodies easily adhere between the chain and the rubber tyre of the driving-wheel; thereby the chain easily climbs on to the wheel. If in this case the teeth of the chain stick on the driving-rollers of the driving-wheel, the driving must not be continued owing to the danger of breaking the chain. Before continuing to drive in reverse, the vehicle must be driven in a forward direction for a short while until the chain is correctly located on the driving wheel.

"Whilst driving in reverse it is therefore necessary for the chain to be watched, if possible, by the second driver.

"(e) Non-skid devices.

"On roads covered with ice or snow, snow chains have to be put on every third or fourth chain-link. The snow-chain is to be fastened with its two shoes to the chain-link in such manner that the chains are lying crosswise over the rubber-pads. In the upper part of the chain, the closed side of the chain-shoe must point in the direction of driving. The chain-shoes are to be secured by splints.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"(f) Driving with trailer.

"Connection of pneumatic brake: the cable for the parking tail-light has to be connected carefully. When a trailer is coupled whose brakes have been applied, the brakes of the trailer are to be released before commencing the journey and the pressure in the air container of the pneumatic brake is to be examined. The pneumatic brakes of the trailer will become released when the pressure reserve is about 2 atmospheres, absolute pressure. When there is a danger of skidding, the hand-brake may be applied slowly and thereby the trailer alone may be stopped.

"INSTRUCTIONS FOR REPAIR WORK.

"GENERAL OBSERVATIONS:

"The following instructions for putting the various structural parts of the carriage into good condition must be observed. For any more extensive repair work expert supervision in a workshop is required.

"The ordering of spare parts has to be done in accordance with D 660/2.

"Spare parts for the engine and the clutch are to be ordered in accordance with the list of spare parts of the firm Maybach, which list is issued with each vehicle.

"ENGINE:

"(a) Removal of engine.

"The removal of the engine and clutch must be carried out in the following order: disconnect the fuel pipes, air pipes, exhaust pipes, water pipes, oil pipes, electric wires and rods; take off the radiator; disconnect the cardan shaft at the clutch flange, and disconnect the suspension of the engine.

"(b) Valves.

"The adjusting of the valve clearance can be carried out after lifting the valve cover. The hand crank of the engine is turned until one valve, e.g. the exhaust valve, is

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"completely lifted. The opposite valve - inlet valve - of the cylinder is then in a closed position and can be adjusted by turning the eccentric, after loosening the eccentric screw. The valves are to be adjusted to a play of 0.25 millimetres. When changing valve springs, the piston of the respective cylinder is to be put in the upper-dead-centre position. After pressing down the spring washers, the key can be taken out with the aid of pliers.

"The Seeger securing device fitted to the valve disc prevents a destruction of valve and piston in the event of the spring breaking.

"For the purpose of grinding the valves, the water in the engine must be drained, the pipe junction to the radiator, the ignition cable connections and the terminal flange at the exhaust collecting pipe are to be disconnected and the head of the cylinder is to be taken off. After loosening the screws of the cylinder head and taking off the valve gear, the entire cylinder head can be taken off by lifting it. When so doing, care has to be taken that the cylinder head gasket is not damaged. Major unevennesses in the valve seatings should be removed, before grinding, with a suitable cutter.

"(c) Cleaning of piston heads.

"In order to remove the carbon deposits in the piston heads, the pistons are to be put into the upper-dead-centre position. The carbon deposits on the valves and on the cylinder head are to be scraped off and removed carefully without damaging the valve seats.

"(d) Fitting cylinder head.

"When putting on the cylinder head, care has to be taken that the cylinder head gasket is in perfect condition. In the case of the slightest defect a new gasket must be inserted. Attention must be paid to the mark "OO" on the camshaft-wheel.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"The screw-nuts of the cylinder head are to be tightened little by little, starting from the centre. After putting on the head, the valve clearance is to be adjusted at 0.25 millimetres. The engine should then be run warm without load, whereupon all the screws of the cylinder head are to be tightened once more.

"Before finally fastening the cylinder head, the valve lift of the front and rear inlet valves are to be measured, as a precaution. The lift must amount to 4.5 millimetres in the lower-dead-centre of the corresponding piston.

"(e) Carburettor.

"For the purpose of cleaning or of changing the jets, the air supply pipe is to be loosened from the air filter and the upper lid with the six square-neck screws taken off. The fuel jets are then accessible from above.

"The jets are to be installed in accordance with the instructions of the Jet Diagram. When new main jets are used, the exchange may only apply to jets of a different size. The type of jet, which is shown by the manufacture number engraved on the jet, must always be the same. The jets must not be reamed or caulked or altered in any other manner.

"Incomplete closing of the starter device causes damage to the engine. Disturbances in the carburettor may arise owing to: clogged jets, clogged filters, leaking float valve and penetration of water. The jets must only be cleaned by blowing through them. Leaking floats are to be replaced.

"(f) Fuel pump.

"If not enough fuel is supplied, some leakage in the circulation mechanism, from the fuel pump to the fuel tank, may be the cause. Tightening of all connections, examination of the packing of the glass bell fitted to the pump and of the packing of the three-way cock are likely to remedy the defect. In the pump, moreover, the

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

" following disturbances might arise:-

1. If fuel escapes from the ventilation hole at the back of the membrane casing, then the membrane is broken and must be replaced.

2. If oil and not fuel escapes from the ventilation hole, then either the lubrication of the ram carried out from the crank case is excessive, or the ram or the ram guide has been worn out by long use. In this case the damaged parts must be replaced.

3. If, after long use, the fuel production diminishes, worn-out valves may also be the cause. In this case the valve casing must be replaced.

"(g) Overhauling.

"During the guarantee period any large repair work is to be carried out by the workshop of the supplier firm. Engines in need of a complete overhaul are to be sent, after expiration of the guarantee period, to the firm Maybach, Friedrichshafen, or to the workshops of their contractors for the purpose of repair.

"For smaller repair work which in view of its urgency may be carried out by the crew, the following limits of play are indicated for assembling:-

1. The piston play is 6/100 to 7/100 millimetres, measured transversely to the piston pin. This is to be examined, on assembling, with a steel strip. The requirement for obtaining this play is a round and cylindrical cylinder liner of maximum ovality 2/100 millimetres.

2. The cylinder liner is to be examined before installing new pistons or, if necessary, to be replaced by a new one. At the same time the two rubber packing rings are to be replaced.

3. The piston rings should have a percussion play of 0.3 millimetres and a groove play of 2/100 to 3/100 millimetres. Before the installation they are to be lubricated with plenty of oil.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"4. The seating of the piston pin in the piston eye has to be such that the piston, at a temperature of 20° centigrade, can still be pressed into the pin bore by hand.

5. The play of the piston pin in the connecting rod bushing shall be such that, even if the piston rod, with piston pin put in, has been heated in hot steam cylinder oil of a temperature of about 190° centigrade for 20 to 30 minutes, the piston pin does not get stuck.

6. On installation of new pistons, care has to be taken that the piston is of conical shape towards its upper part. For the adjustment of the connecting rod, special tools only may be used.

7. The play of the connecting rod bearing should be 6/100 to 7/100 millimetres, in the state of tight tension on the crank pin. This bearing brass must be in tight tension when it is to be adjusted to this play. Any scratching must be avoided as much as possible. The play is to be ascertained by measuring with a micrometer, from the crank pin and the bearing. The bearings of the casings are to be inserted with the aid of special reamers, with a play of 7/100 millimetres.

8. After the installation of new pistons, the engine is slowly, over a length of five hours, to be accelerated from ticking over to 1800 revolutions per minute. During the driving, care has to be taken that overhauled engines are driven gently and should not carry a weight until they have run warm. When running in new pistons, lubrication is to be applied from above.

"CLUTCH:

"The clutch is adjusted in such manner that the measurement "A"* is about 41 millimetres. The lost motion of the clutch pedal must not be less than 2 centimetres. Care has to be taken that the pedal is adjusted in time. The clutch itself cannot be adjusted. Wear of the lining may be permitted to continue until "A" is about 53 millimetres.

* This refers to a photograph not included in this report.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"On installation of the clutch care has to be taken that the clutch hubs should be easily movable on the sliding shaft. For carrying out the installation, an auxiliary shaft is required having at least one part which fits into the groove profile of the hub. The shaft must be arranged in such manner that the driving plates can be shifted over the shaft from the back. Then, the parts are to be installed into the flywheel in this order: first driving plate, intermediate ring, second driving plate.

"TRANSMISSION GEAR:

"Defects of the transmission gear and steering gear are to be removed by skilled workmen. For removal of the transmission gear, the rear part of the carriage body has to be removed.

"RUNNING GEAR:

"The right and left casings of the lateral drives are to be examined frequently as to whether they fit tightly. Through loosening of the screws a crack can arise between the lateral drive casing and the fastening flange.

"In order to avoid damage, the screws on the fastening flange are, therefore, frequently to be examined as to whether they fit tight; if necessary, they must be tightened and secured. For the purpose of tightening the driving wheel, the brake and the hub have to be removed.

"Guide wheels and running wheels whose rubber tyres have become defective are to be replaced by wheels with new tyres.

"(a) Removal of running wheels and guide wheels.

"After screwing off the wheel-cap locked by a spring ring, the wheel nut which is fitted with a securing disc is to be removed. Thereupon each running wheel with its bearings can be taken off from the axle. On installation care has to be taken that the packing rings are not damaged.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"(b) Removal and installation of a driving wheel.

"After removal of the split pins and after loosening of the hexagon nuts, the driving wheel can be drawn off from the driving axle with a special tool. On installation of the driving wheel extreme care has to be observed. The driving wheel must not be knocked on to the driving axle.

"(c) Alignment of the running gear.

"The alignment of the running gear can be carried out with improvised tools as follows:-

"The driving wheels and idler wheels are to be straightened with a straight-edge or the like, in such manner that an oblong with correct right angles is formed. Into the guide ring of each of the driving and idler wheels an iron block has to be fitted. The centrelines of the blocks must be marked accurately and their outer edges must be provided with slots. Into the slots a thin wire, knotted at both ends, is inserted, whereupon the driving and guide wheels are turned in opposite directions until the wire is tightly stretched. Then the internal or external running wheels are straightened with the aid of the straight wire. Lateral deviations are to be straightened out by inserting additional shims on the wheel-carrier arms.

"SHOCK ABSORBERS:

"If the lever of the shock absorber has to be removed from the axle, care must be taken, on re-assembling, that the notch on the frontal surface of the shock absorber axle fits into the centreline of the lever. Any deviation will result in destruction of the shock absorber.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"CATERPILLAR TRACK:

"(a) Tension of tracks.

"Under excessive tension of the tracks, caused by climbing of the track or adhesion of foreign bodies, the shearing bolt of the track adjustment device will break. In order to install a new one the tensioning screw nut and lock nut must be loosened. After installing the new shearing bolt, the chain is tightened again. On an even road the track should not touch the front and the rear running wheels; on the other running wheels it should rest loosely.

"(b) Putting on caterpillar tracks.

"The caterpillar track is to be laid out on the ground in such manner that the rubber pads, when driving forward, are resting on the track links at the front, in the direction of driving. The last track link but one is to be supported by a log. The tractor is driven in reverse on the laid-out caterpillar track. The end of the track is laid over the driving wheel, and, while driving on in reverse, pulled with a hemp rope to the idler wheel. Over the slackened idler wheel both ends of the track may be connected by turning the driving wheel.

"For the purpose of putting a chain on, the tractor may be driven slowly with only one track.

"TRACK LINKS:

"(a) Changing a track link.

"The exchange of defective track links is to be carried out in the following order:-

1. Slacken the track.

2. Knock off the split pins from both track-pins.

3. Knock out both track-pins with the long striking pin provided. Insert the sharp end of the striking pin in the track-pin for guiding the latter.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"4. Pull the track links apart in such manner that the tension acts in the direction of the prongs of the locking plates.

5. The new track link is to be installed in such manner that both prongs of the locking plates fit into the bores provided therefor, in the adjoining link.

6. Drive the track-pins in with the striking pin.

7. Put the track on and tighten it, in accordance with section (b) - page 158.

"(b) Removal of the internal parts of the track link.

1. Remove the packing discs.

2. Take off the internal bushings of the roller bearing as well as the packings, with the removal device. The removal device is to be inserted so far that it catches behind the internal bushing.

3. Take off the defective packings from the internal bushings of the bearing.

4. Remove the rollers from the external rings of the bearing of the track links.

5. Do not remove the external rings of the bearing, or the intermediate bushing unless they are defective.

6. Clean all the parts which may still be used.

"(c) Installation of internal parts of chain link.

1. Clean the chain-link.

2. Insert the rollers in the external bushing of the bearing with grease.

3. Drive in the external ring of the bearing and the rollers by means of the triblet provided for the external ring of the bearing.

4. The internal bushing is to be inserted in order to protect the rollers from falling out.

5. Insert the intermediate bushing.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"6. Drive in the other external bushing of the bearing with the triblet belonging to it.

7. The track link is to be put on the triblet provided for the external ring of the bearing, one internal bushing being used as a hold-up. The cone for driving in is to be on the other internal bushing. Both internal bushings are to be driven, with light blows of the hammer, into the intermediate bushing in the track link bearing.

8. Put on the cone for the internal bushing and the guide ring. The slide surfaces of the slide packing are to be greased and to be driven in with the bell belonging thereto.

"RUBBER PADS:

"Defective or lost rubber pads must be replaced by new ones. The installation of rubber pads is to be carried out as follows:-

"After cleaning the trough of the track link, the track pad is inserted. The screws of one side of the pad are pulled tight. Thereby the track pad is caused to fit correctly. The screws of the opposite side can then be screwed in and tightened. The height of individual rubber pads which are newly inserted, is to be adjusted by cutting the rubber pads already worn off.

"STEERING GEAR:

"On exchanging the steering gear, the steering lever must not be knocked off by force from the steering gear. The lever is to be removed from the steering rod with a removal device.

"On its installation, the steering gear is to be aligned accurately, i.e. after the steering gear case has been fastened to the frame, the support for the steering column is to be fastened without jamming. Before putting up the steering lever, the swivels of the lever rod are to be placed at right angles to the worm. In order to be able to

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"perform this adjustment, it is necessary for the lid of the steering case to be removed from the case.

"The steering lever is then put on the lever rod, shifted by one tooth from the vertical to the front (in the direction of driving). If the steering lever is correctly fastened to the steering gear, the steering stop for the final position will not take place in the steering gear itself, but at the front axle knuckle or steering knuckle. The steering lever must be put on loosely and be screwed on with the screw nut on the steering rod. Satisfy yourself by turning the hand-wheel in both directions that the steering gear moves easily. The steering gear is, after removing the oil filler screw, to be filled completely with gear lubricating oil. In order to make it possible for the air to escape, a tube piece has to be used for filling.

"BRAKE DEVICE AND STEERING BRAKES:

"The steering brakes are so to be coupled with the steering gear that they begin to take effect at about $\frac{3}{4}$ of a turn of the steering-wheel to the right or left. The adjusting can be carried out from the driver's cab.

"The wear of the steering brake is negligible. A change of the linings is, therefore, required very seldom. For the purpose of changing the linings, the floor plate, the bridge of the frame and the joint between differential and lateral drive gear are to be removed.

"Newly lined brakes are to be adjusted and to be ground by driving. After complete cooling, the braking and driving test are to be repeated. If the brake effect lessens without visible cause and if the pneumatic device and the rods are in good order, the cause is to be looked for in the brake linings being clogged with oil.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"SPEED RECORDER:

"In the case of major disturbances the speed recorder is to be exchanged. When a shaft is installed, it is to be tested as to whether it moves easily. For this purpose a screw-driver is to be inserted in the slot of the connecting piece, whereby the movement can be observed. If the shaft moves with difficulty, investigation must be made as to where the jamming occurs (fastening of the clips, too sharp a curve, sagging etc.) It is only after removal of such defects that the shaft may be connected. When the signal lamp fails, the lid found on the head of the casing is to be screwed off. The bulb is then accessible and can be exchanged, if necessary.

"ELECTRIC ARRANGEMENTS:

"When looking for the source of a defect, the circuit diagram must be followed. Accumulator, magneto, lighting-dynamo and signal-dynamo are to be attended to in accordance with the special descriptions. Moreover, the following is pointed out:-

"Before carrying out any work on the starting device, lighting dynamo, magneto, regulating switch etc., the frame wire of the accumulator has invariably to be loosened. In view of danger of short circuit, no tools must be placed on the accumulator. Fuses which have blown are to be replaced by new ones. Any defects in the wires must first be removed.

INSTRUCTIONS FOR MAINTENANCE.

"GENERAL OBSERVATIONS:

"Careful maintenance and frequent testing as to condition and fitness for the road, together with correct driving, will ensure that the tractor is always ready for use.

"Only the lubricants prescribed by the Supreme Command of the Army may be used for lubrication. The lubrication scheme issued with each vehicle is strictly to be complied with. As a supplement to the handbook for drivers (H Dv 471) short instructions

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"for lubrication and maintenance are given hereunder:-

"ENGINE:

"On examination of the oil gauge in the engine, the vehicle must stand in a horizontal position. Exchange of oil is only to be carried out when the engine has run hot and at the following mileages:-

Mileage in kilometres	500 km.
" " "	1200 km.
" " "	2500 km.
after after every further	2500 km.

"The stuffing box of the water pump and the throttle rods are to be lubricated after every 1000 kilometres.

"TRANSMISSION GEAR AND CLUTCH:

"The transmission gear casings for driving, reduction and differential gears contain separate oil chambers which are to be lubricated separately. The places for lubrication are shown in pictures 3[x] and 6.[x] The oil filler screw for the differential gear is accessible through a flap in the floor of the driver's cab. The filler screw for the gearbox and the dip-stick can be reached through a flap in the floor of the crew's compartment.

"The oil in the gearbox is to be exchanged at the same mileages as the oil in the engine. The oil level in the gearbox and in the driving wheel casing is to be 20 - 30 millimetres below the inlet aperture.

"The main bearing of the clutch is to be greased after every 2000 kilometres.

x Photographs not included in this report.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"CARBURETTOR:

"For cleaning or for changing jets the suction cap is to be loosened and the upper lid to be taken off. The fuel jets are then accessible from above.

"The starting device is to be tested from time to time as to complete closing, when the starter button is released. If the starting device does not close tight, fuel consumption will increase and damage to the engine will result.

"FUEL FILTER:

"The filter fitted to the fuel pump and the fine-mesh strainer in the carburettor are to be cleaned at certain intervals.

"After cleaning the milled screw nut under the filter glass must be re-tightened.

"AIR FILTER:

"The air filter is to be cleaned on each filling with fuel. The filter lining is to be removed by lifting, to be cleaned in petrol used for washing, moistened with engine oil, and before installation the oil must drip off well.

"The removable oil tank is to be filled with engine oil after cleaning, as far as the indicating pointer. Care must be taken that the packing is there. Badly cleaned filters reduce the performance of the engine, increase fuel consumption and diminish the length of life of the engine.

"OIL FILTER:

"The mud-cup of the oil filter is to be taken off and cleaned once a week. The discs of the filter must only be cleaned by compressed air. The packing must be tightened with the stuffing screw nut, if necessary. Care has to be taken, however, that afterwards the spindle can still be turned easily by hand. Defective packings are to be changed.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"COOLING APPARATUS:

"The radiator is to be filled with clean water. The strainer in the filler cap must not be removed during filling.

"If an anti-freeze agent is mixed with the cooling water, the radiator is to be rinsed well with fresh water after the danger of frost is over.

"In the case of loss of water all the pipe connections and the stuffing box of the water pump must be examined; if necessary, the packing is to be tightened or replaced.

"At certain intervals the inside and outside of the radiator must be cleaned.

"If the radiator boils very easily, ½ kilogram of "P3", first dissolved in water, is to be added to the radiator. After termination of the journey the hot water is to be drained; after the engine has cooled, the radiator is to be rinsed with fresh water and to be refilled with water.

"In spring and autumn the radiator is to be rinsed with a "P3" solution. For this purpose 2 - 3 tablespoonsful of "P3" are to be dissolved in a bucket of water, to be filled into the radiator and fresh water to be added. After a few days the "P3" solution is to be thrown out and the radiator to be re-filled with water.

"When the radiator has become dirty through dust, compressed air should be blown through it from both sides.

"The fan belt is to be examined as to correct tension.

"The tension bands of the lighting-dynamo must be pulled tight in order to obtain correct engagement of the water pump spindle.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"STEERING GEAR:

"The oil level of the steering gear must be examined after every 5000 kilometres and, whenever necessary, to be supplemented by gear oil. The steering gear is to be tested from time to time for lost motion. The joints are to be lubricated frequently.

"SHOCK ABSORBERS:

"The oil level of the shock absorbers is to be examined after every 2000 kilometres of driving. Special oil only is to be used for re-filling.

"CATERPILLAR TRACKS:

"After every long journey an examination must be made whether all the fastenings of the track pins are still there and whether the rubber pads are in good condition. The contents of the grease chambers of the chain links are to be examined after each long journey. The amount of grease used up is to be replaced.

"BRAKE DEVICE:

"The compressed-air container is to be emptied of water before any long journeys, in particular in frosty weather. The removal of the water is absolutely indispensable since otherwise, in the case of frost, the device would become frozen. The linings of the brake bands are frequently to be examined as to whether they are clogged with oil. Defective connections are to be replaced.

"ELECTRIC ARRANGEMENTS:

"After every 2000 kilometres of driving the gap between the electrodes of the spark plugs is to be examined. The gaps should be 0.4 millimetres. The spark plugs are to be removed and cleaned. All the cables are to be examined as to places worn through; if necessary, they are to be insulated or replaced. The cable connection and cable joints are to be examined as to whether they fit tightly. The terminal clamps of the accumulators are to be kept clean and to be greased slightly. The level of fluid in

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"the cells is to be examined, and if necessary it is to be supplemented by distilled water. The fuses and incandescent lamps of the supply tank are to be replaced in good time, if necessary. The teeth of the starter pinion and of the flywheel are to be cleaned and re-greased frequently.

"GENERAL MAINTENANCE:

"By elimination of minor defects, major damage can be avoided. Therefore all nuts, supports etc. of the carriage and carriage body are to be examined as to whether they fit tightly. Any changes in the valve clearance and defects which may arise in the electric devices are to be removed immediately.

"The clutch is to be examined frequently. The clutch lever must have the prescribed play.

"After thorough cleaning of the vehicle all polished metal parts are to be greased for protection against rust. SURFACES COVERED BY COLOURED PAINT MUST NOT BE CLEANED WITH RAGS SOAKED IN OIL OR GREASE. The red paint of the lubrication points to be lubricated by hand is to be replaced if necessary. All the rods are to be examined as to lost motion and to be lubricated regularly with a few drops of oil.

"At least once a year the tyres of the front wheel and of the spare wheel are to be taken off, the rims to be freed from rust and painted with rust protection dye. (The foregoing instructions do not apply to "Luka tyres"). Any defective tyres are to be replaced. If the tyres of the front-wheels are worn off in a one-sided manner this shows that the track alignment is not in order.

"The hood is to be lifted when the vehicles are at rest. All the leather straps are to be greased weekly with leather oil or leather grease.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"The stock of tools, equipment and spare parts is to be examined frequently. Any damaged parts are to be repaired or replaced.

"CARRIAGE BODY.

"DESCRIPTION:

"The light 3-ton tractor (Sd. Kfz.11) has an open metal carriage body with a hood for any kind of weather. In order to facilitate its removal, the carriage body is divided behind the driver's cab. The driver's cab offers accommodation for two persons. Observation mirror, spotlights and two wind-screen wipers are fitted to the wind-screen; the direction indicators are fitted behind the entrance in the driver's cab. The accumulator is arranged under the second driver's seat.

"ACCOMMODATION OF EQUIPMENT AND BAGGAGE:

"From the crew's compartment, the tool cases situated behind the driver's cab are accessible. In the upper shelf the tool cases 1, 2 and 3 are found. In the cases 1 and 2 the tools and spare parts are placed, in case 3 spare chain-links, rubber pads and non-skid chains. In the middle shelf the spare wheel and below it the wire rope (tow-rope) are placed. Tools and spare parts required for minor repair work are placed below the driver's seat. A list of the accommodation of tools and equipment is found on the back of the driver's seat and also in the tool cases 1 and 2.

"For accommodation of the equipment of the trailer, the right and left hand side shelves are provided.

"REMOVAL OF THE CARRIAGE BODY:

"In order to lift up the rear part of the carriage body, the fastening screws are to be loosened, the leather connection between the front and rear wings to be removed and the electric wire to the parking tail-light to be severed.

SERVICE, REPAIR AND MAINTENANCE - TRANSLATION (CONTINUED).

"For work to be carried out on the transmission gear and the brake device only the rear part of the carriage body is to be removed. When the driver's cab is to be removed, the positive or negative cable is first to be removed from the accumulator, the electric wires for direction indicators, spotlights, wind-screen wipers etc. are to be broken at their terminal clamps and the screw connections between the dash-board and the driver's cab to be loosened."

LABORATORY REPORTS.

Samples of most of the main units of the vehicle were despatched to the Laboratory for an examination of the materials of construction. Reports from the Laboratory upon these samples have been reproduced in this section on pages 175 to 405.

The results of this investigation of materials have been summarised on pages 171 to 173 by the Chief Chemist and Metallurgist.

LABORATORY REPORTS (CONTINUED).

SUMMARY OF LABORATORY INVESTIGATIONS.

Reproduced below is a memorandum from the Chief Chemist and Metallurgist upon the subject of the materials employed in the construction of the ZGKW 3.t.

"28th March, 1944.

"METALLURGICAL EXAMINATION OF ZGKW 3.t.

"The general picture derived from the many detailed reports has the following principal aspects:-

"1) "Everywhere we have found high material quality, with no evidence that performance has been sacrificed in the interests of economy or production man-hours.

"It should be noted that this particular vehicle is alleged to be of early vintage, i.e. 1938.

"In our present circumstances, it is my opinion that it is going to be very difficult to manufacture an equally high quality product in this country.

"2) "a) All steels appear to have been carefully made - of satisfactory cleanliness, and often with effecient grain-size control.

"b) With regard to alloying elements, while nickel is rarely encountered, the chrome-molybdenum combination is very common; generally these alloys are used in rather larger amounts than is English, or U.S.A. practice, i.e. Chromium around 1.2%, and Molybdenum around 0.3%. Such amounts have been met in some relatively small sections which certainly do not merit such high contents.

"3) "a) From our domestic experience, the outstanding German quality was in the steel castings; their standards of soundness, delicacy and neatness, mechanical properties and finish were substantially better than we have previously seen anywhere.

LABORATORY REPORTS (CONTINUED).

SUMMARY OF LABORATORY INVESTIGATIONS (CONTINUED).

"The supreme example of such metallurgical craftmanship was the Track Shoe which was of exceptionally delicate sections, and light weight, and had a most elaborate procedure for dealing with the core print, and also had the added complication of being locally case hardened. I imagine with a specially developed plant lay-out, this latter refinement could, however, be achieved during a modified normalising cycle for the castings.

"b) It was also very surprising that gearbox, final drive, and differential casings were made of a very good grade of pearlitic (or white-heart) malleable iron - with the high properties of Tensile around 30 tons/sq.inch and reasonable ductility.

"4) "Everywhere we found the forgings to be well made, with accurately controlled grain-flow, particularly in the case of the gears. With one exception all gears were made of Case Hardening chrome-molybdenum steel, and quite efficiently case hardened to have core strength 55-85 tons/sq.inch, and a good level of hardness of the case. The one exception was a particularly heavily loaded gear which was made of the orthodox case hardening 4¼% Nickel and Chromium steel, with core strength 85 tons/sq.inch.

"5) "Torsion shafts were of a normal good standard of chrome-vanadium steel practice; carefully heat-treated with good atmosphere control, but no special surface finishing by shot-blasting etc., - or very thorough protection against corrosion.

"(The torsion shafts from a later model were of a similar standard of properties, but were made of a 1% chromium, 1% silicon steel).

LABORATORY REPORTS (CONTINUED).

SUMMARY OF LABORATORY INVESTIGATIONS (CONTINUED).

"6) "The frame side-members were of high duty manganese-molybdenum, and manganese-copper steels, obviously hot-formed, with Tensile Strength of around 40 tons/sq.inch.

"7) "Miscellaneous Items.

"Bronze Bearings (in Diff. casings) of a normal cast phosphor-bronze type.

"General Bolts. The usual heat-treated carbon steel around 50 tons/sq.inch tensile strength.

"Nuts. Of the usual bright drawn steel, with carbon content between 0.20 and 0.40%; no extravagant use made of free-cutting steel.

"Cast Iron. Of normal non-alloy, approximate 14 tons/sq.inch Tensile Strength - no apparently very high steel mixes, and phosphorus contents not very low (about 0.5%).

"Rubber. Very good properties - generally synthetic of, apparently, Buna-S type.

H.S. BAVISTER,
CHIEF CHEMIST & METALLURGIST."

NOTES:

1) Regarding Rubber.

The word, "rubber", has been used throughout this report, to refer to any materials which exhibited the physical properties usually associated with rubber. It should be understood, that except where any definite statement to the contrary has been made, as in the Laboratory Reports, such materials may be natural rubber or synthetic compounds.

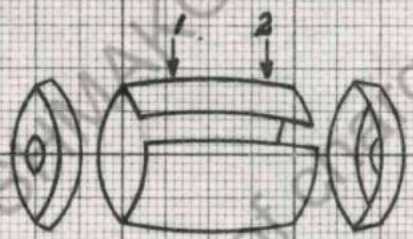
2) Regarding Dimensions.

Dimensional data included in this report is intended largely to indicate only the general proportions of the parts concerned and in cases where measurements were scaled from the vehicle, no very great accuracy was attempted.

In all cases, the number of significant figures employed, in the statement of a dimension, should be regarded as the measure of accuracy with which that dimension was observed or calculated.

REPORT 26KW PAGE 407

GRAPH OF LOAD - DEFLECTION TEST UPON BARREL SPRING ASSY FROM 26KW 3t REAR TOWING ATTACHMENT.



ASSY UNDER TEST.

LOAD LBS.

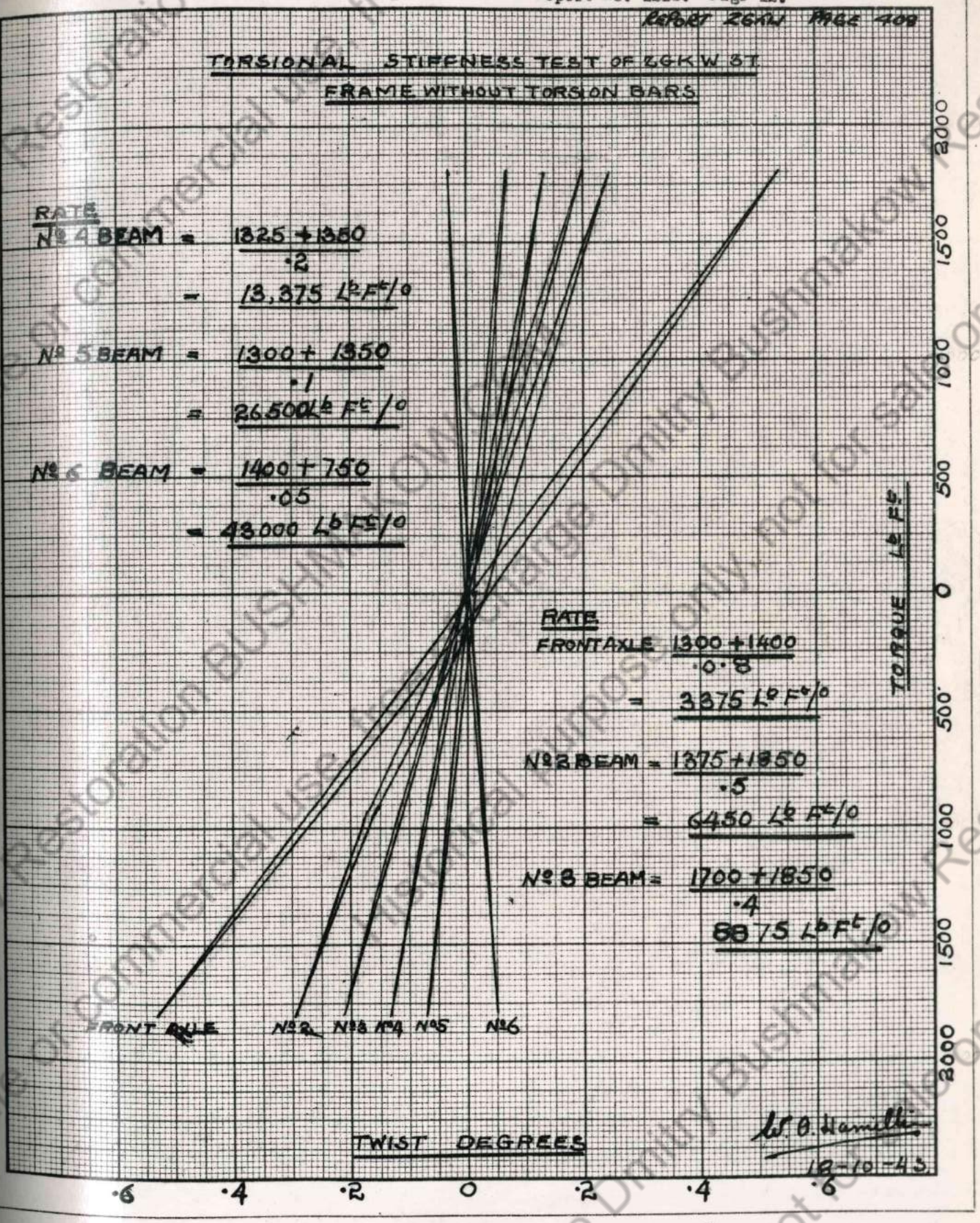
4000
3600
3200
2800
2400
2000
1600
1200
800
400

DEFLECTION - INCHES

0·2 0·4 0·6 0·8 1·0 1·2

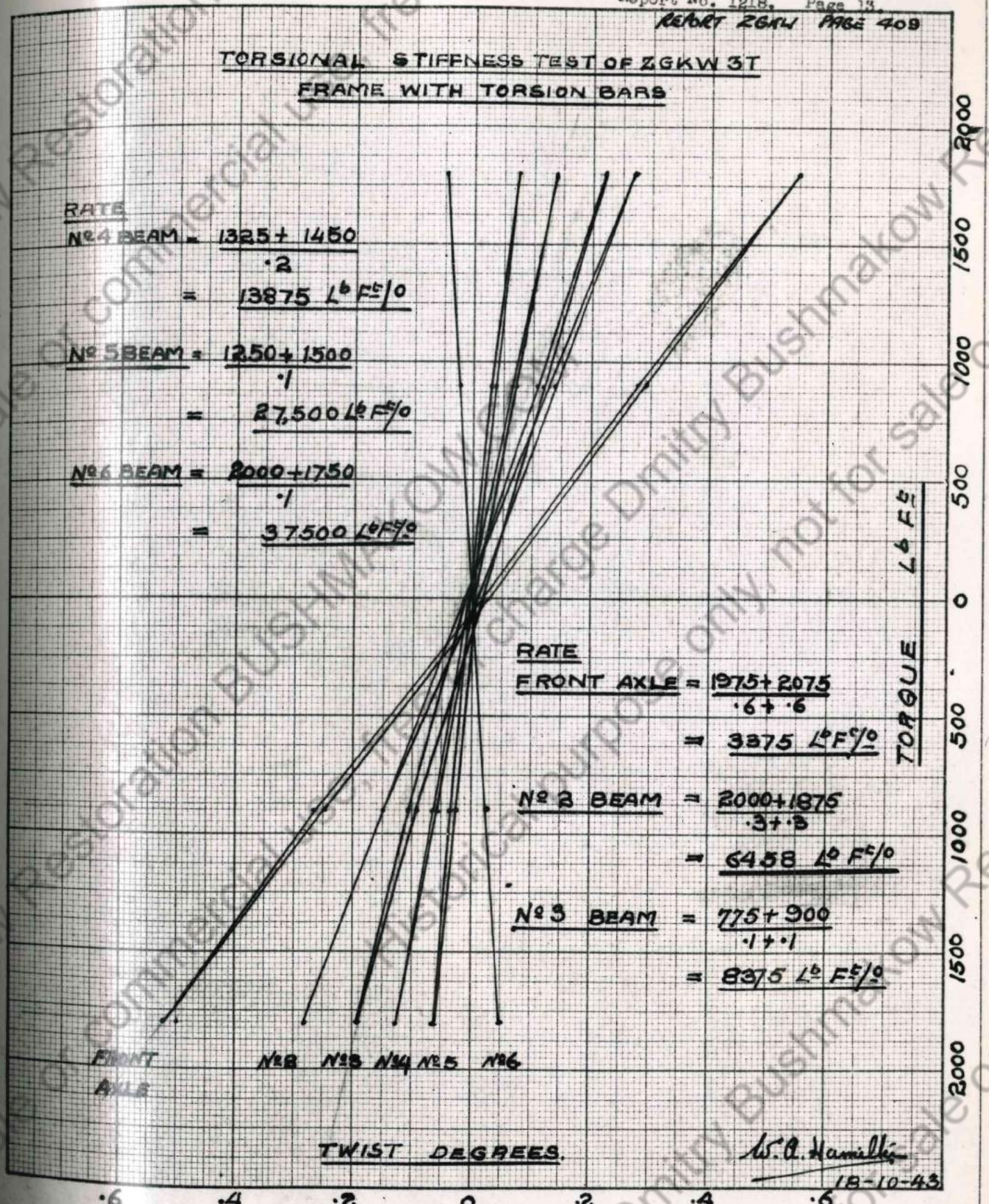
Report 26HW Page 402

TORSIONAL STIFFNESS TEST OF 26KW 3T FRAME WITHOUT TORSION BARS

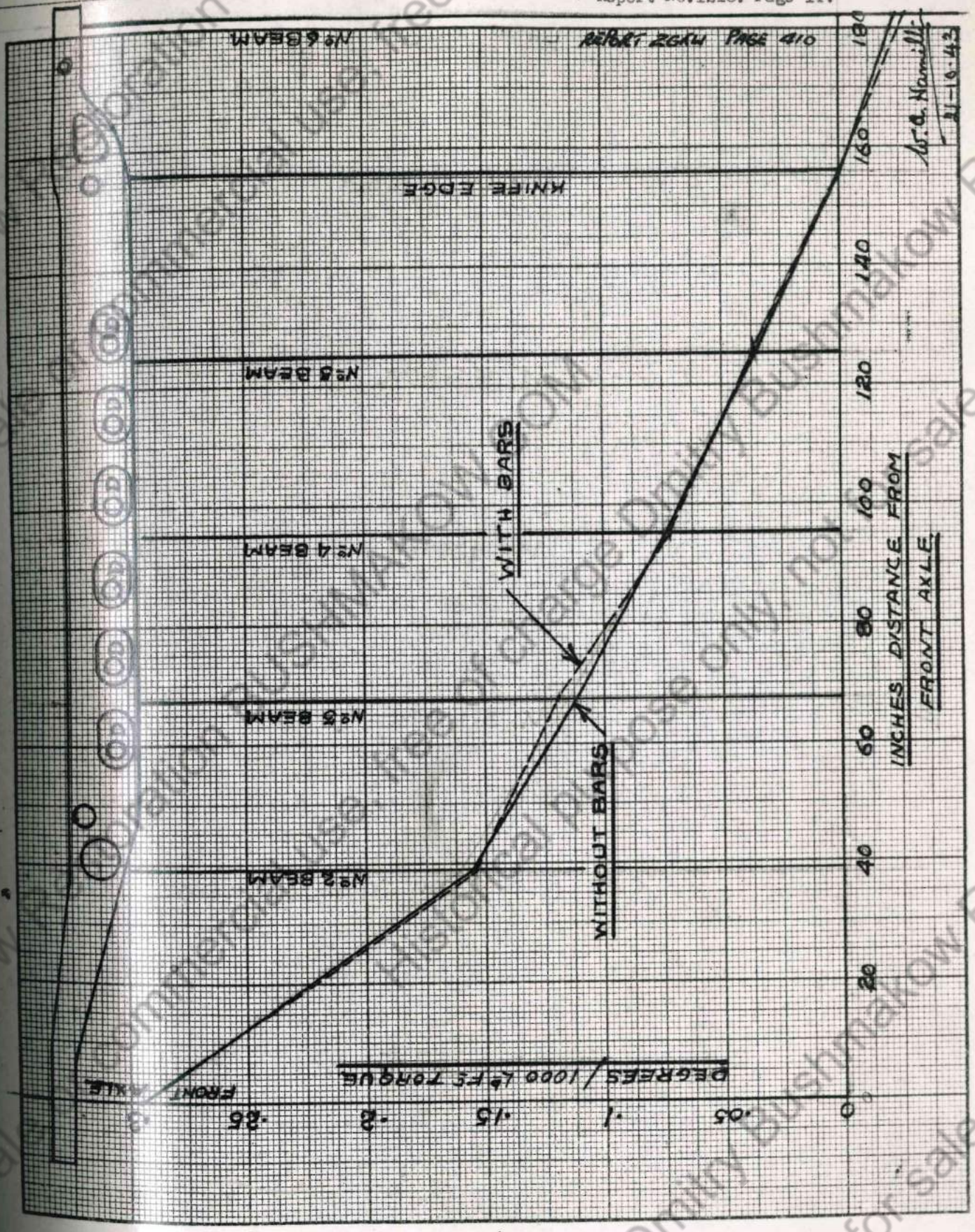


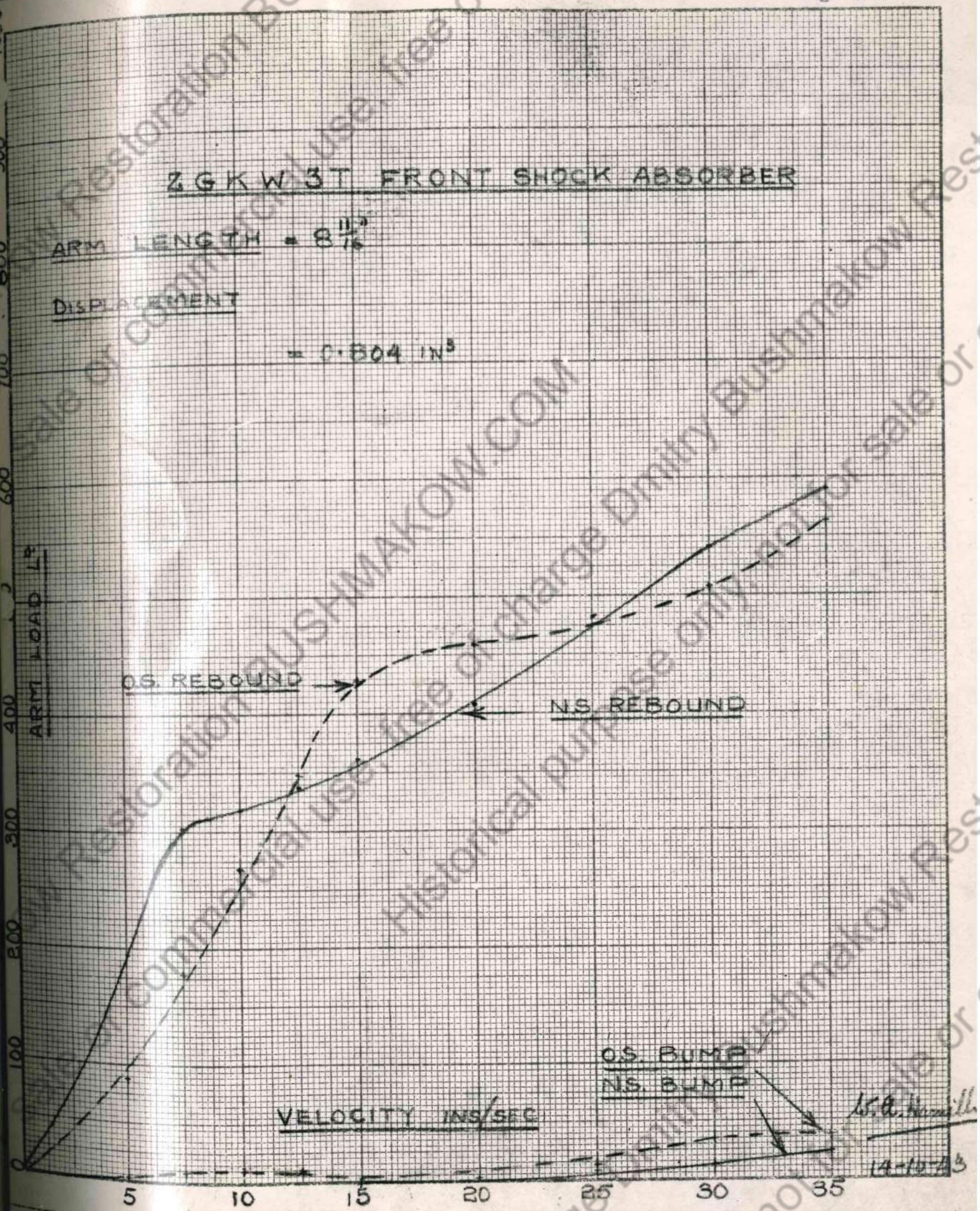
W. B. Hamilton
12-10-43.

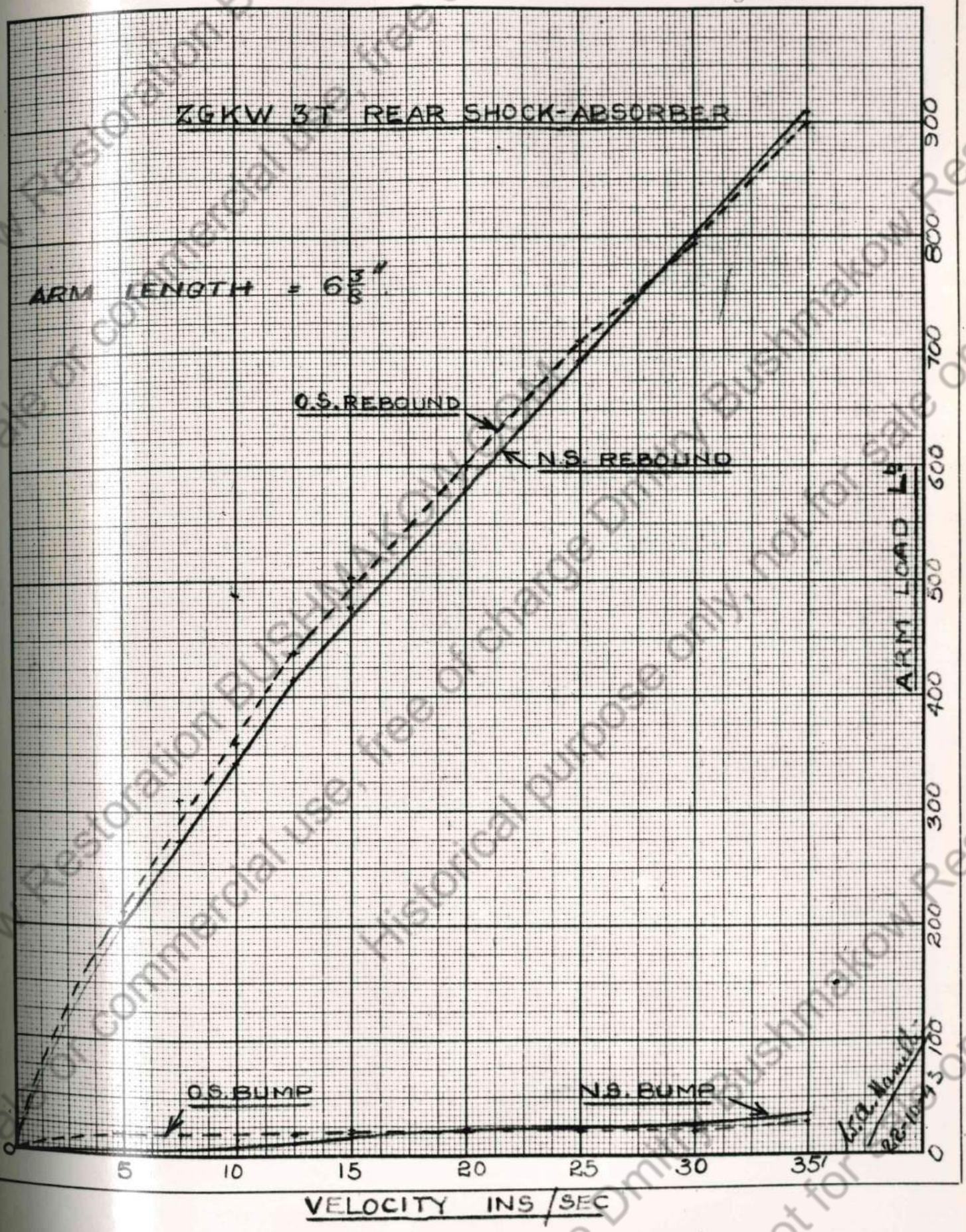
TORSIONAL STIFFNESS TEST OF ZGKW 3T FRAME WITH TORSION BARS



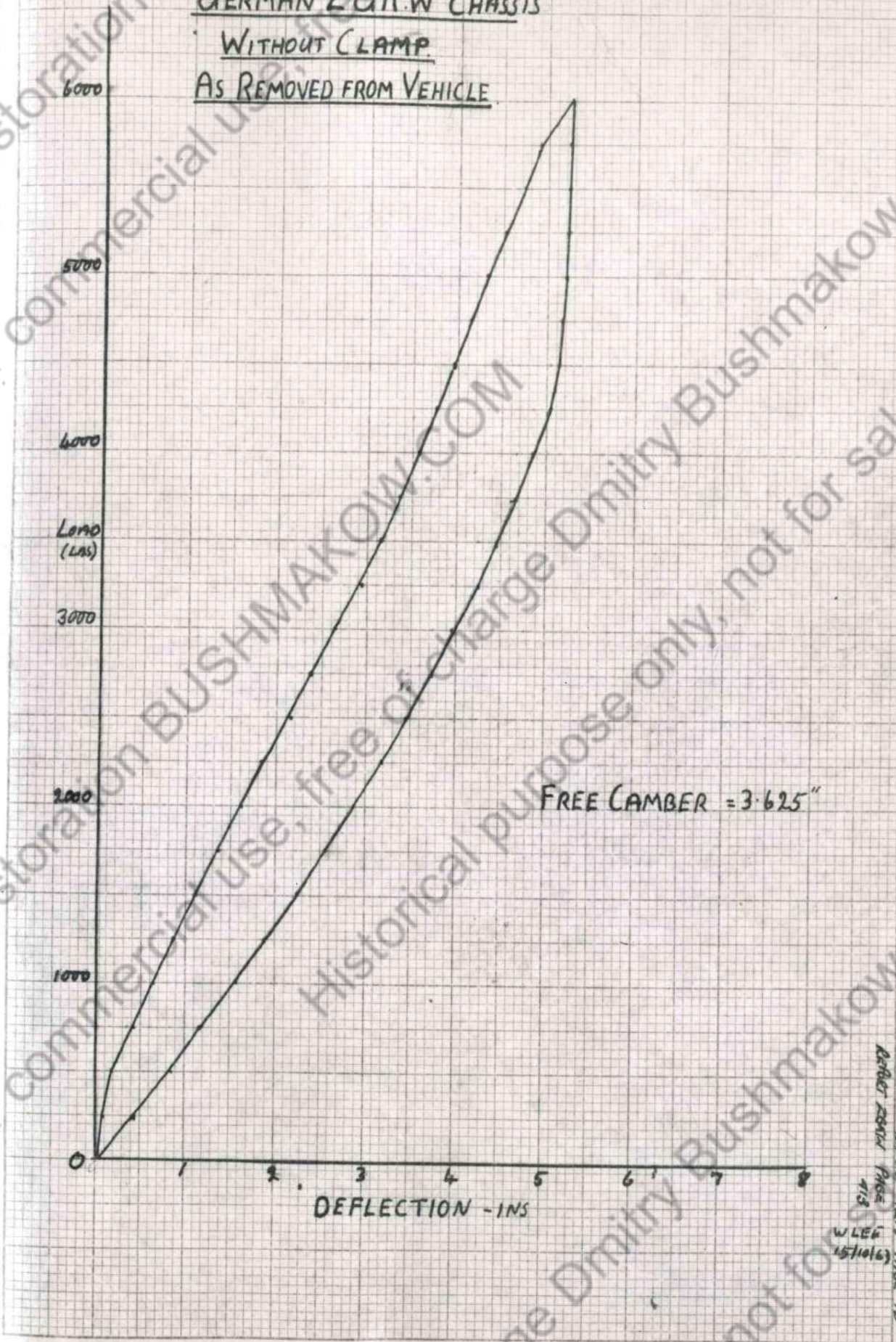
W.A. Hamilton
18-10-43


REPORT ZGAU PAGE 410
Lt. C. Hamill
11-10-43
KNIFE EDGE
No 6 BEAM
No 5 BEAM
No 4 BEAM
No 3 BEAM
No 2 BEAM
WITH BARS
WITHOUT BARS
INCHES DISTANCE FROM FRONT AXLE
DEGREES / 1000 LB FT TORQUE
FRONT AXLE
0
20
40
60
80
100
120
140
160
180
.05
.1
.15
.2
.25





FRONT SPRING REMOVED FROM GERMAN ZGKW CHASSIS WITHOUT CLAMP. AS REMOVED FROM VEHICLE.



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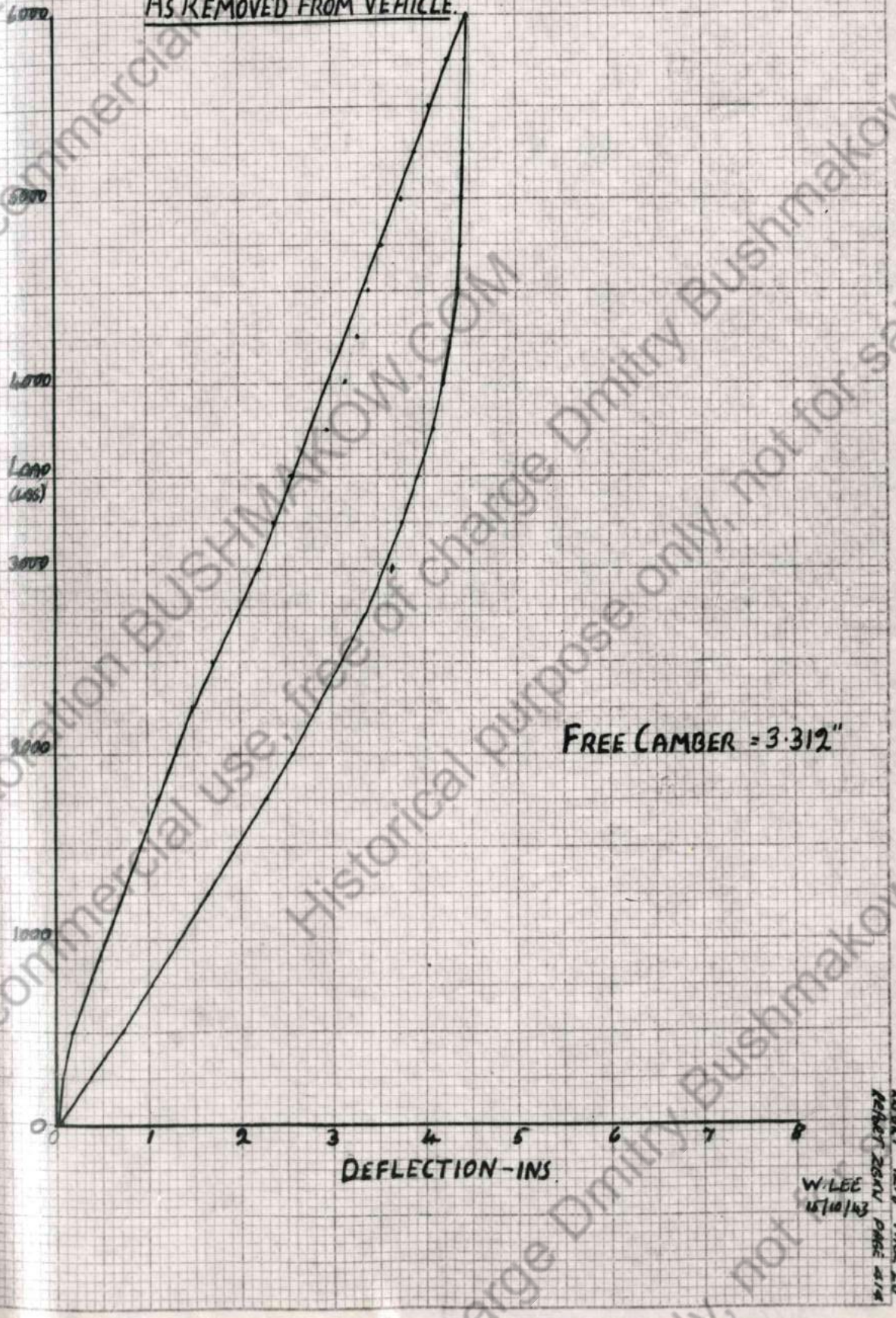
REPORT ZGKW PAGE 413
WLEE 15/10/63

FRONT SPRING REMOVED FROM GERMAN ZGKW. CHASSIS.

WITH CLAMP

AS REMOVED FROM VEHICLE.



W. LEE
15/10/43

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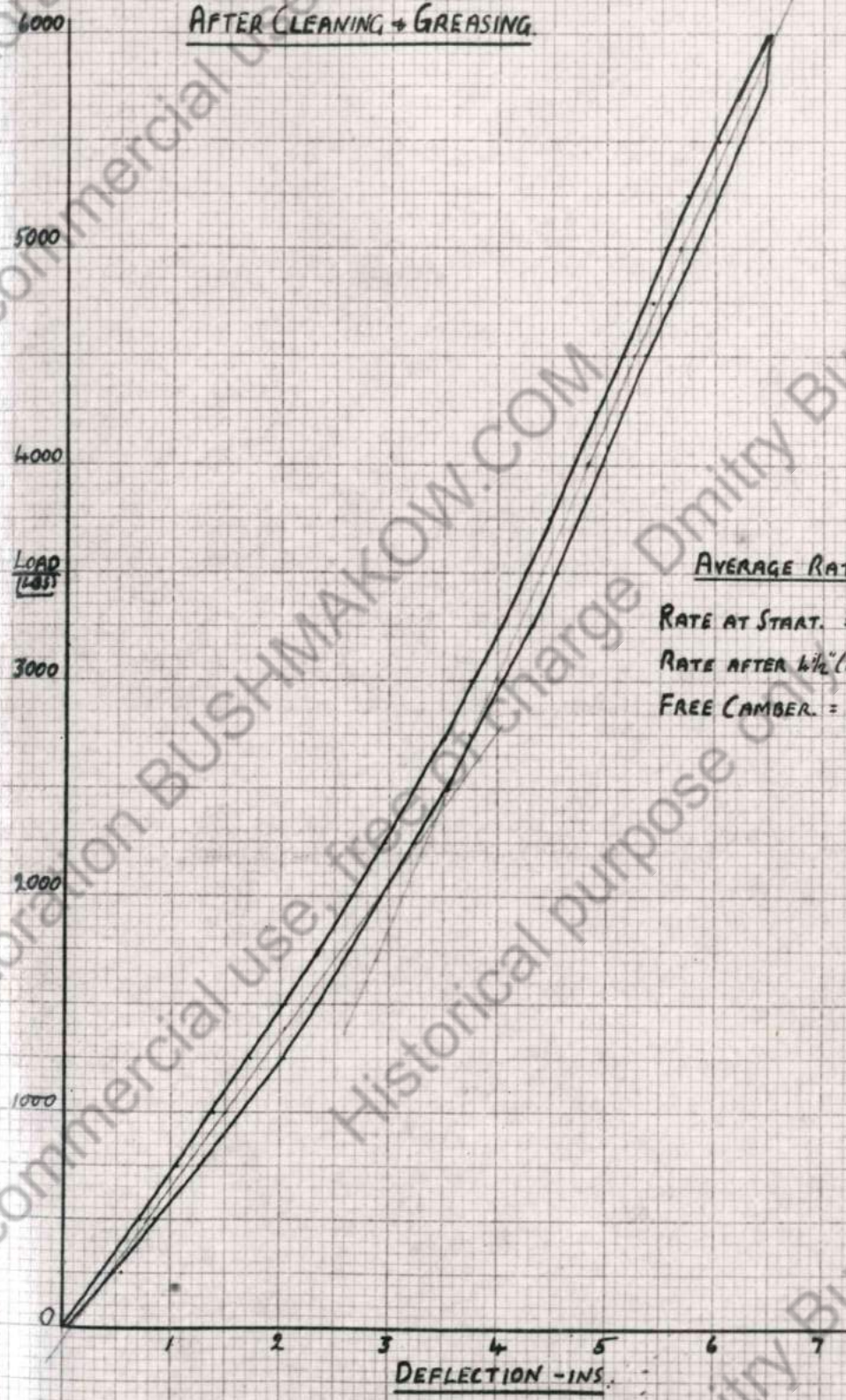
REPORT ZGKW PAGE 414

FRONT SPRING REMOVED FROM GERMAN Z.G.K.W. CHASSIS WITHOUT CLAMP AFTER CLEANING + GREASING.



AVERAGE RATES

RATE AT START. = 710 LBS/IN.

RATE AFTER 4½" (APPROX) = 1160 LBS/IN

FREE CAMBER. = 4.50"

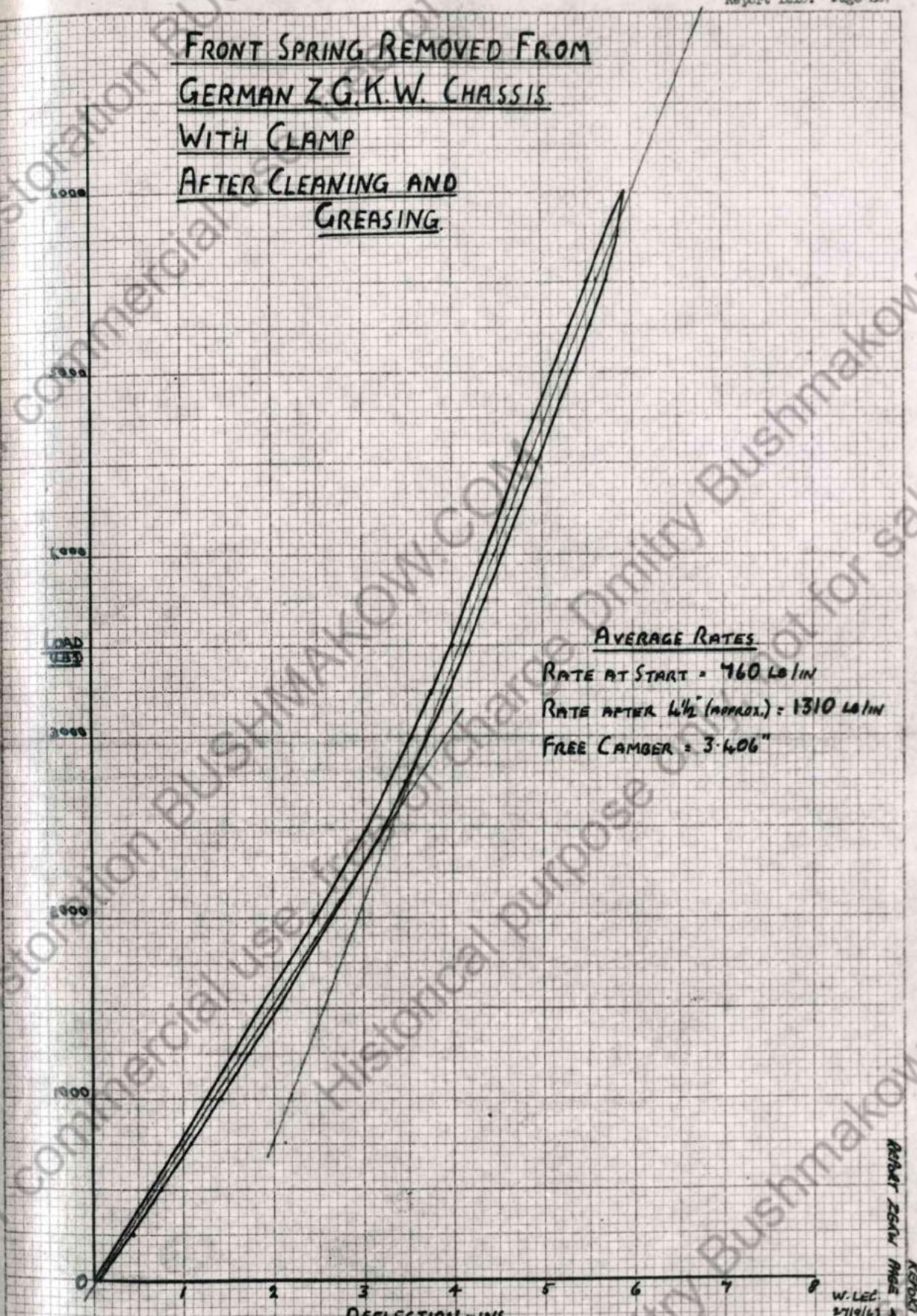
REPORT ZOKW PAGE 415

W. LEE 27/9/43

REPORT 1218 PAGE 21

THIS IS NOT CONSIDERED TRUELY REPRESENTATIVE OF THE SPRING OWING TO THE FACT THAT Nº 1 LEAF APPEARS TO HAVE BEEN SHORTENED AND DOES NOT OPERATE ON THE EYE END OF THE SPRING.

FRONT SPRING REMOVED FROM GERMAN Z.G.K.W. CHASSIS WITH CLAMP AFTER CLEANING AND GREASING.



AVERAGE RATES.

RATE AT START = 960 LB/IN

RATE AFTER 4½" (APPROX.) = 1310 LB/IN

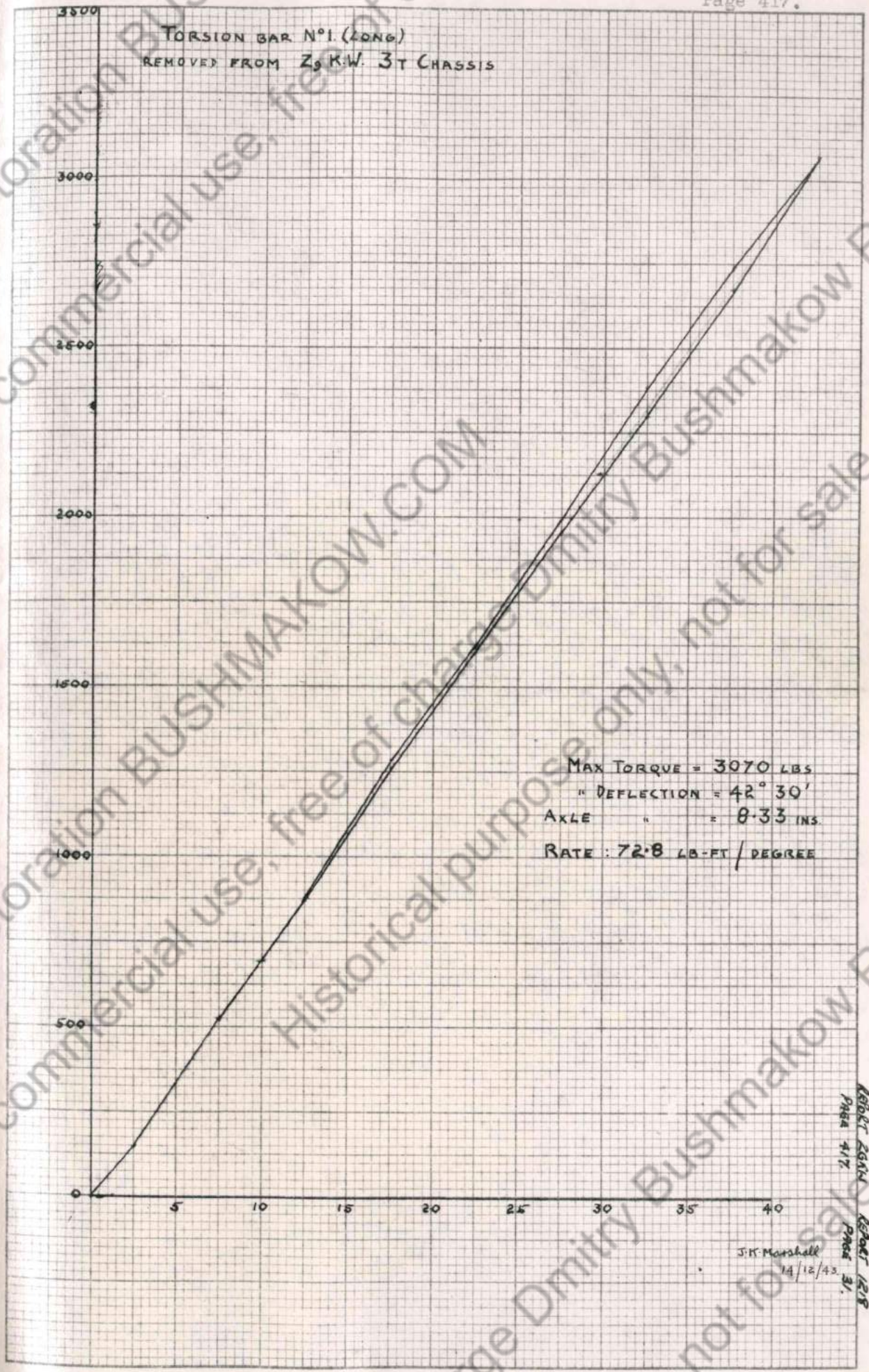
FREE CAMBER = 3·406"

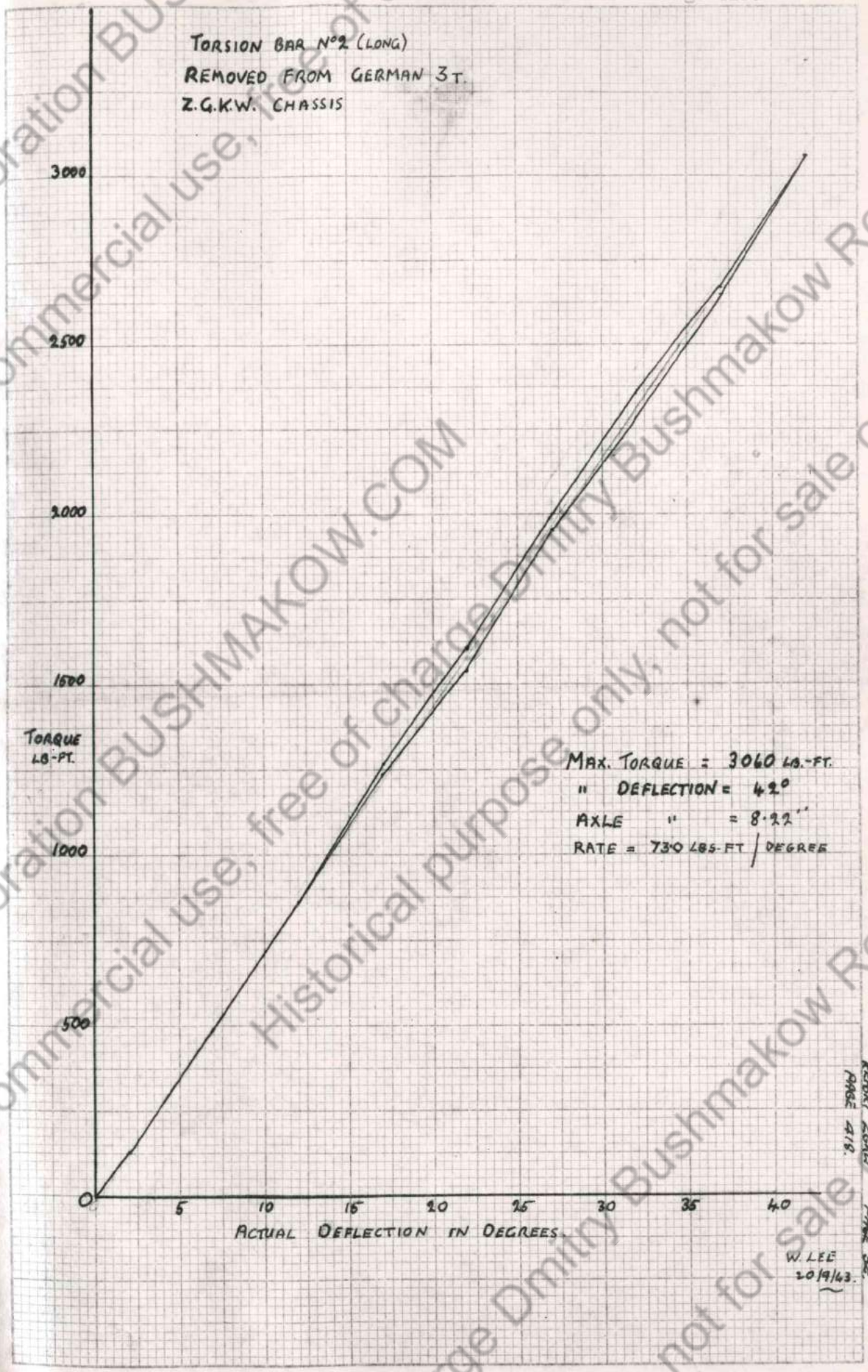
W. LEC. 7/10/41

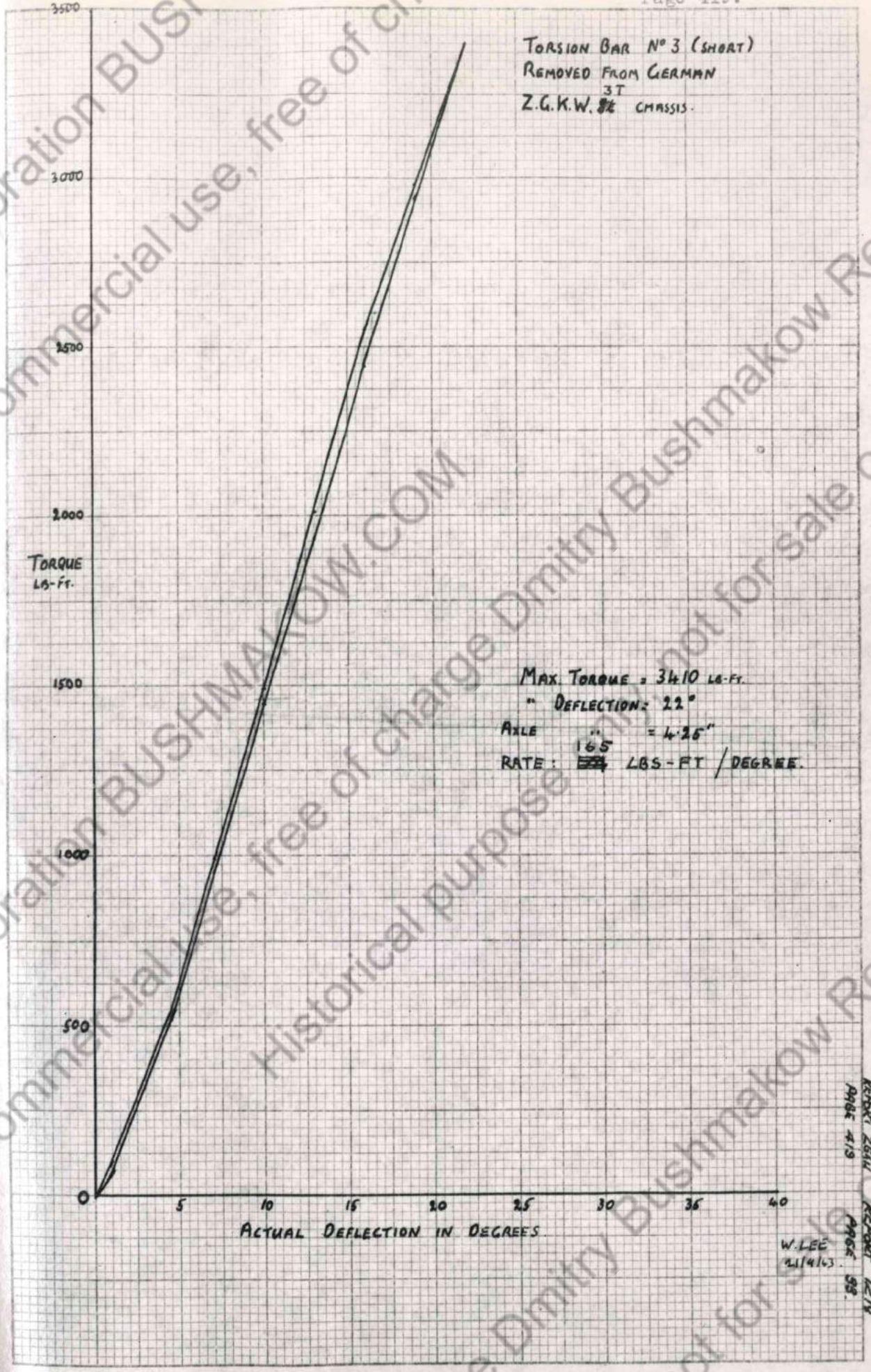
REPORT ZGKW PAGE 416

REPORT 1218 PAGE 22

THIS IS NOT CONSIDERED TRUELY REPRESENTATIVE OF THE SPRING OWING TO THE FACT THAT N° 1 LEAF APPEARS TO HAVE BEEN SHORTENED AND DOES NOT OPERATE ON THE EYE END OF THE SPRING.

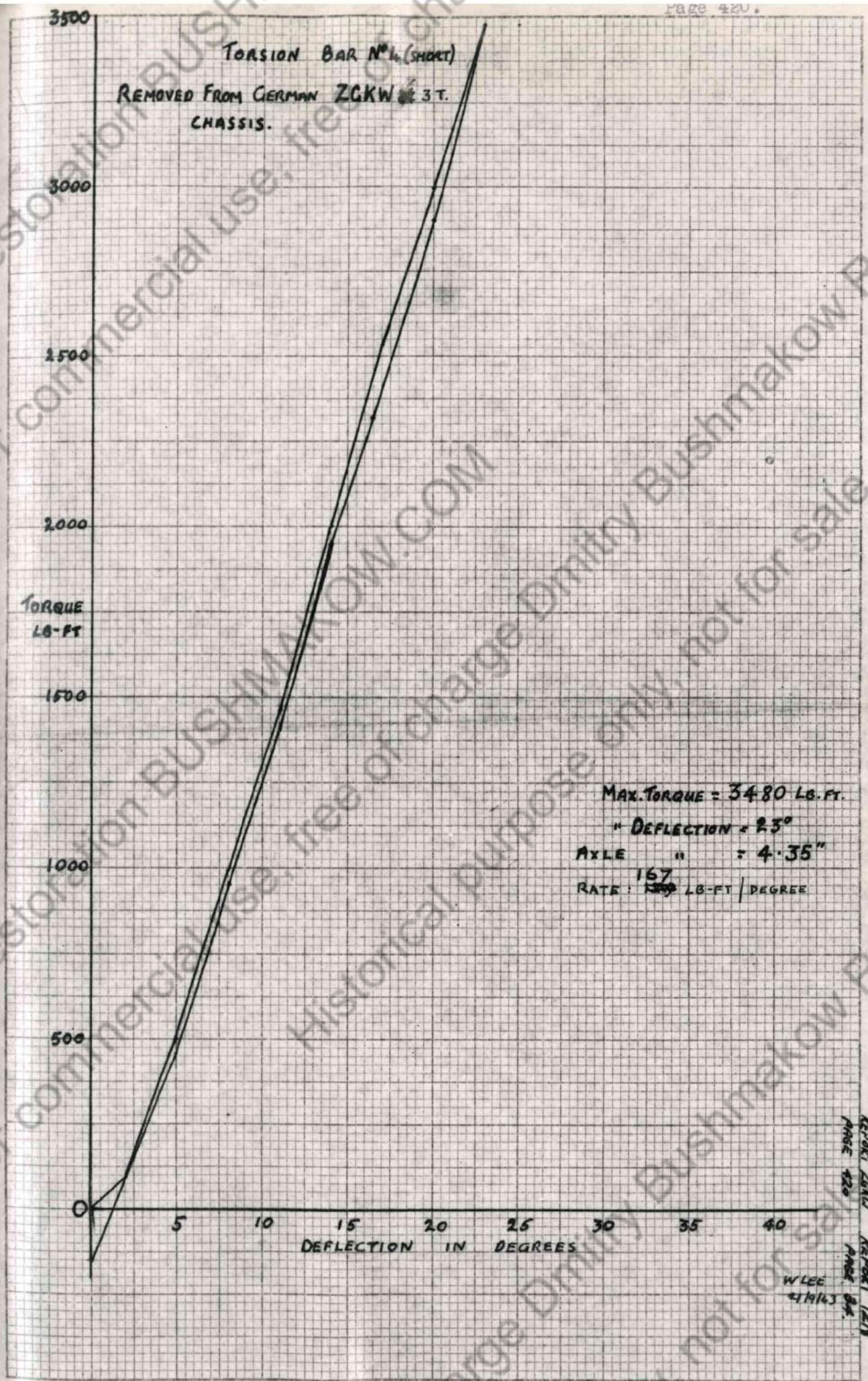






REPORT 2614 REPORT 4218
PAGE 419 PAGE 99.

W. LEE
21/4/43.



REPORT 2000 PAGE 420 REPORT 1218 PAGE 424

W LEE 21/9/43

REPORT 1218. PAGE 421.

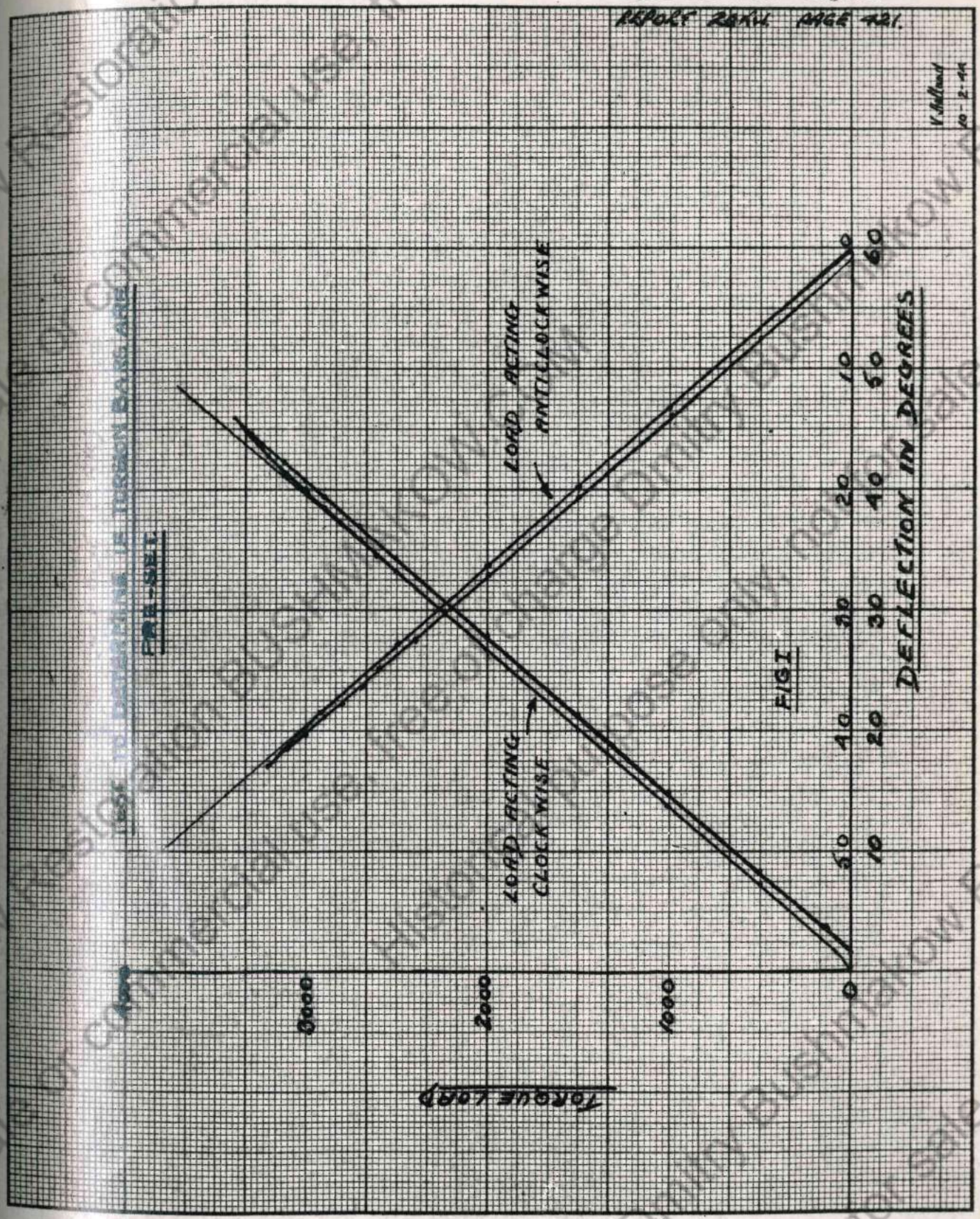
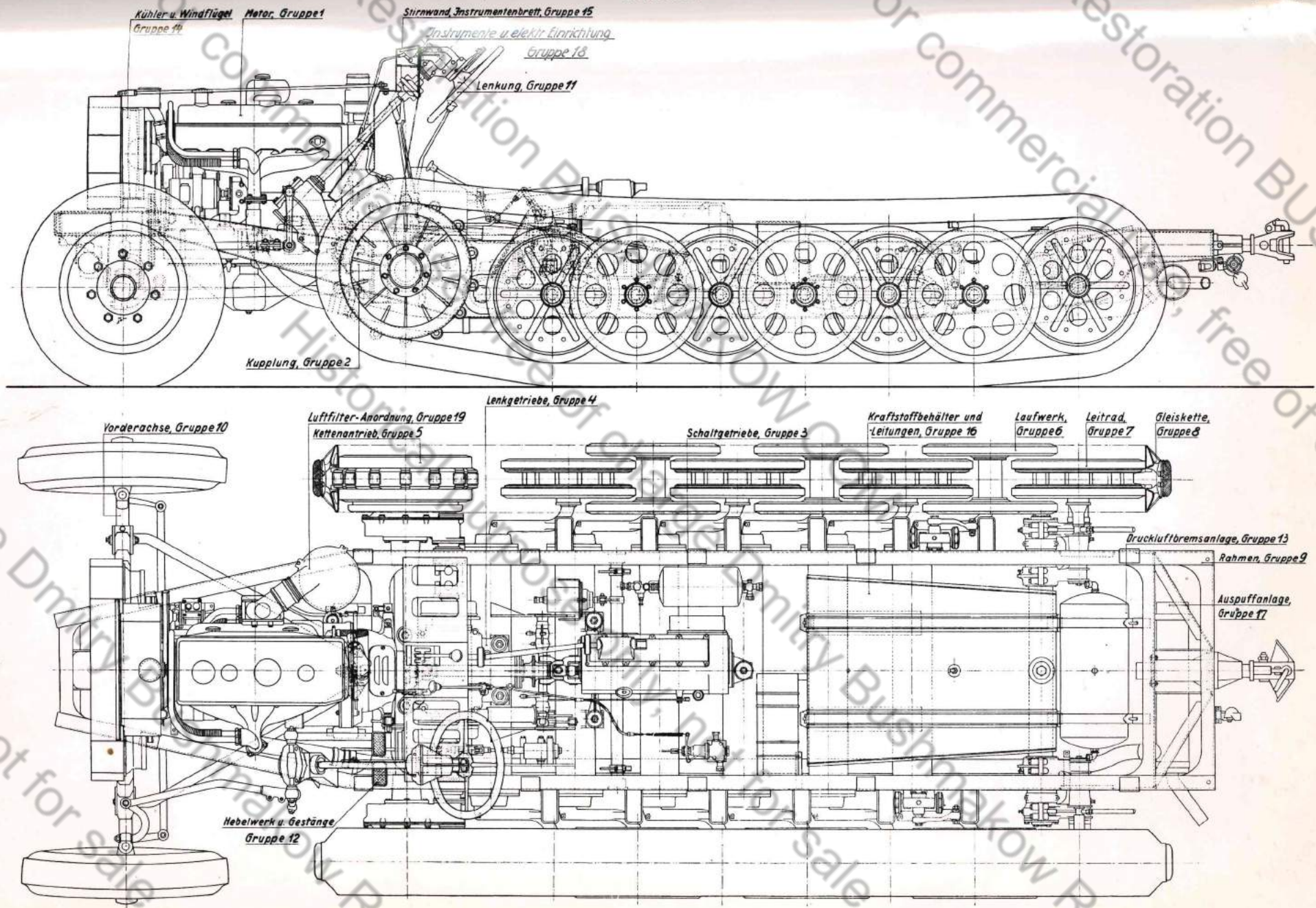


FIG I

Fahrgestell

021 A 32 808 U1

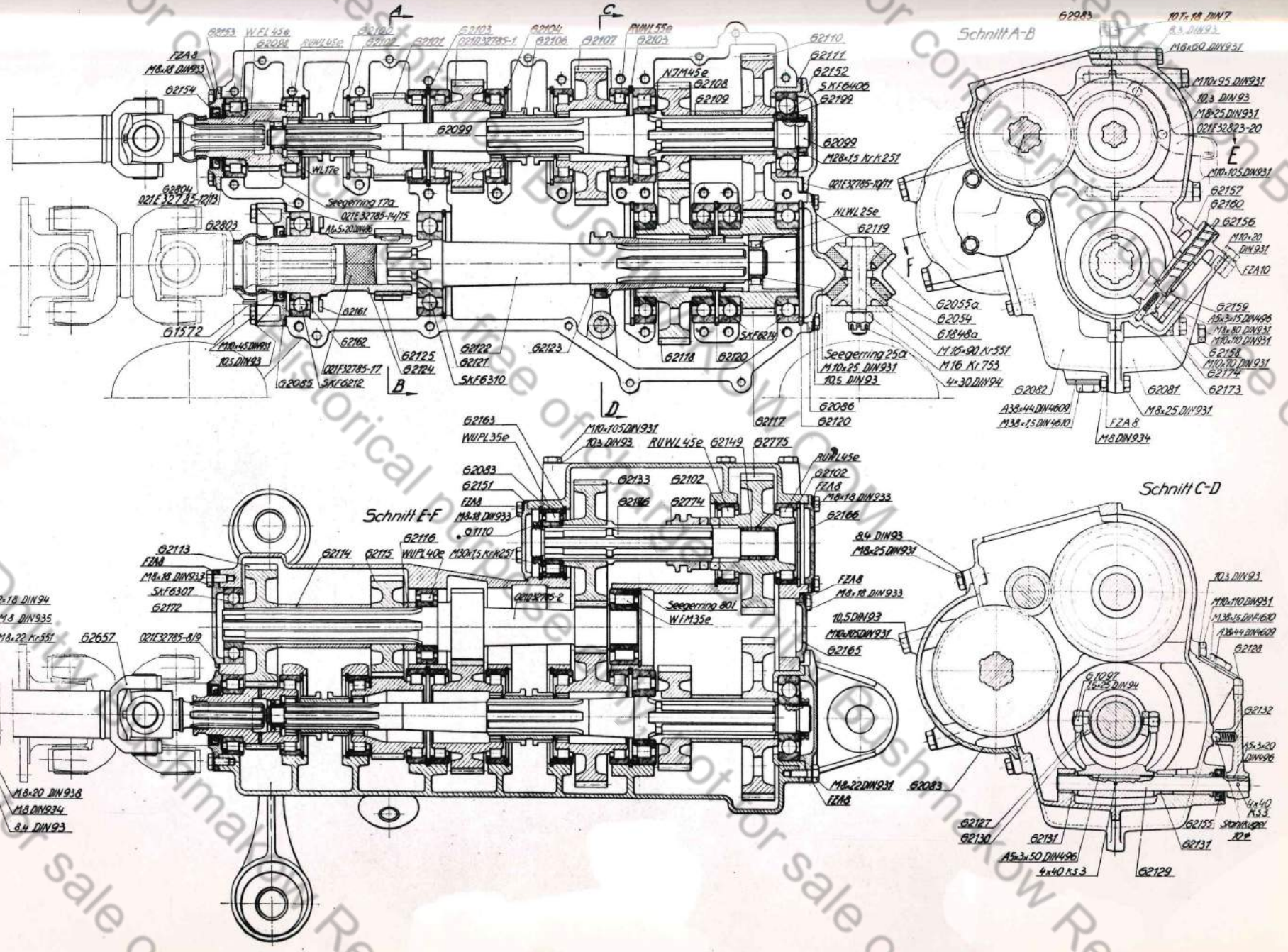
Skizze 1



Schaltgetriebe

021 A 32 812 U1

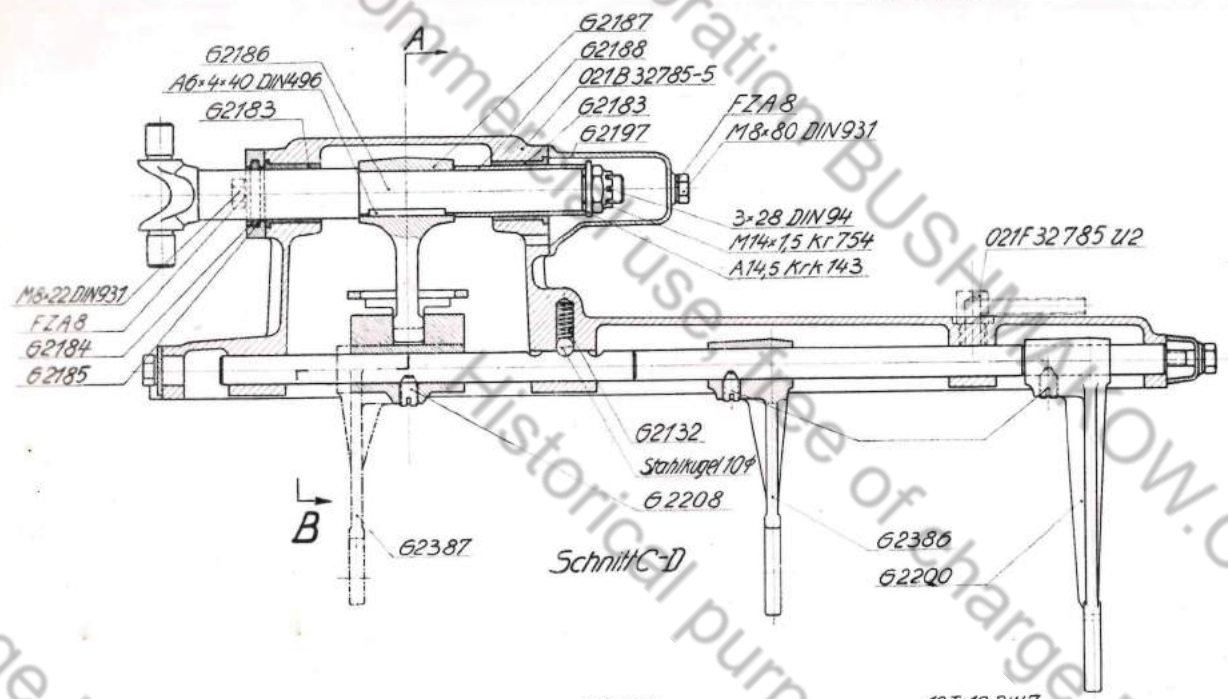
Skizze 2

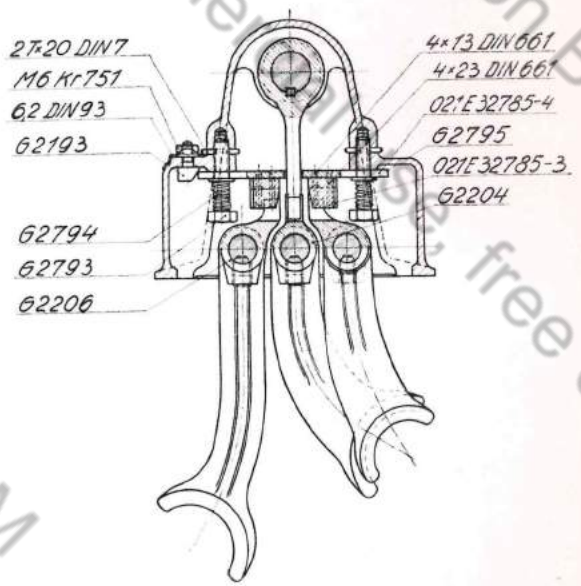


Schaltung

021 B 32 785 U 4

Skizze 3





Schnitt A-B

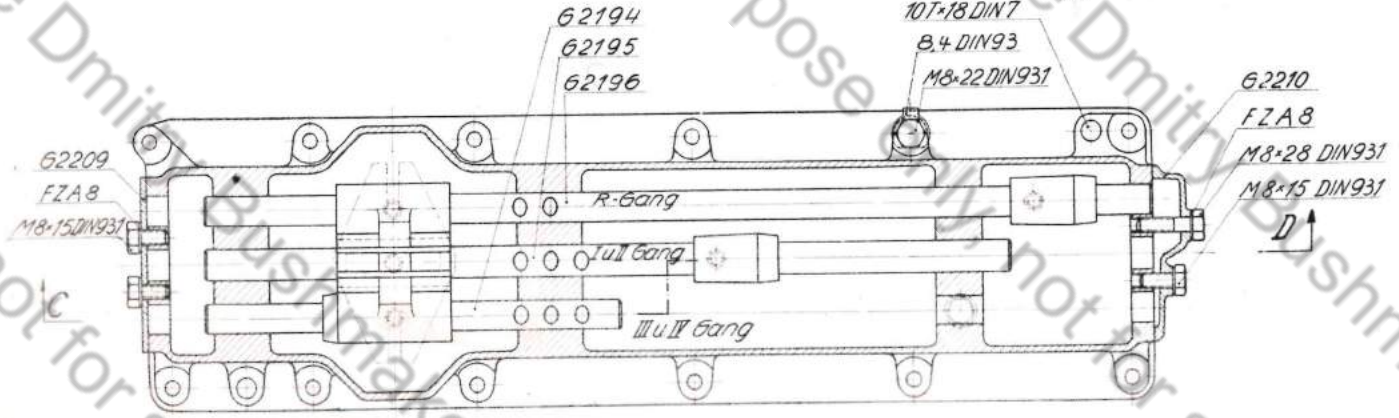
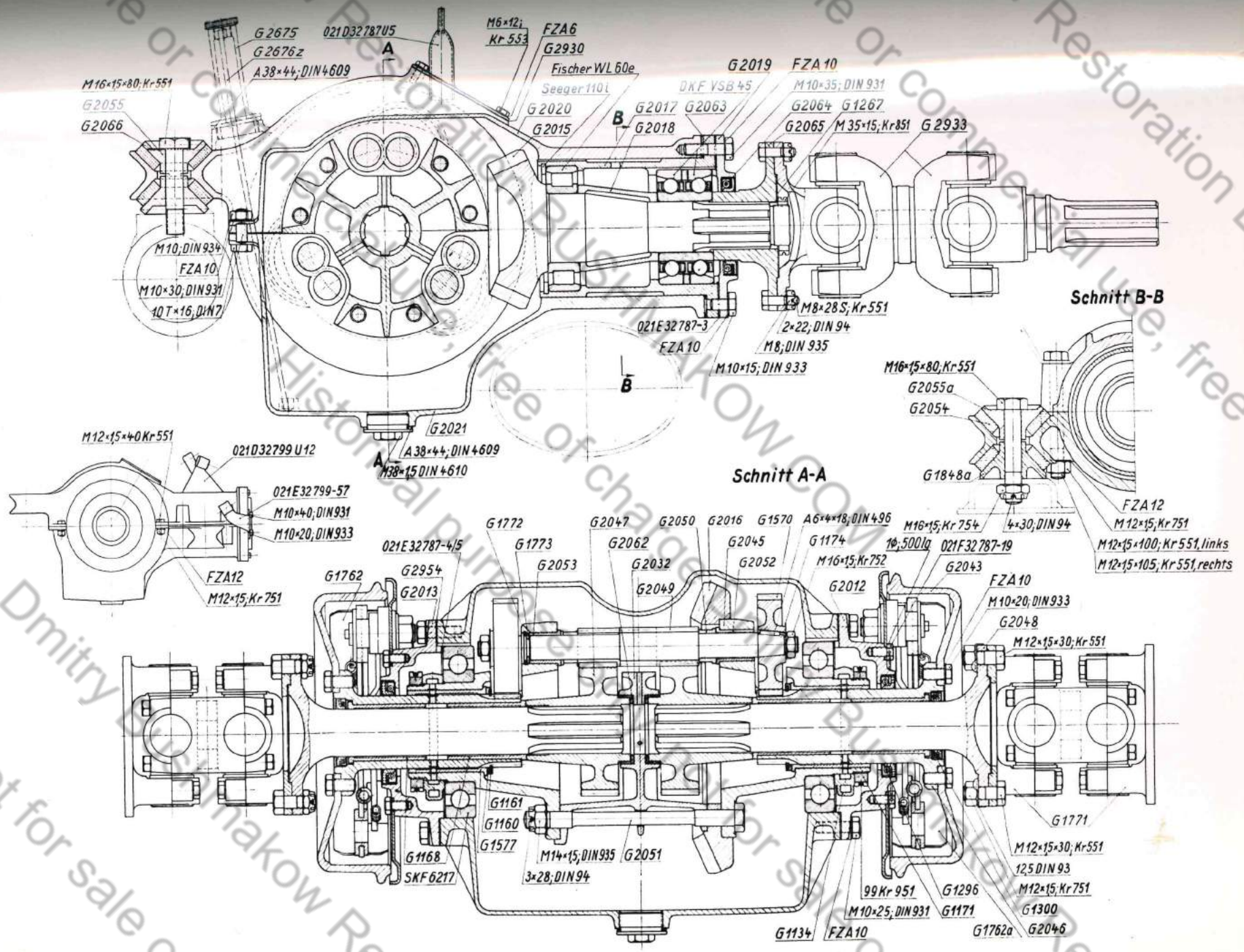


PLATE 3.

Lenkgetriebe

021 A 32 787 U 4

Skizze 4



Kettenantrieb

021 B 32 816 U 2

Skizze 5

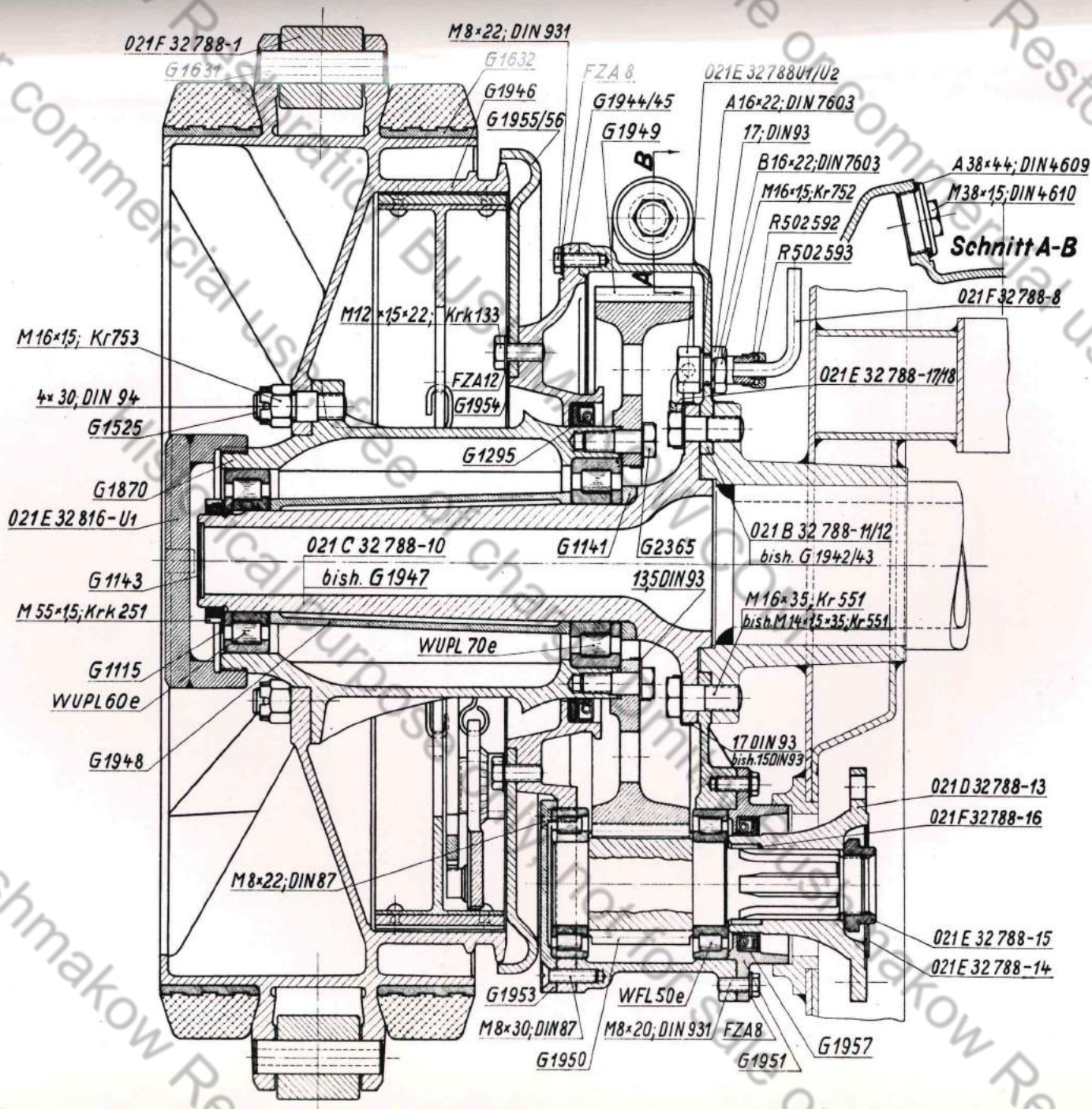
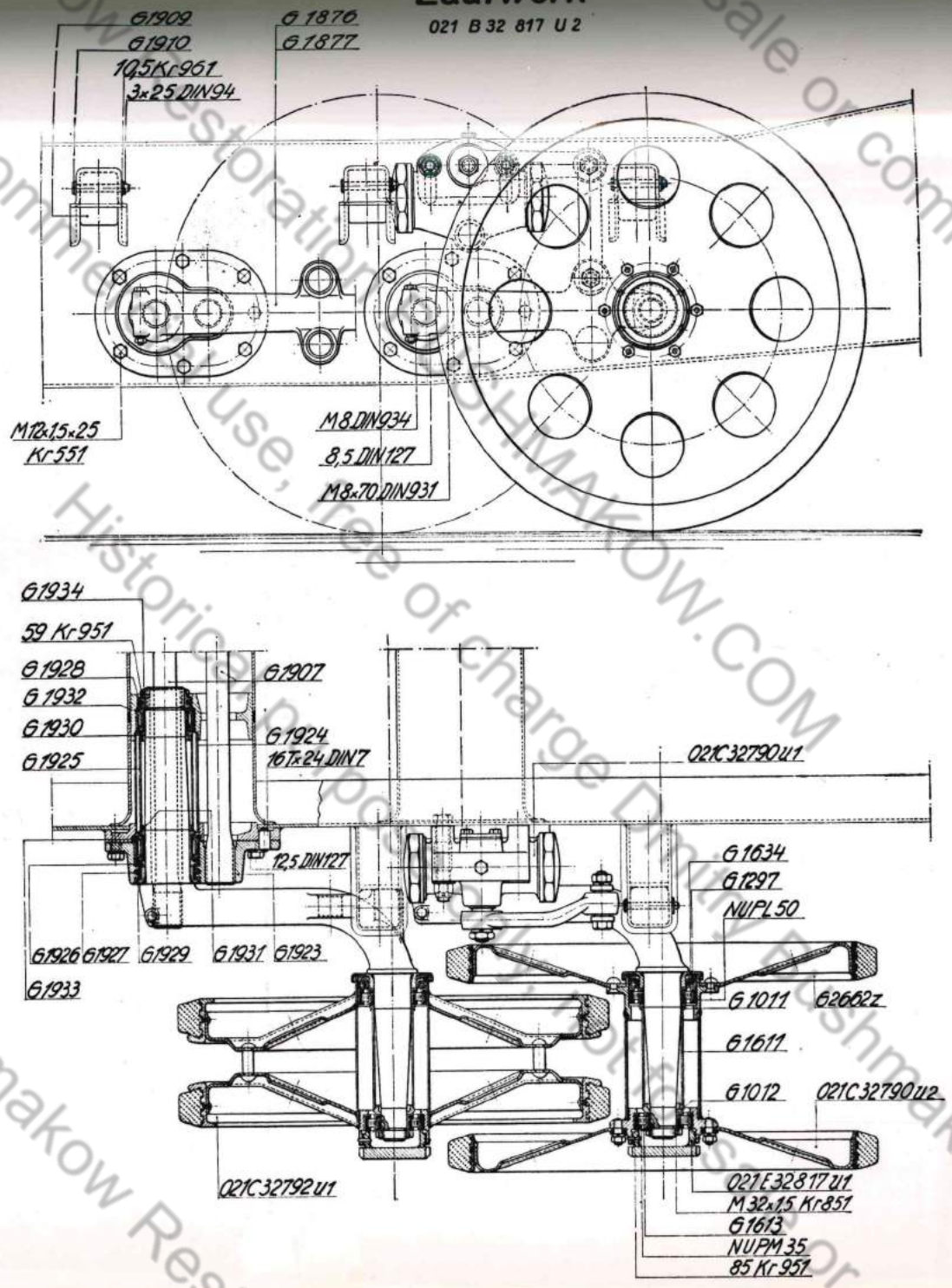


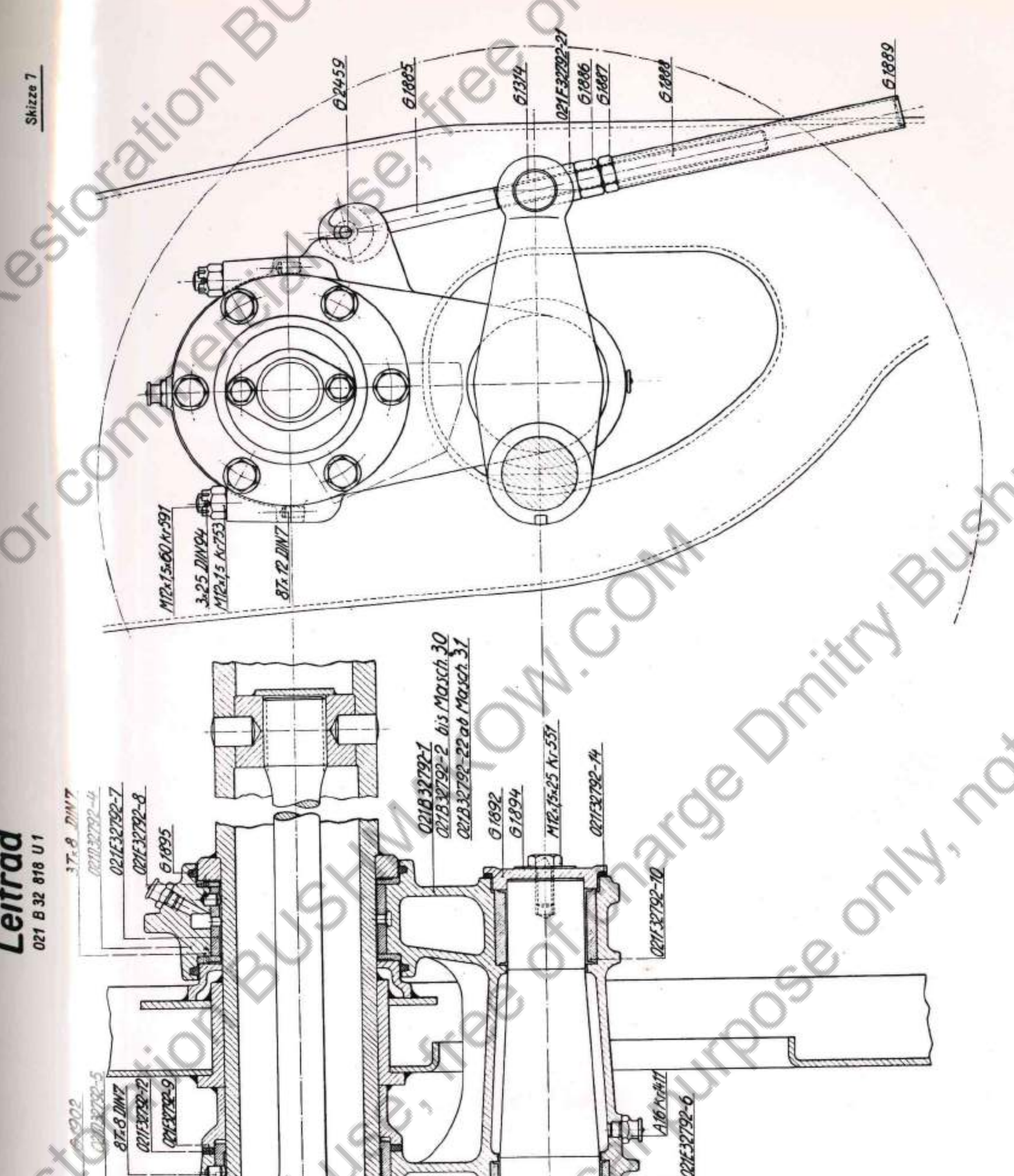
PLATE 5.

Laufwerk

021 B 32 817 U 2

Skizze 6

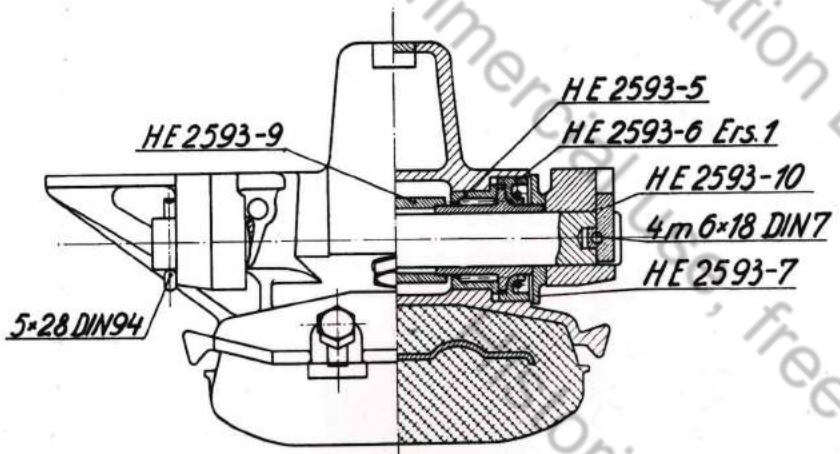


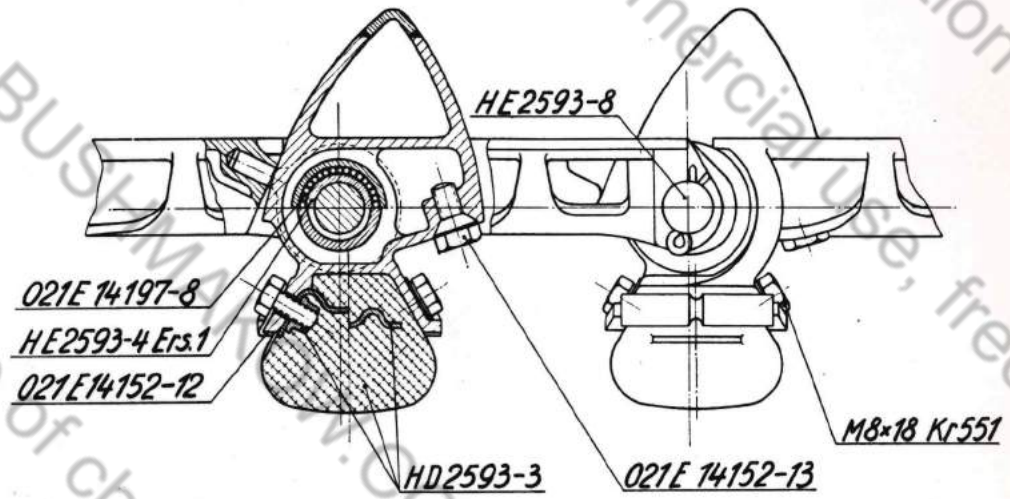

Skizze 7
Leitrad
021 B 32 818 U1
G 2459
G 1885
G 1314
021E32792-21
G 1886
G 1887
G 1888
G 1889
M12x1,5x60 Kr591
3,2x25 DIN 94
M12x1,5 Kr 753
8,7x12 DIN 7
3,7x8 DIN 7
021D32792-4
021E32792-7
021E32792-8
G 1895
021B32792-1
021B32792-2 bis Masch.30
021B32792-22 ab Masch.31
G 1892
G 1894
M12x1,5x25 Kr 551
021F32792-14
021F32792-10
A 16 Kr 611
021E32792-6
021E32792-15
021E32790-43
NUP 50
G 1902
021D32792-5
8,7x8 DIN 7
021F32792-12
021C32792-9
021D32792-3
021D32792-19
M12x1,5x25 Kr 551
12,5 DIN 127
8,5 DIN 127
M8x15 DIN 933
G 1893
G 1899
M12x1,5x35 Kr 551
021C32792-20
021F32792-13
021F32792-17
G 1011
G 1297
G 1170
G 1611
G 1012
G 1613
NUP 135

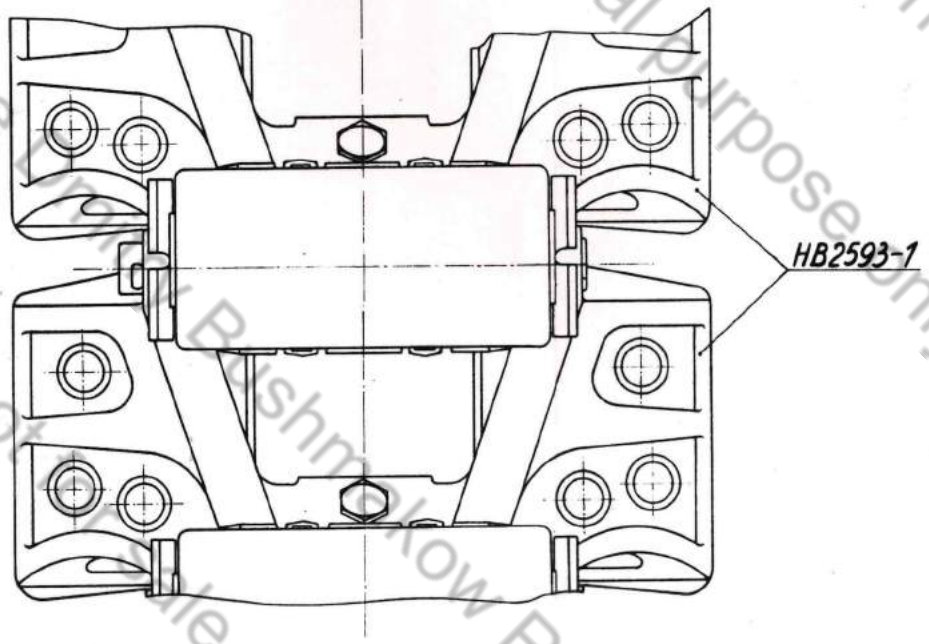
Gleiskette

021 B 32 794 U 1

Skizze 8



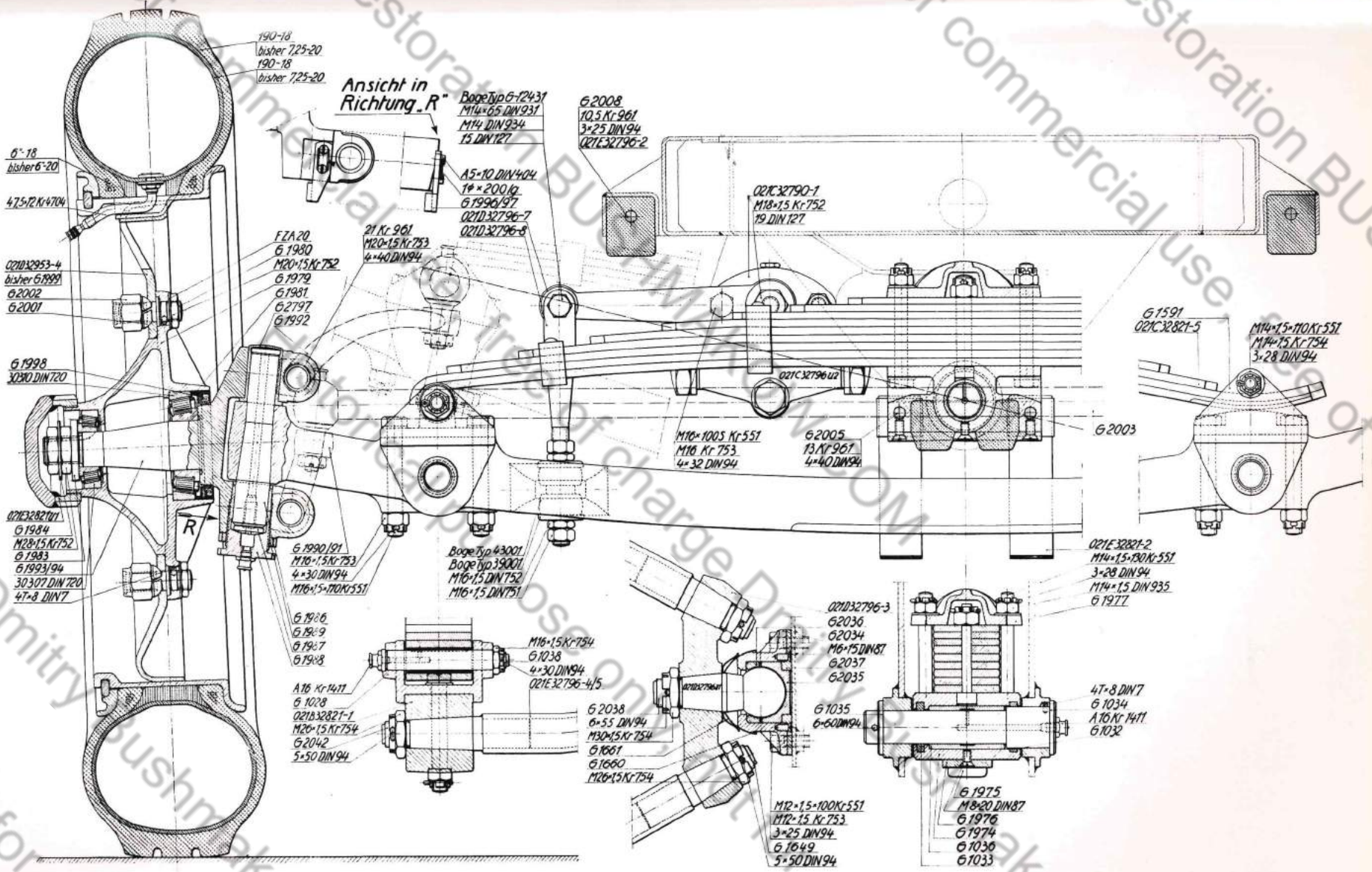




Vorderachse

021 A 32 821 U 2

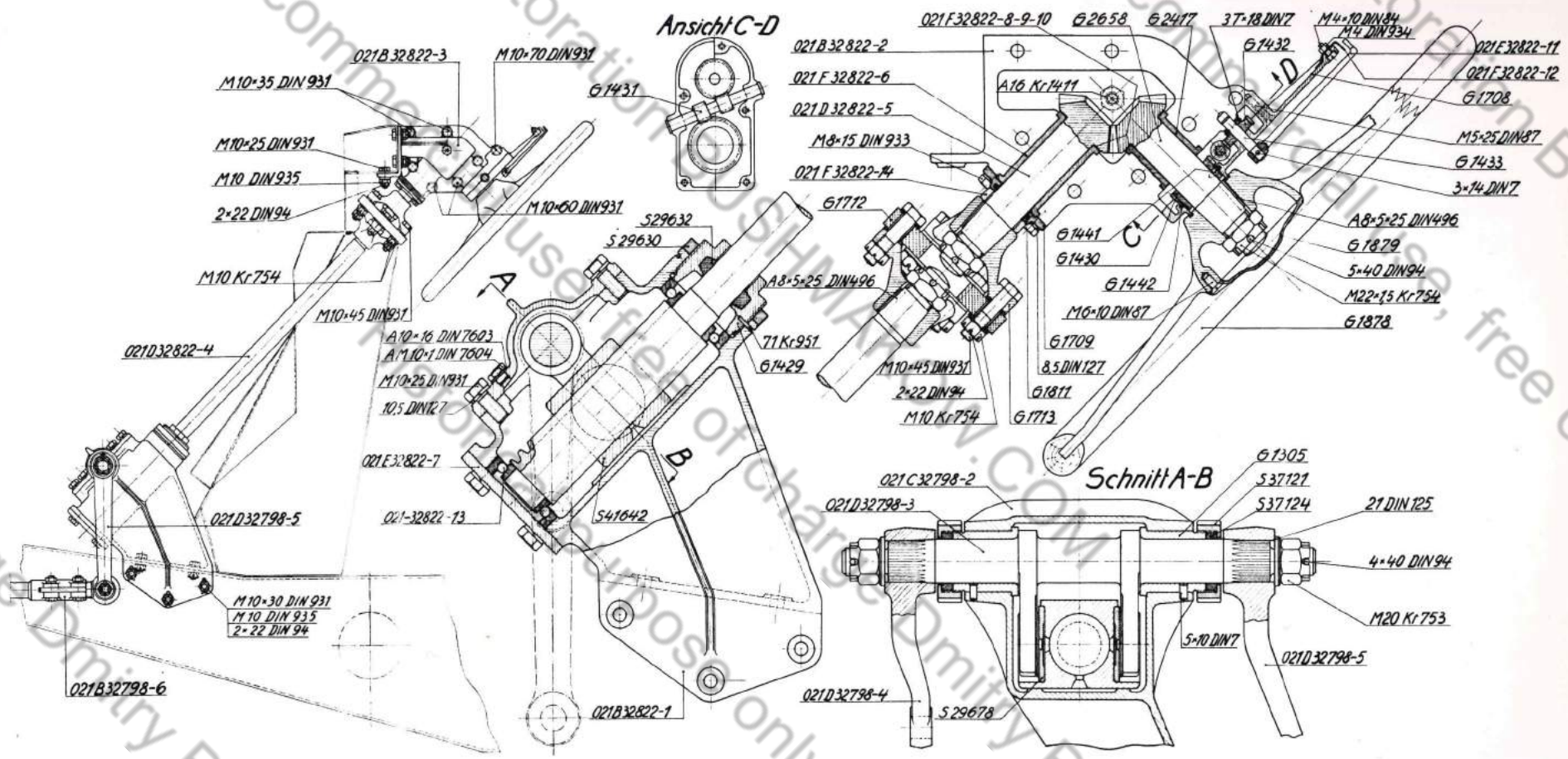
Skizze 9



Lenkung

021 B 32 822 U 1

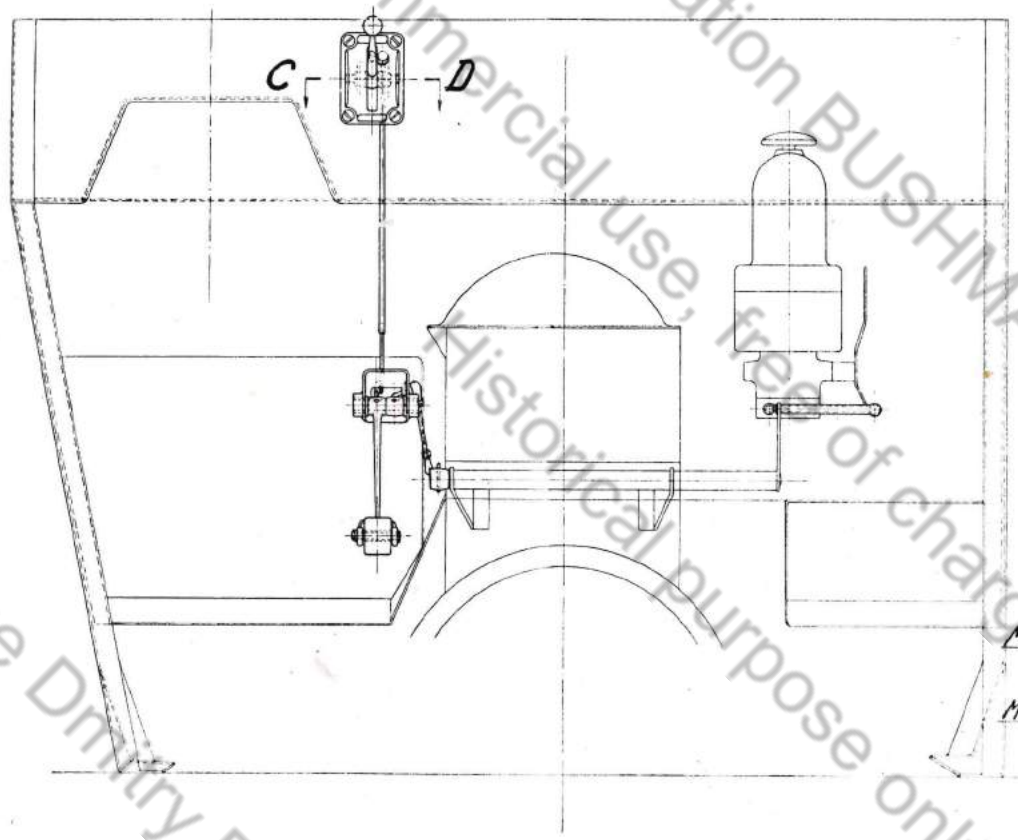
Skizze 10

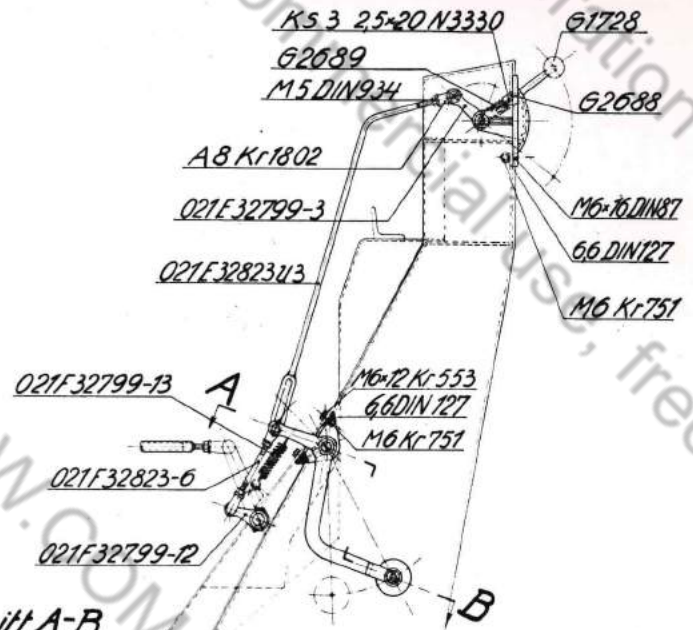


Gasgestänge

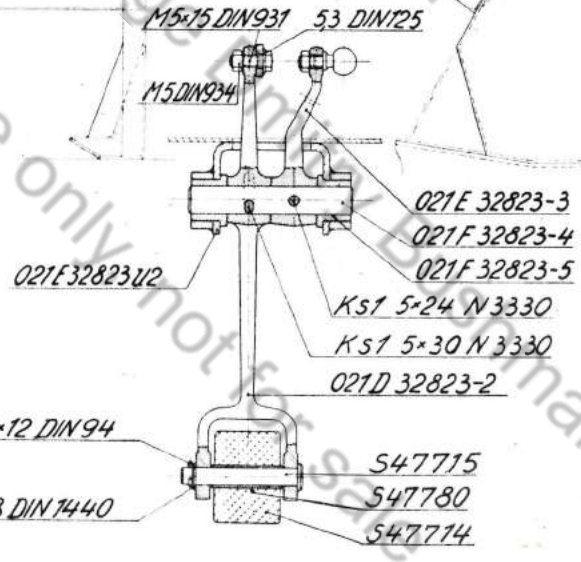
021 B 32 823 U 8

Skizze 11

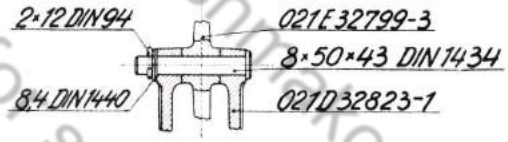




Schnitt A-B



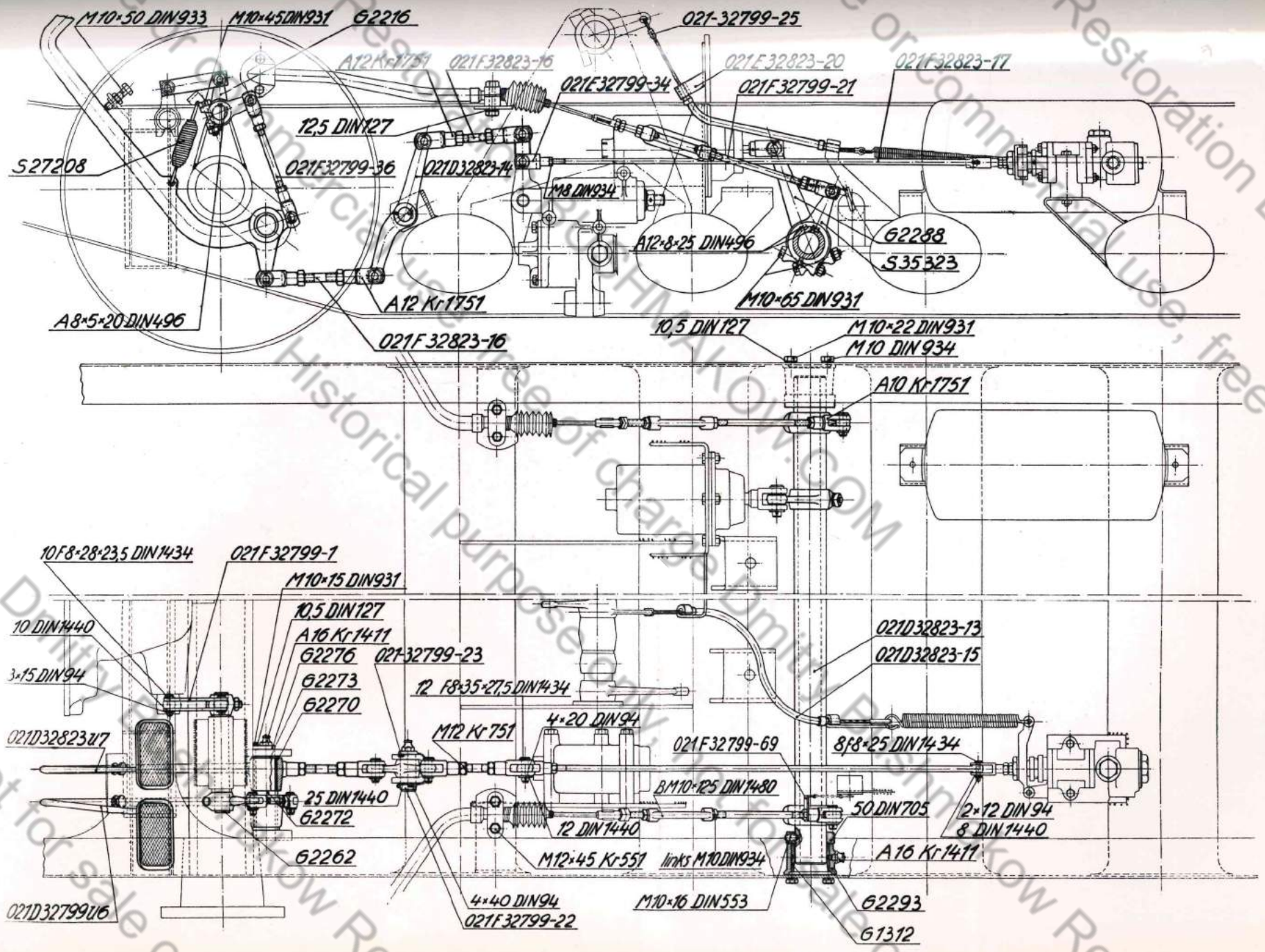
Schnitt C-D



Kupplungs- und Bremsbetätigung

021 B 32 823 U 9

Skizze 12



Lenkbremsbetätigung, in Ansicht

021 B 32 799 U 17

Skizze 13

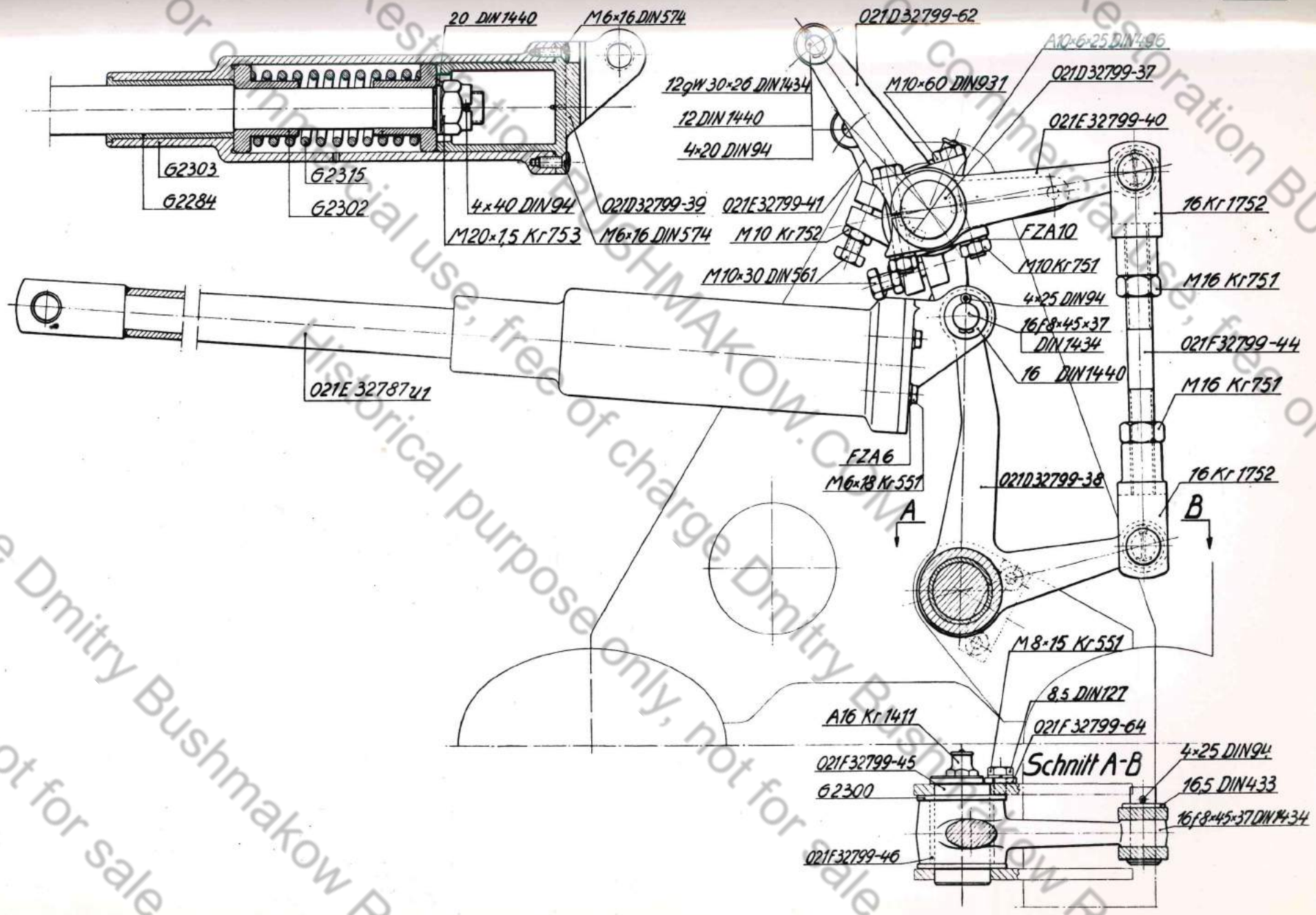
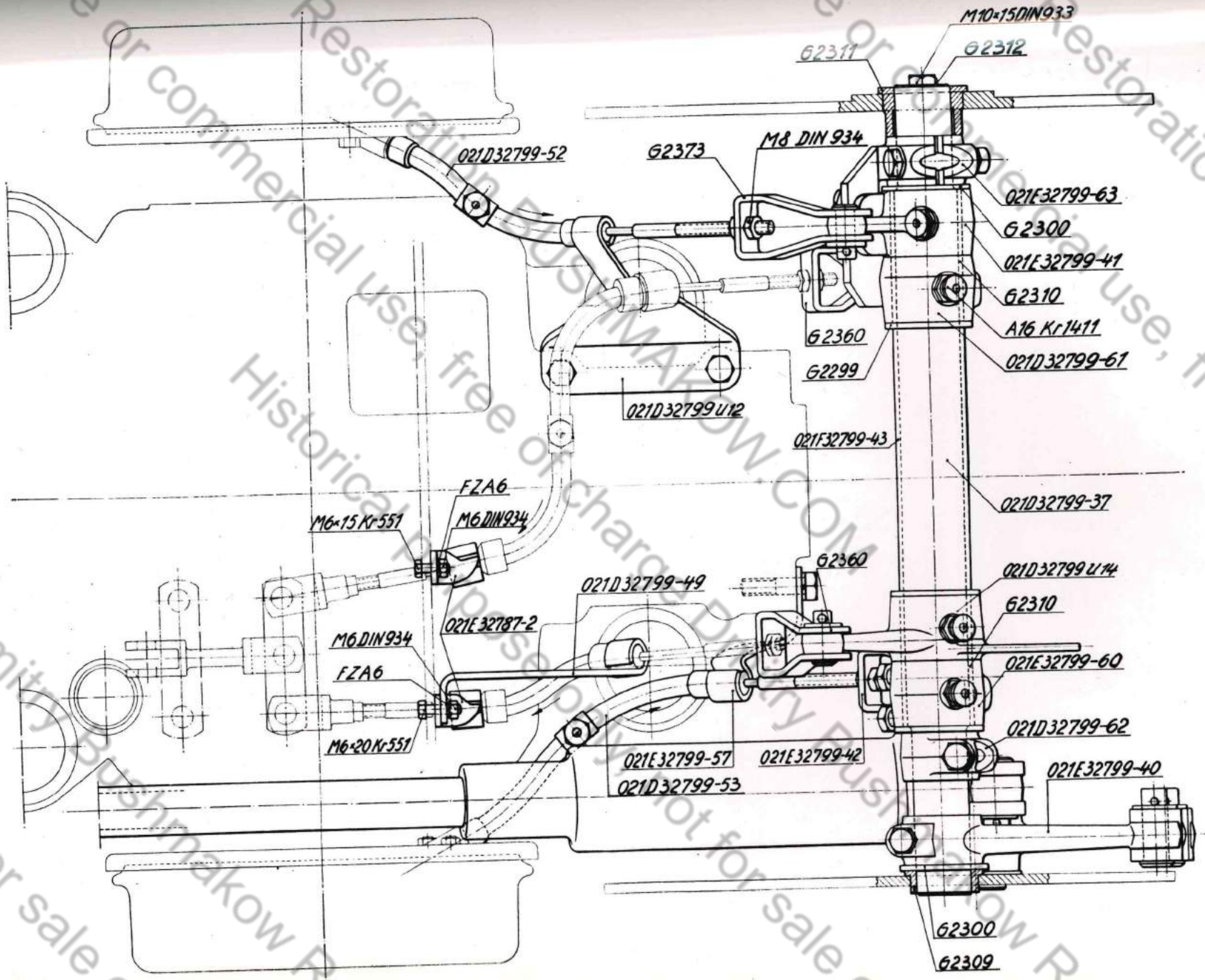


PLATE 13.

Lenkbremsbetätigung, in Draufsicht

021 B 32 799 U 18

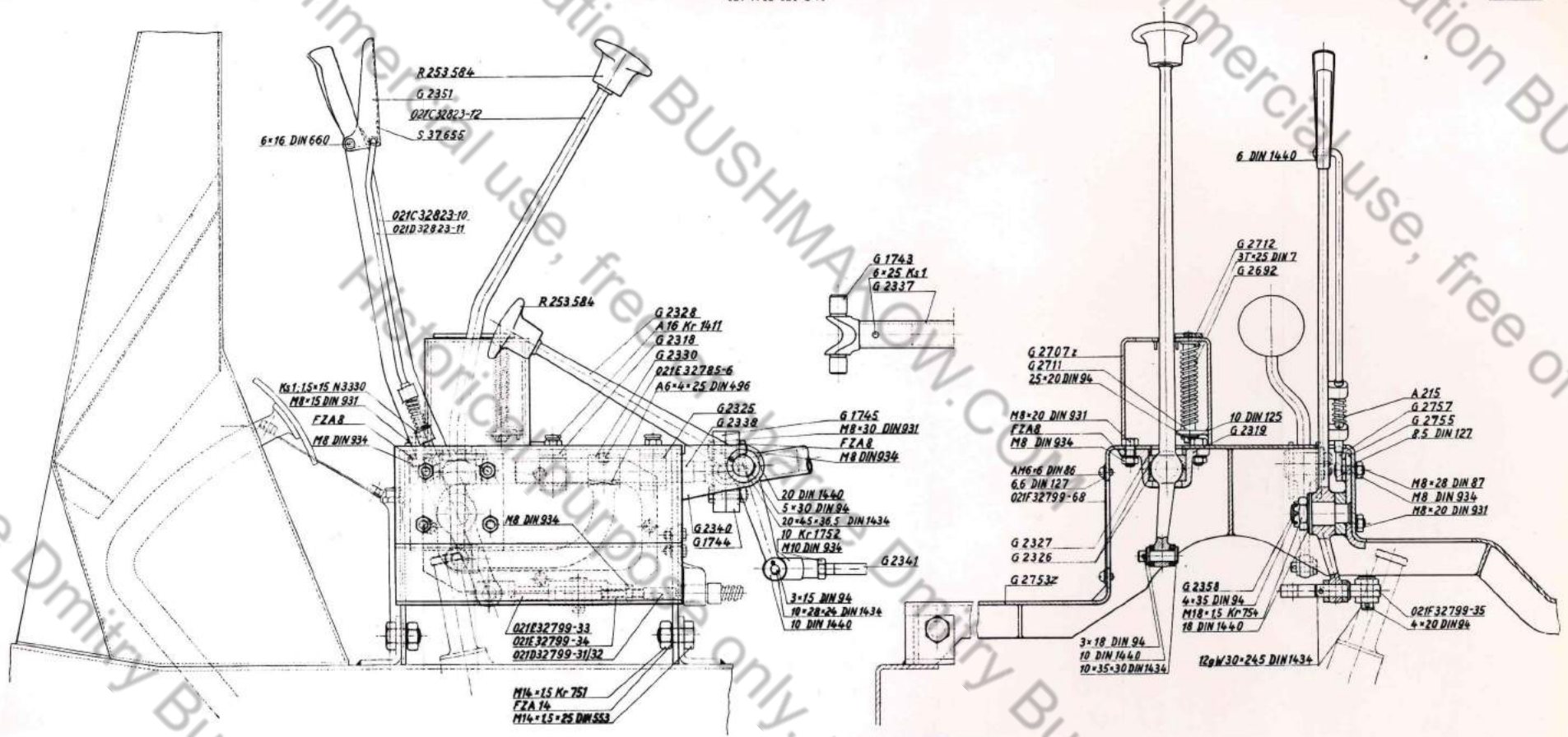
Skizze 14



Schalt- und Bremshebel

021 A 32 823 U 10

Skizze 15



Druckluftbremsanlage

021 B 32 824 U 3

Skizze 16

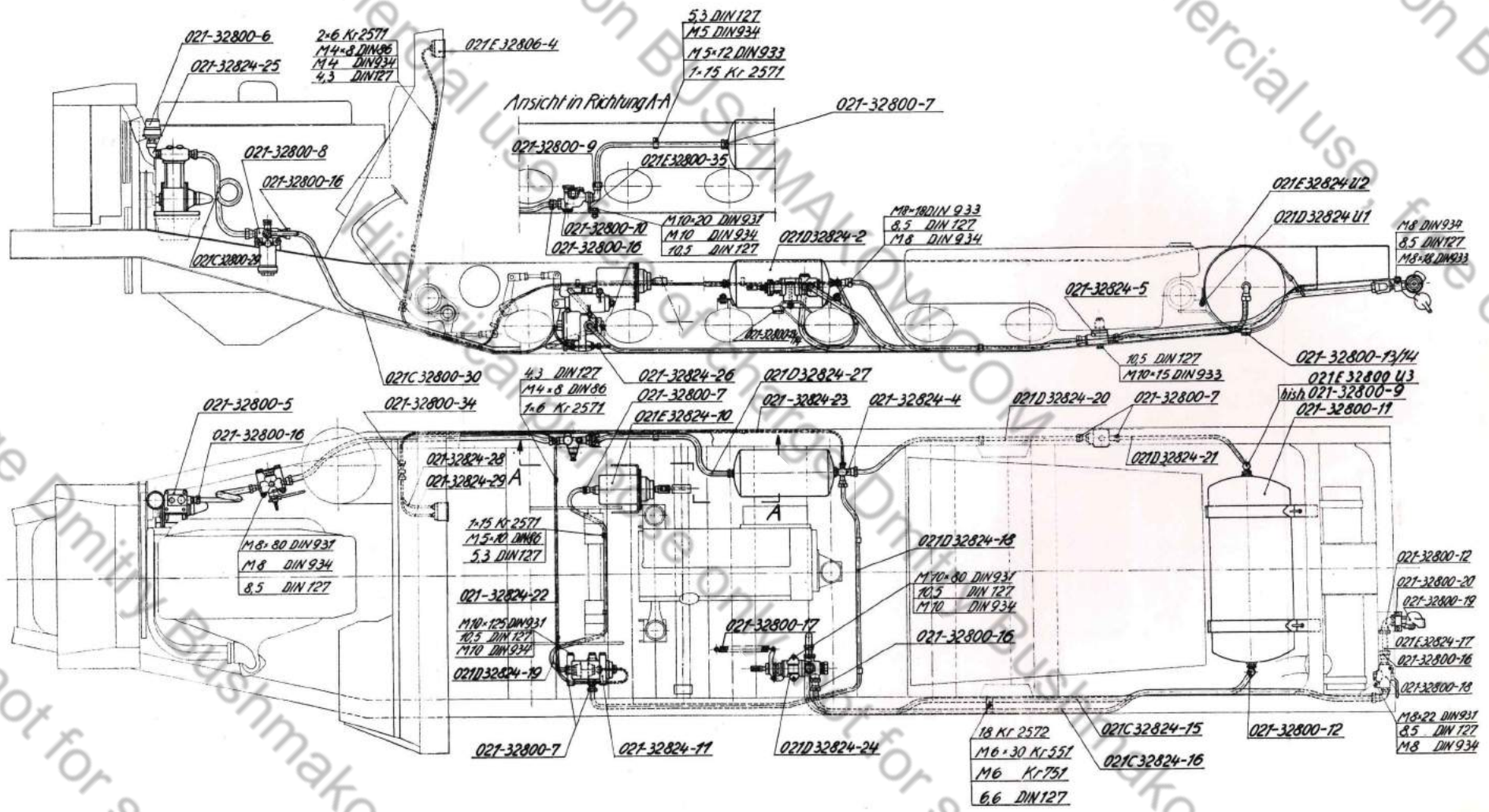


PLATE 16

Kühler und Windflügel

021 B 32 825 U 1

Skizze 17

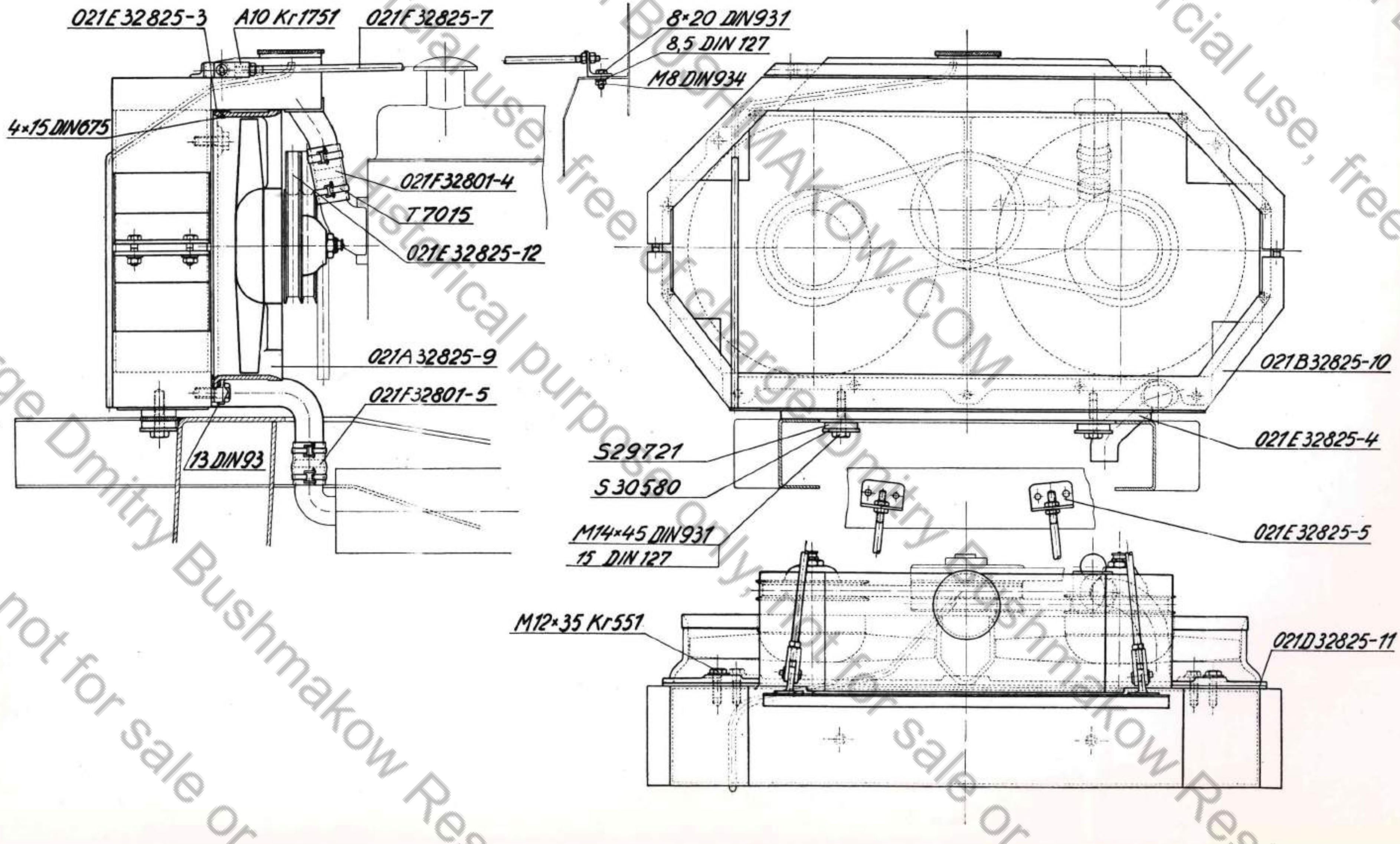
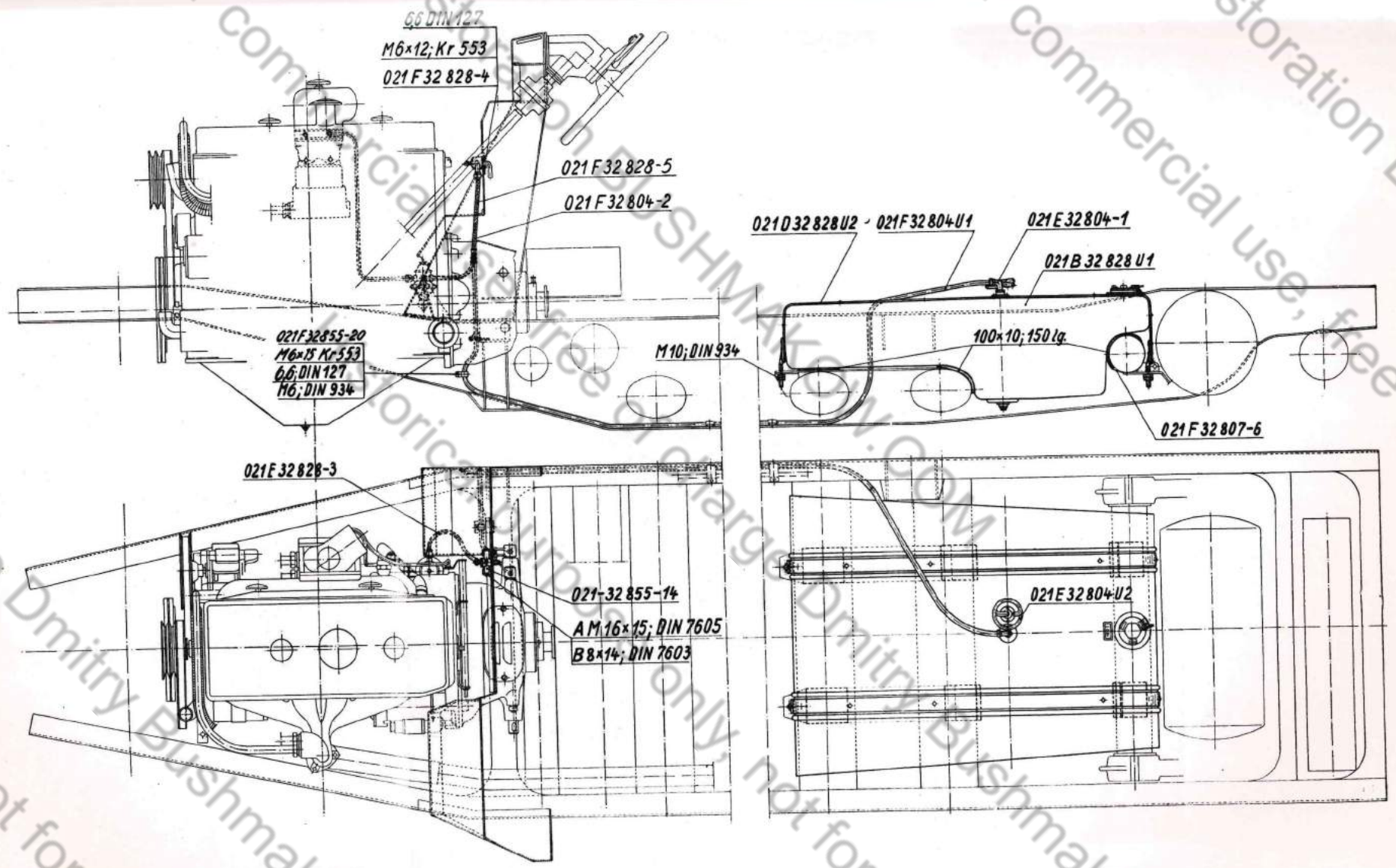


PLATE 17.

Kraftstoffbehälter

021 B 32 828 U 3

Skizze 18



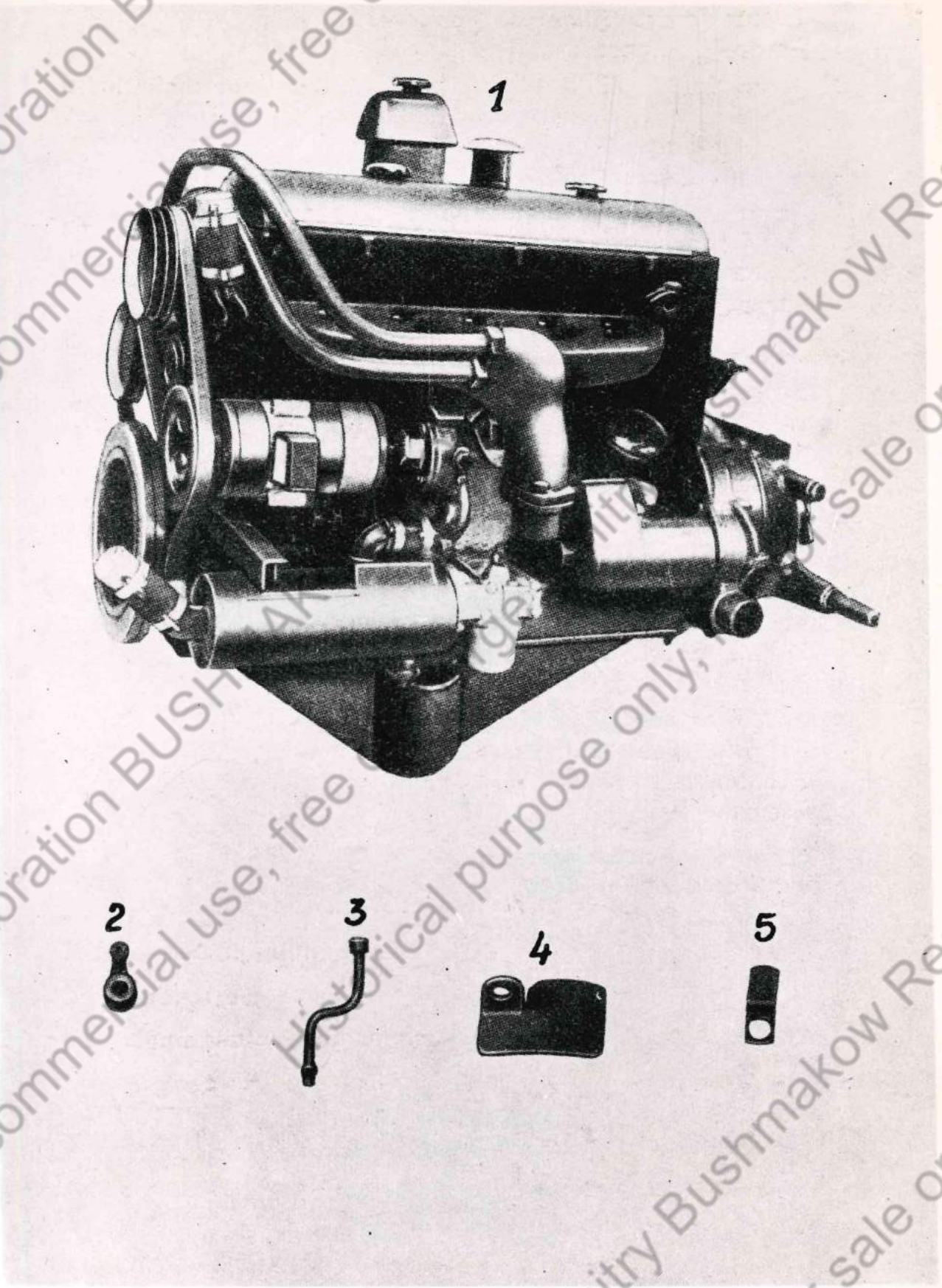


PLATE 19.

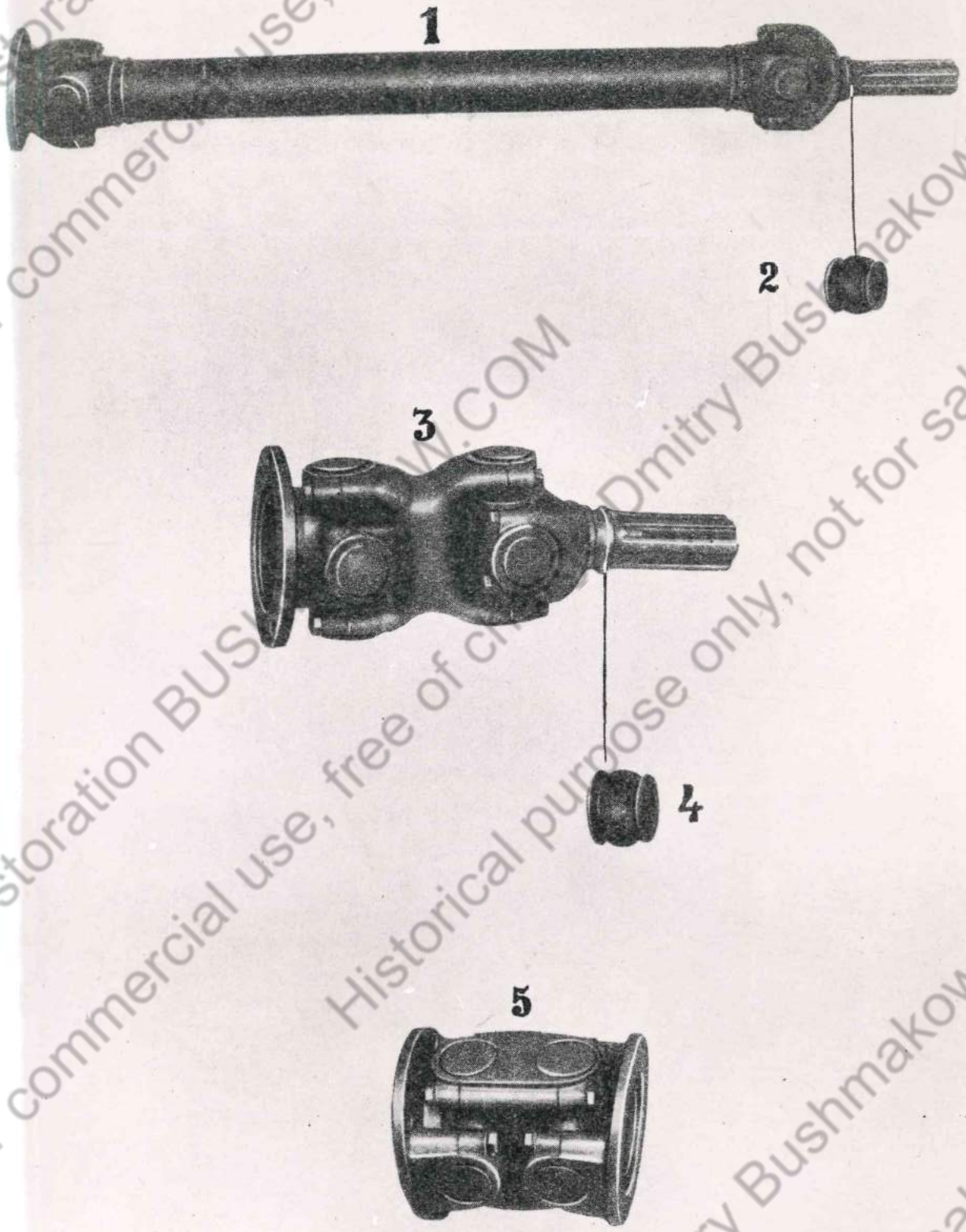


PLATE 20.

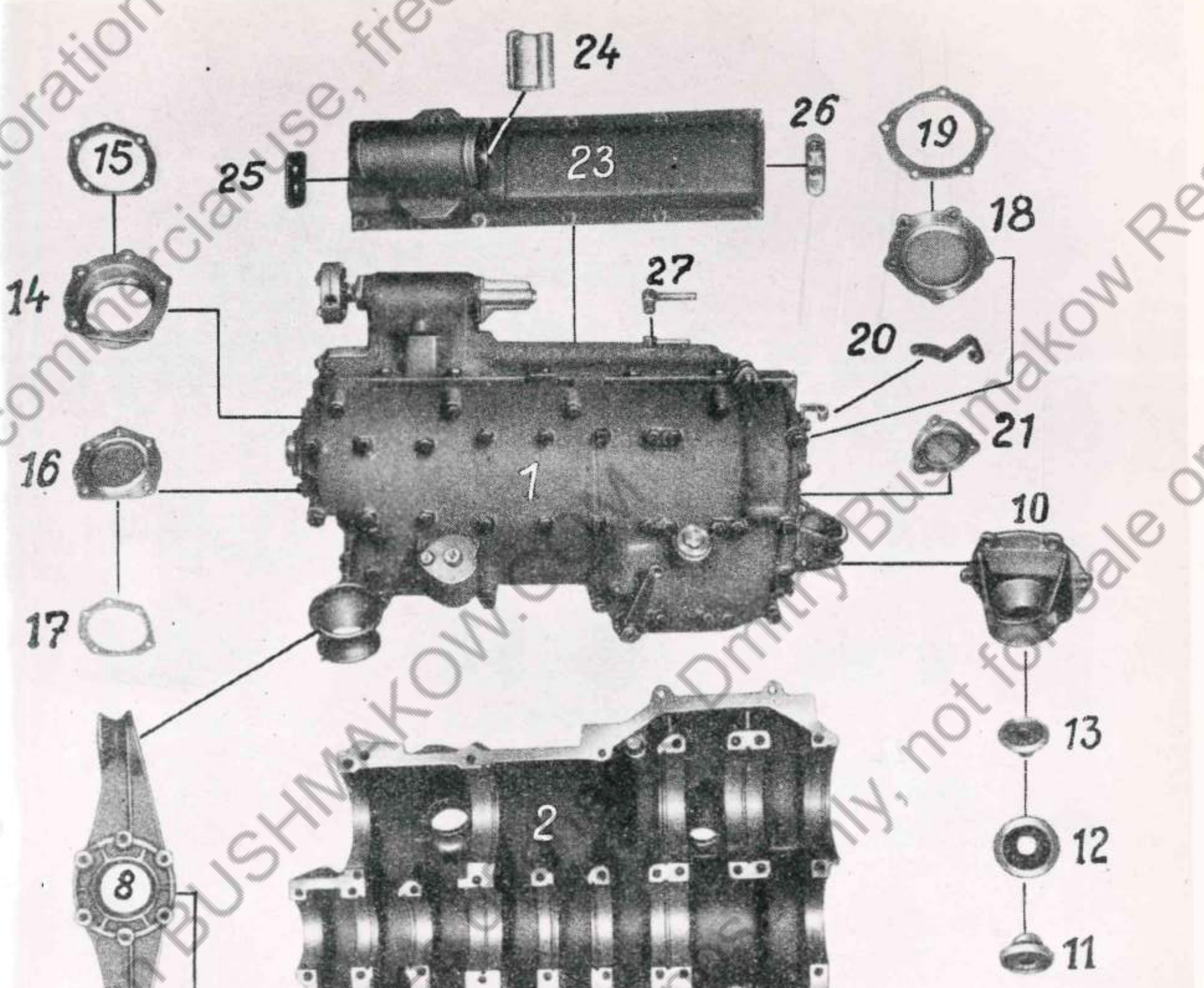
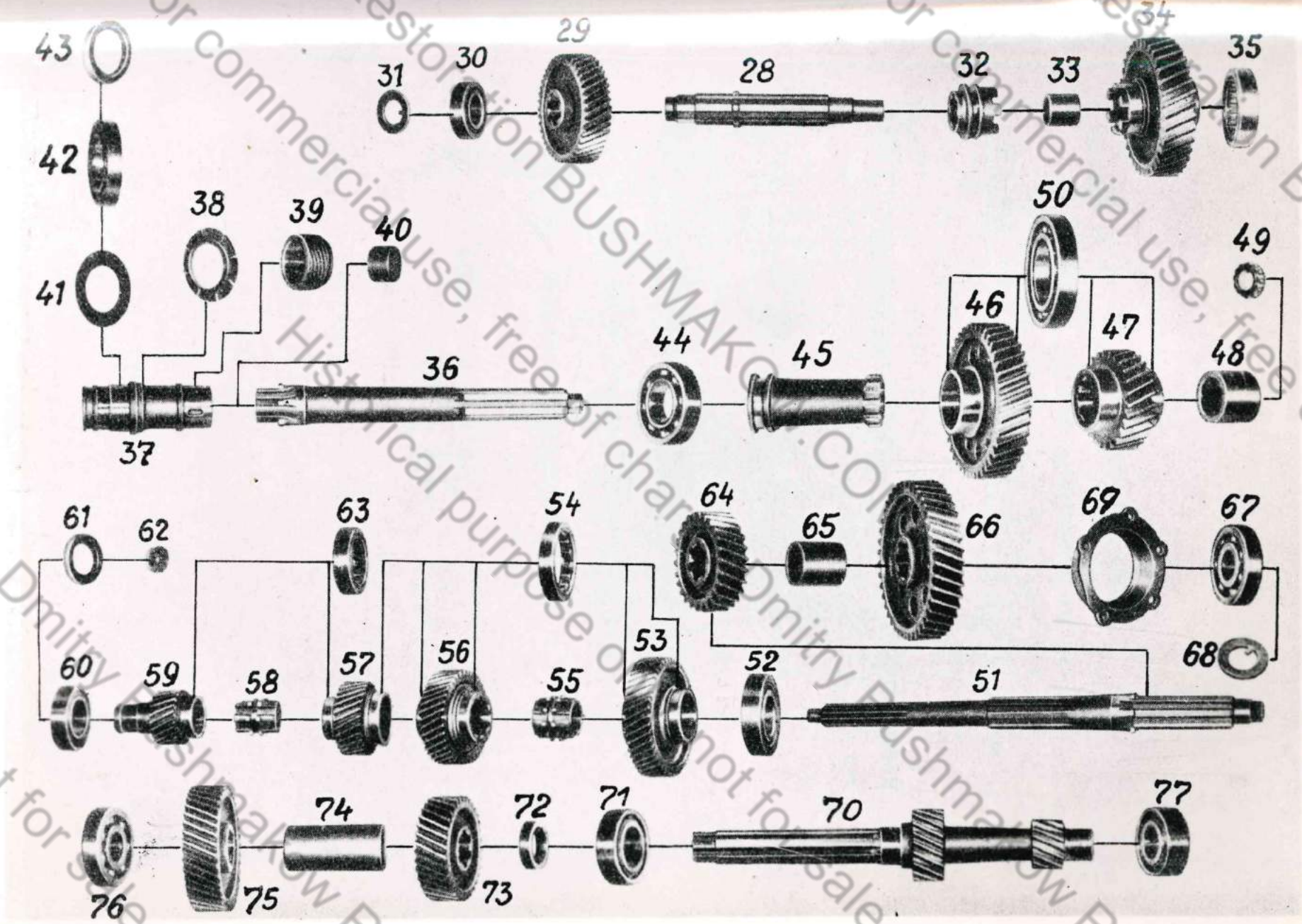


PLATE 21.



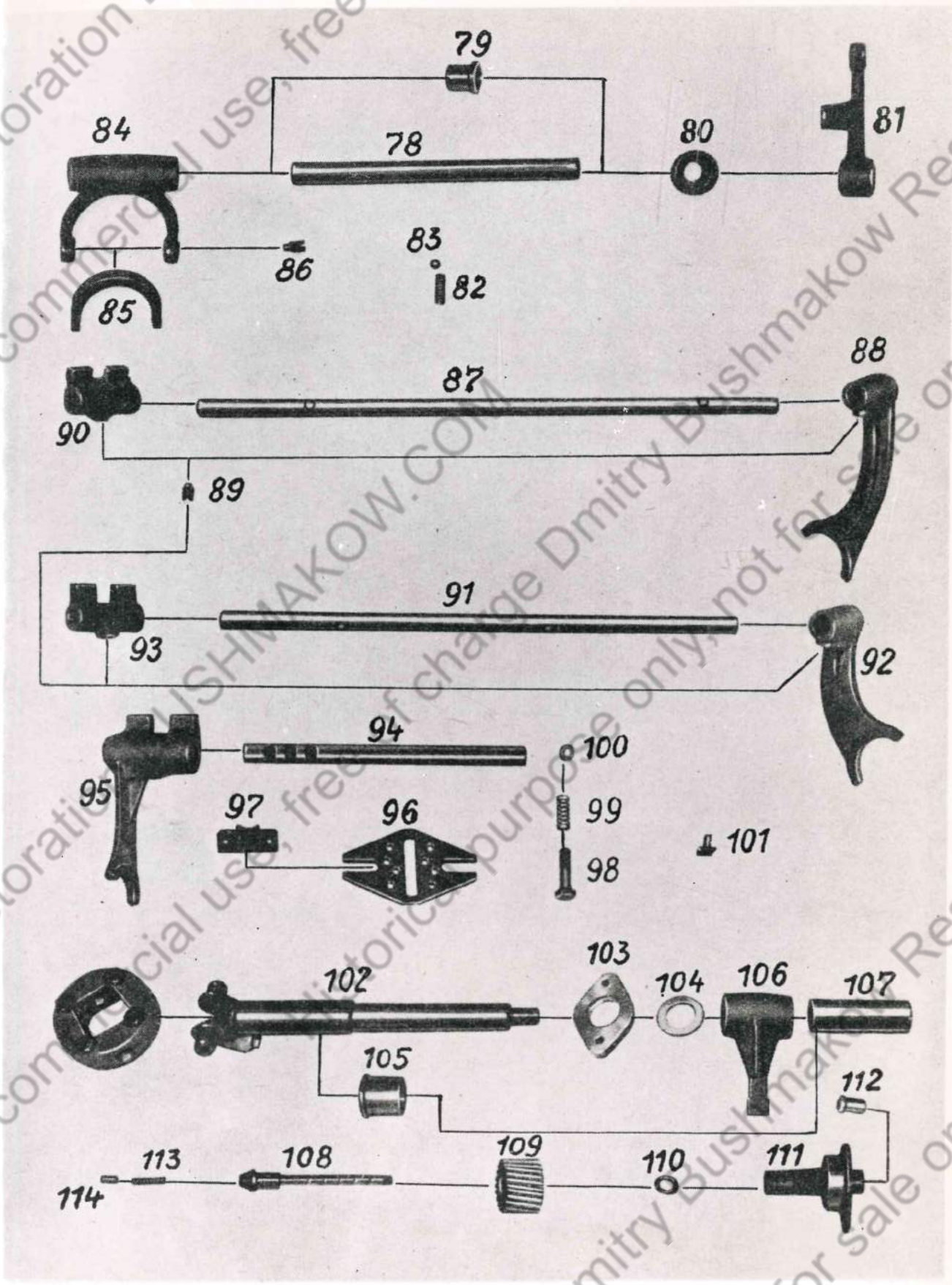
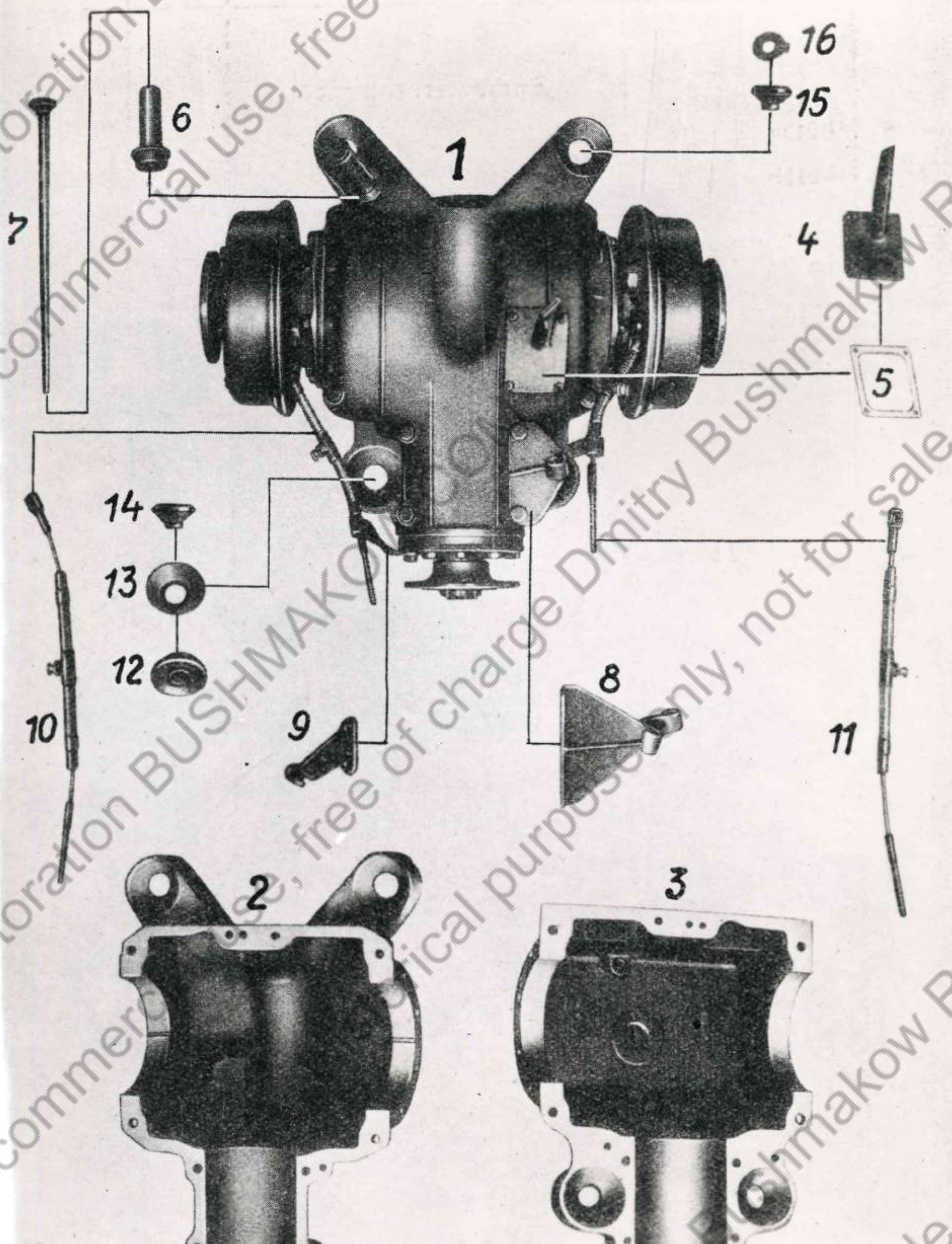


PLATE 28.



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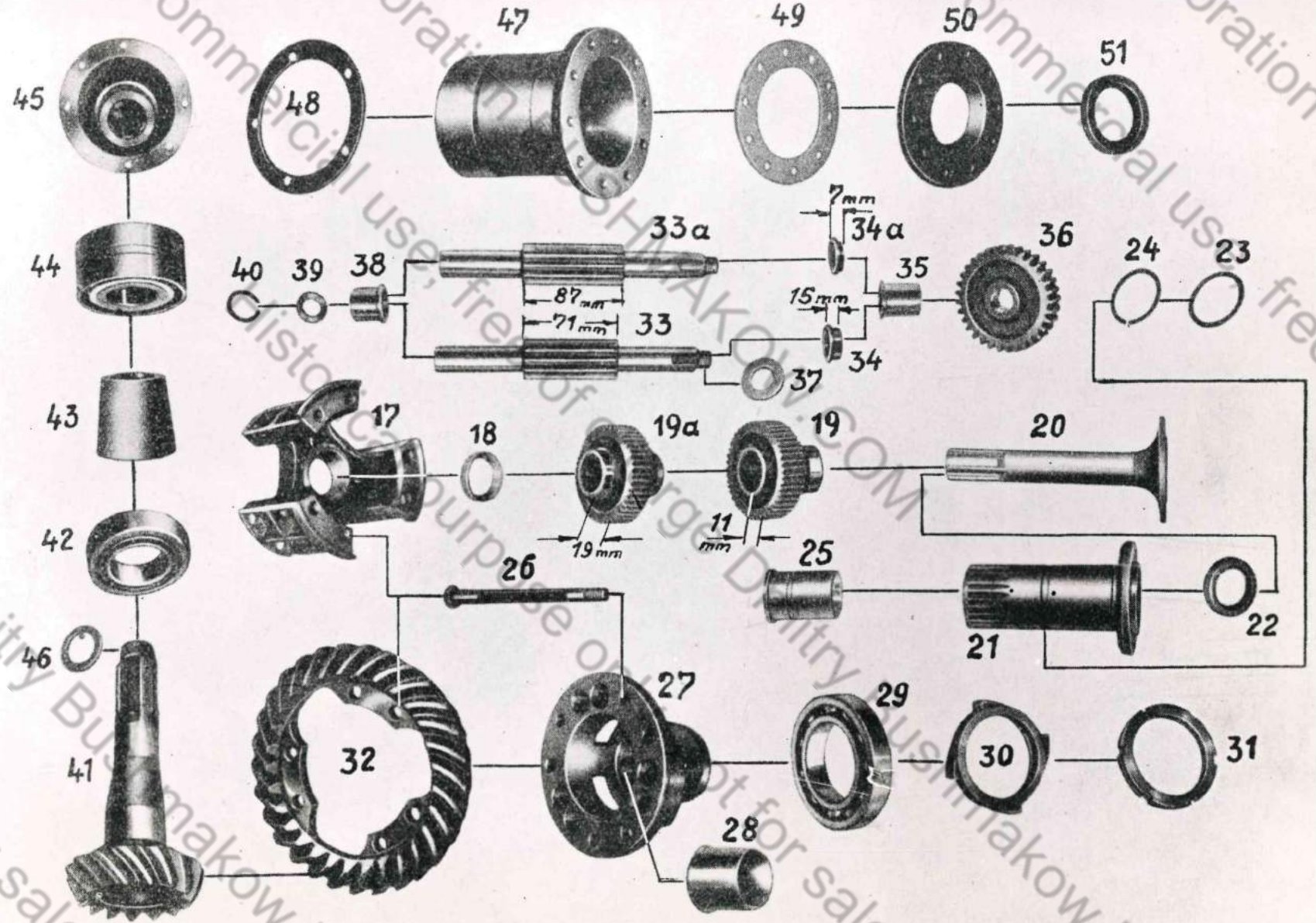
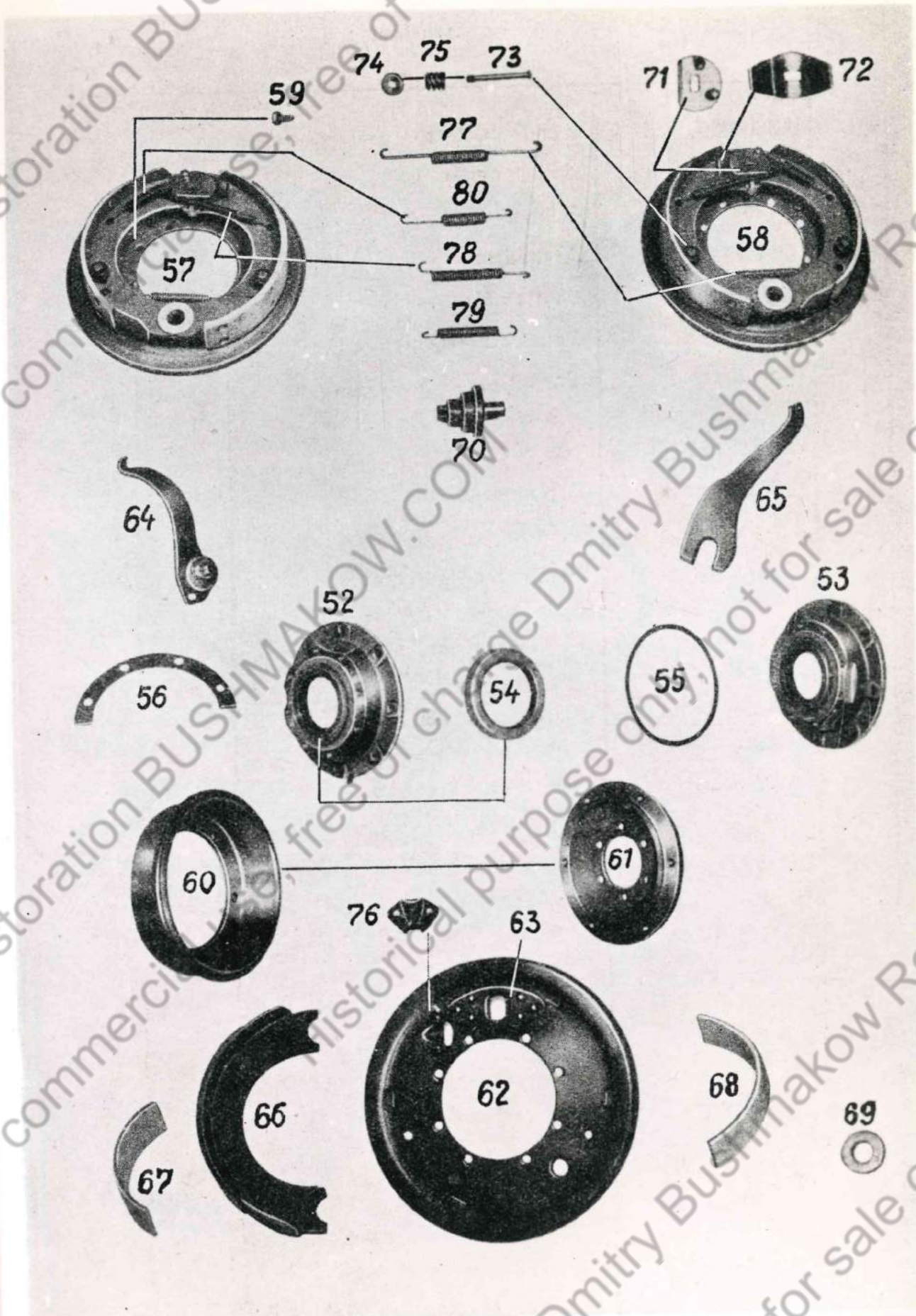


PLATE 25.



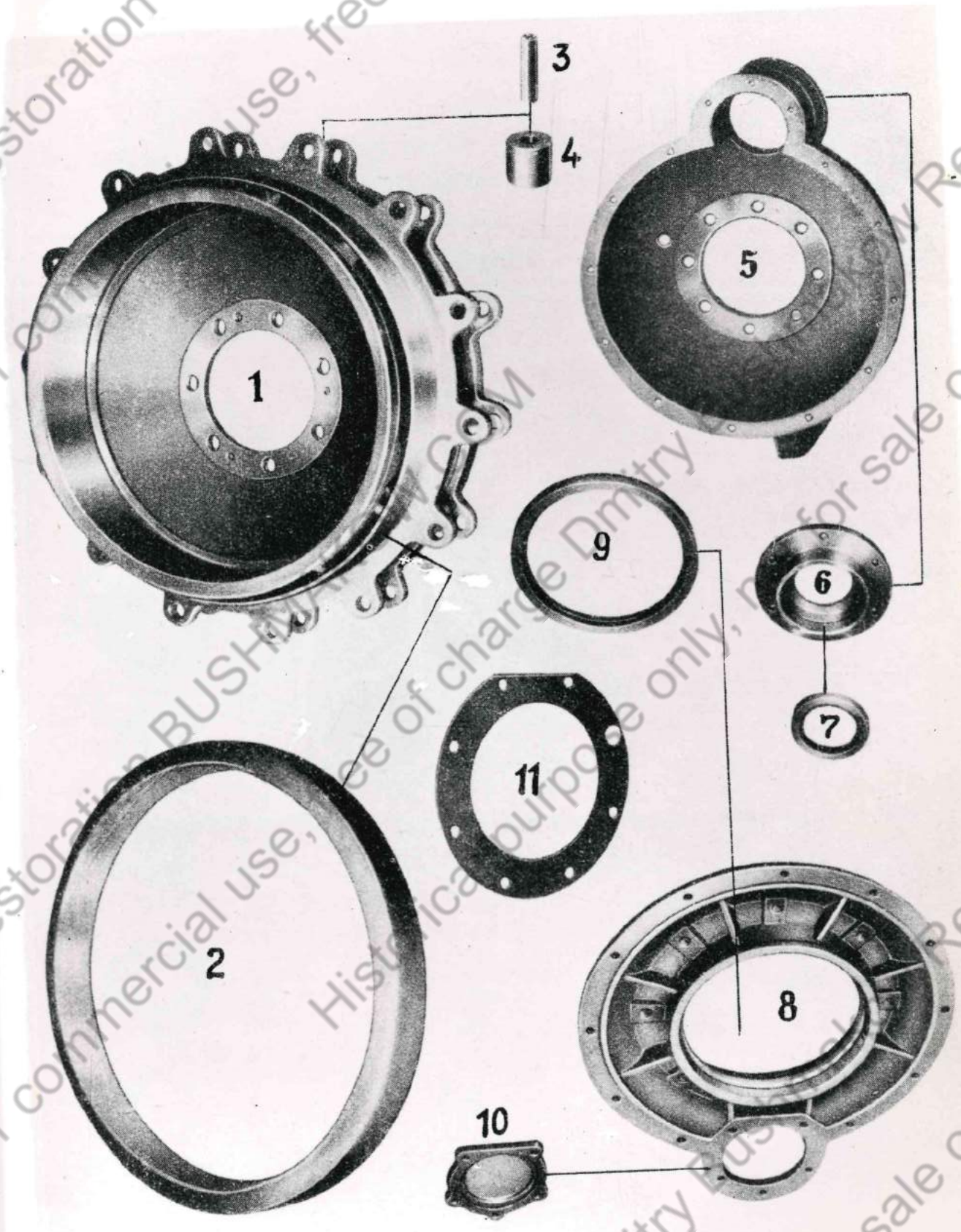


PLATE 27

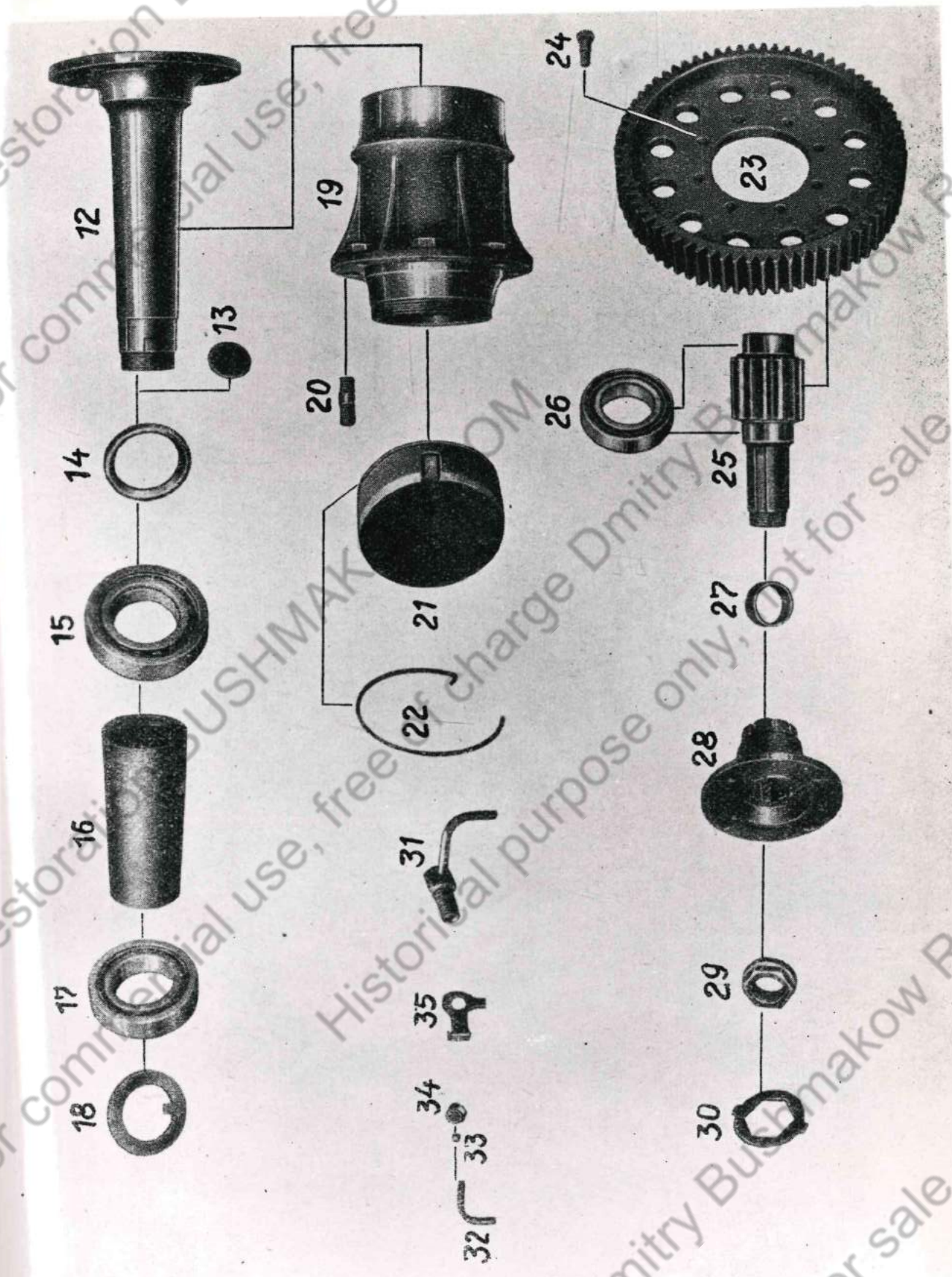


PLATE 28.

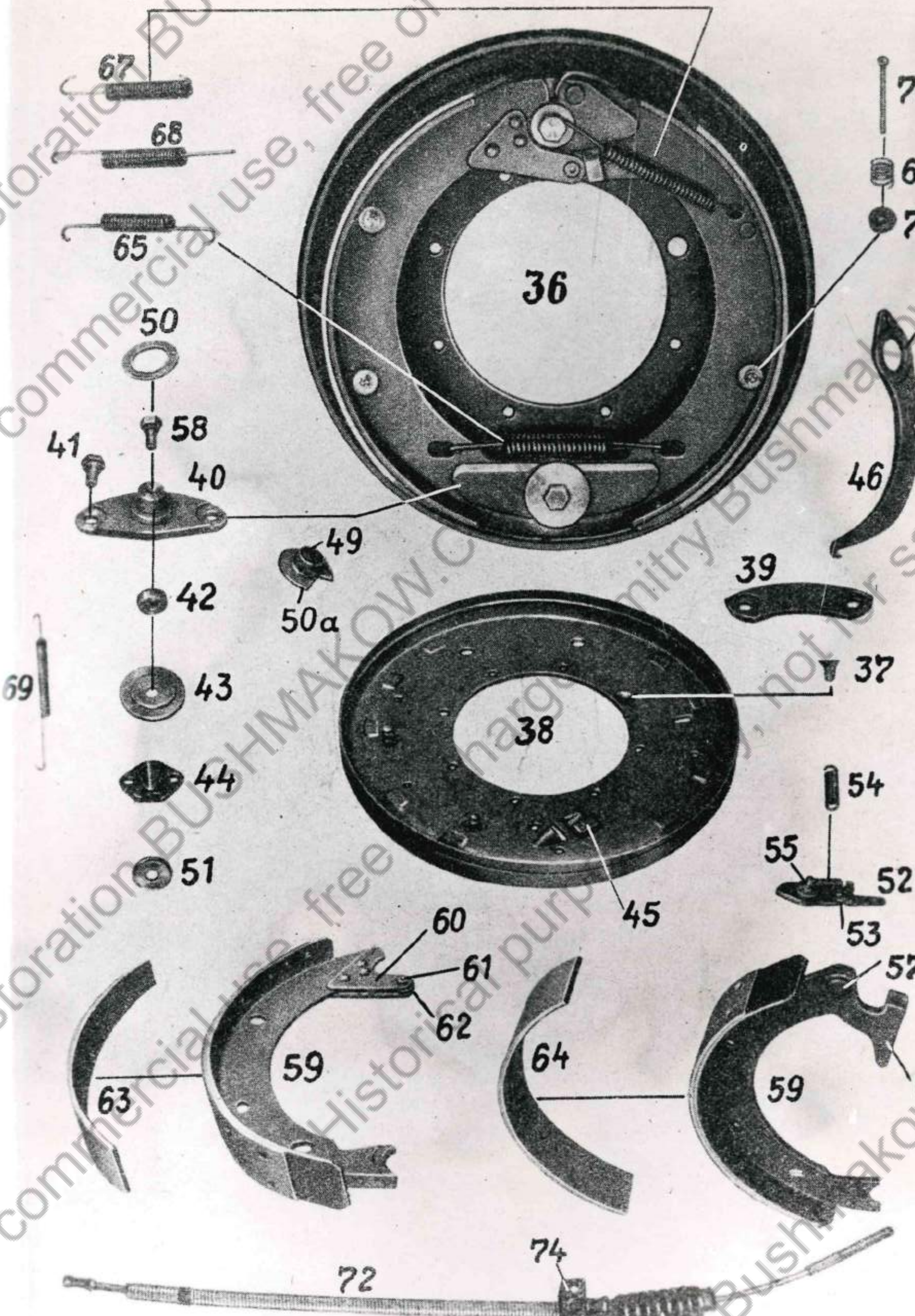

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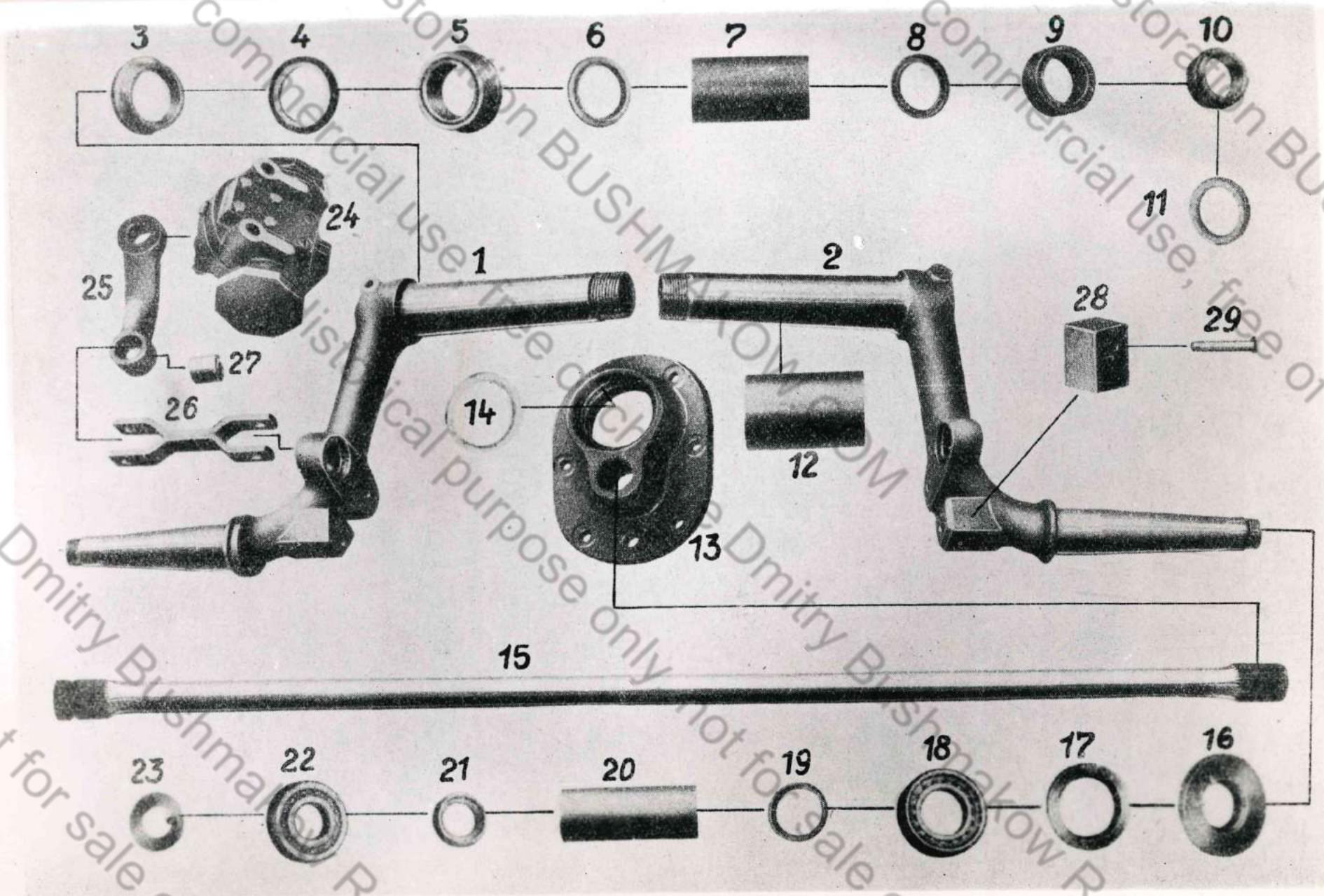
PLATE 29.



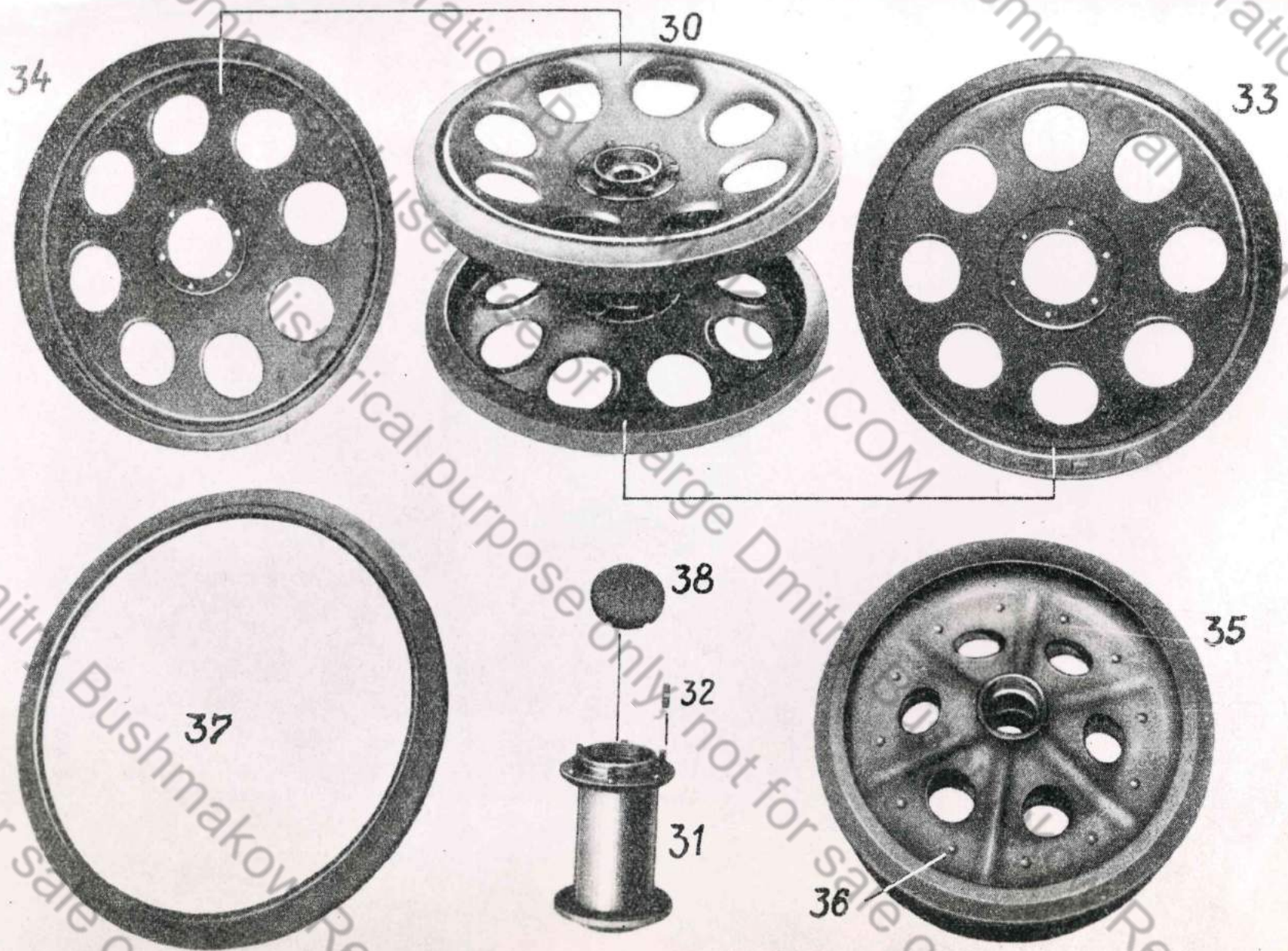
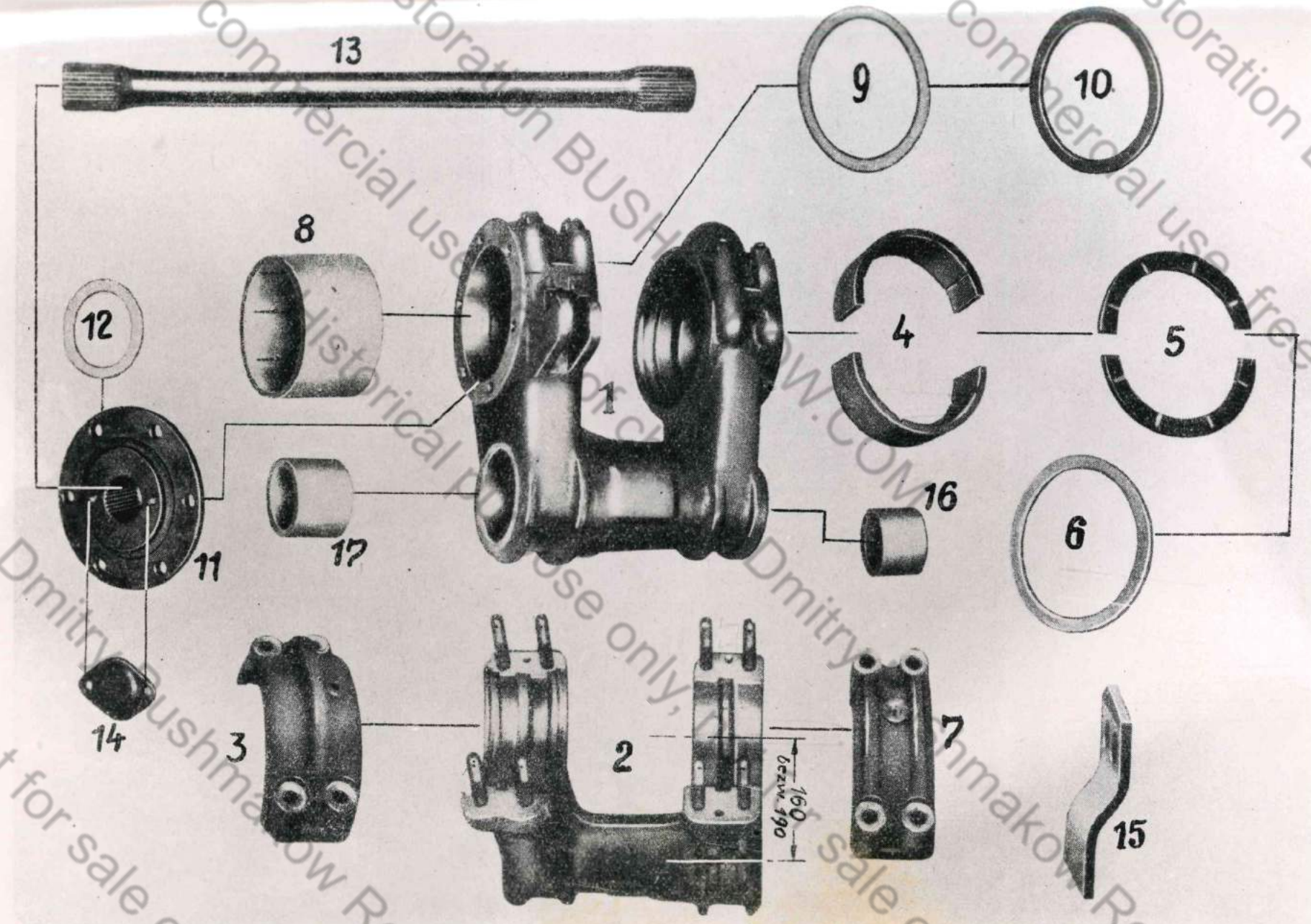


PLATE 51.



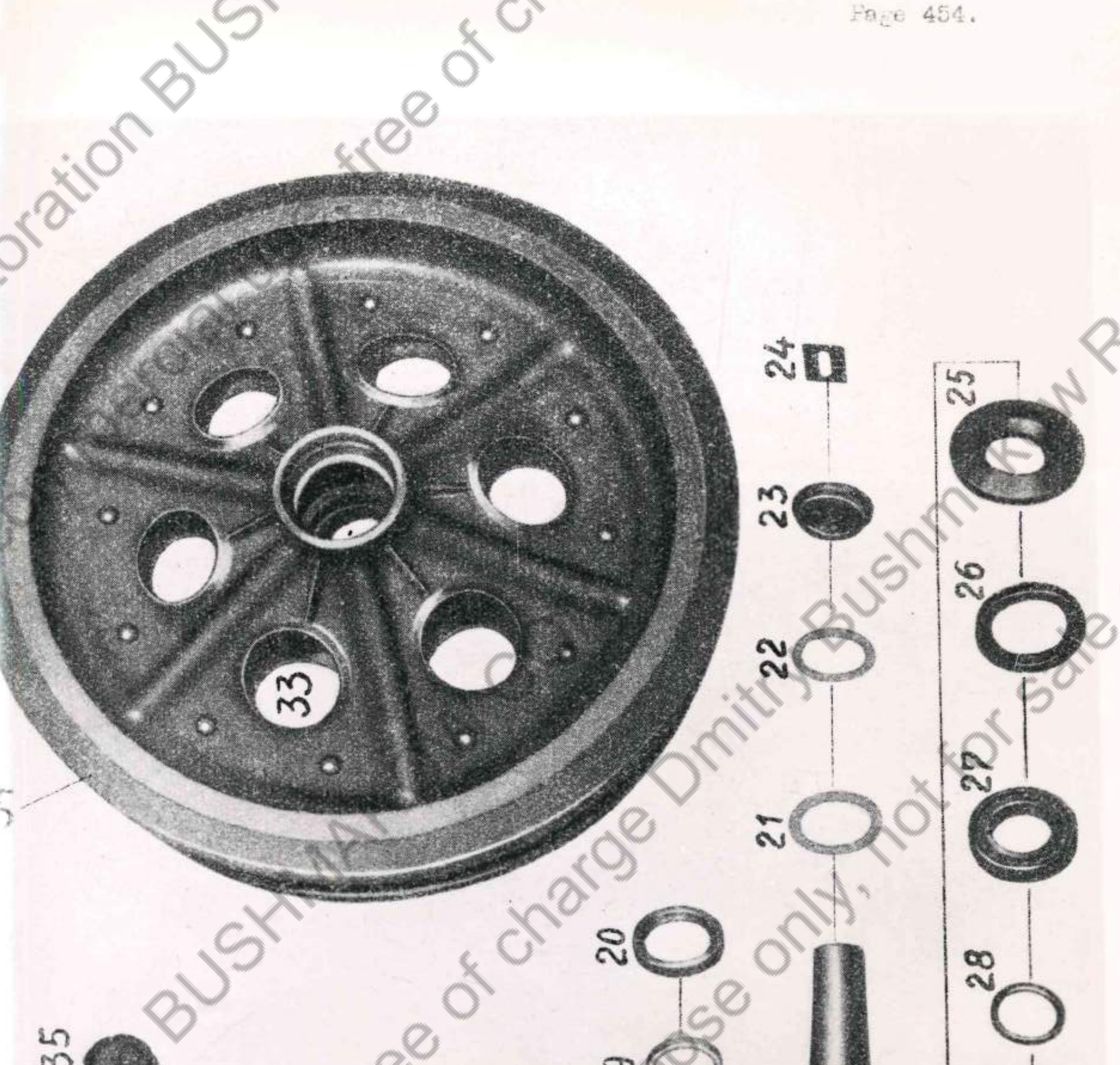


PLATE 33.

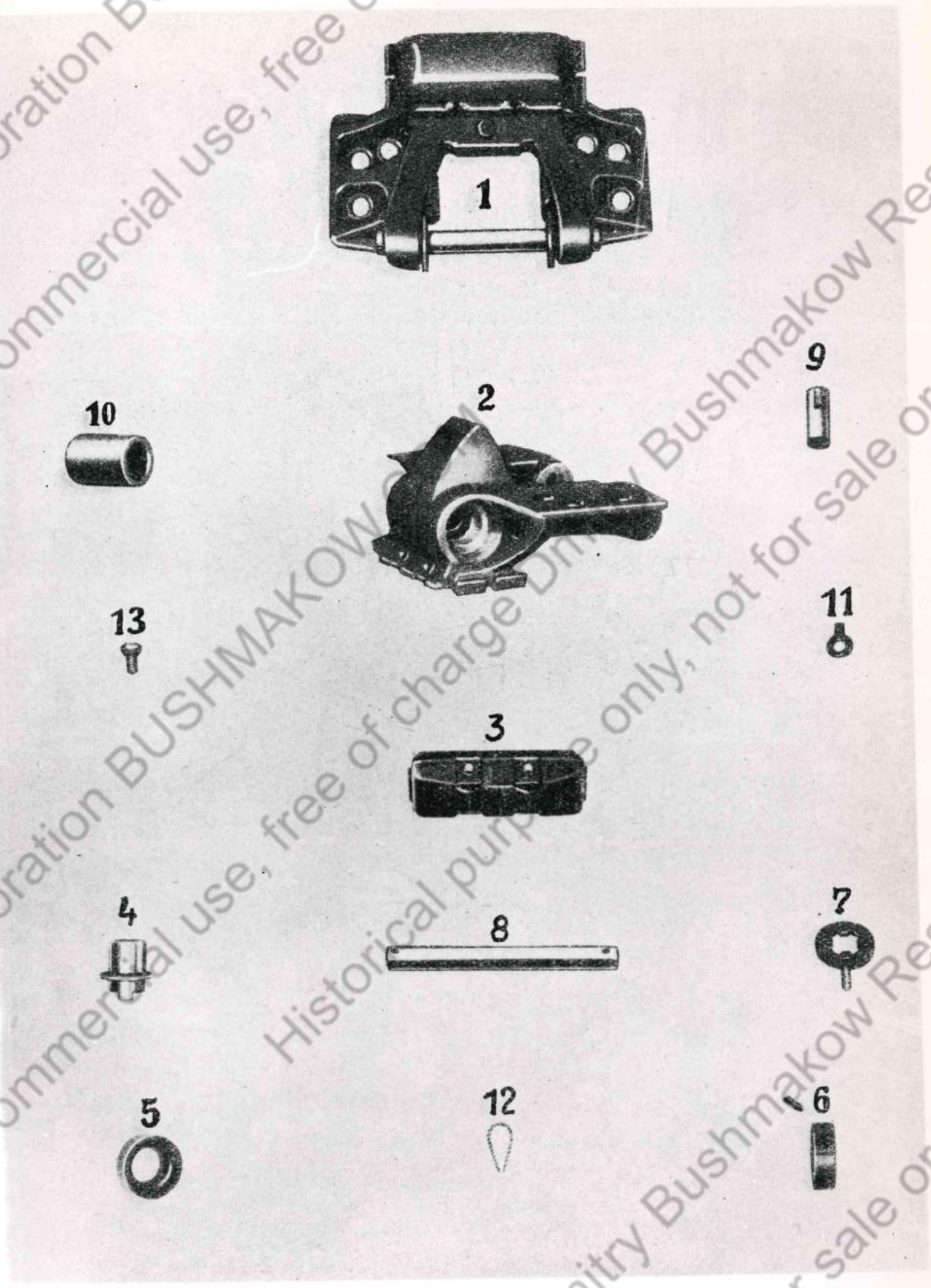
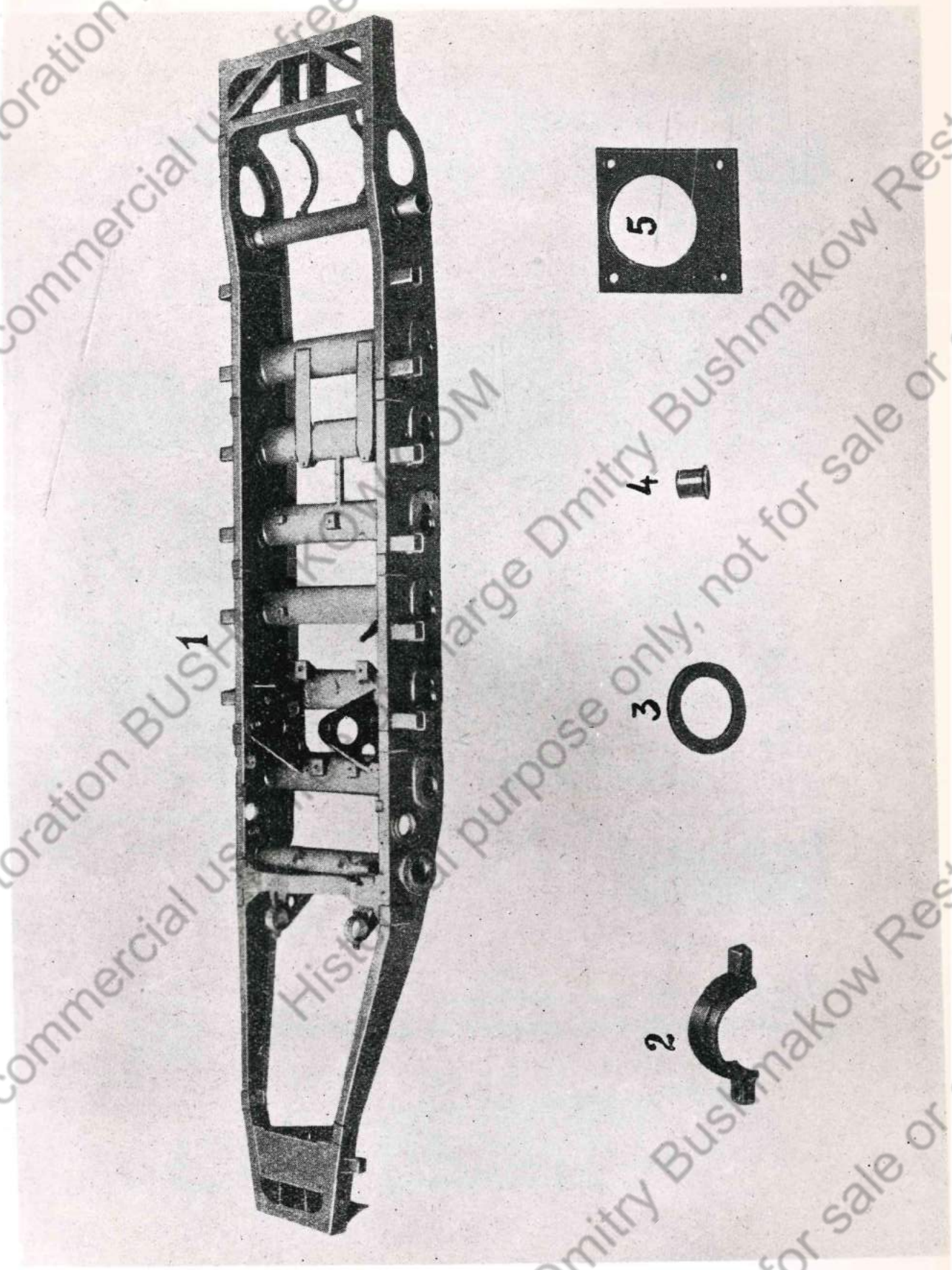


PLATE 34.



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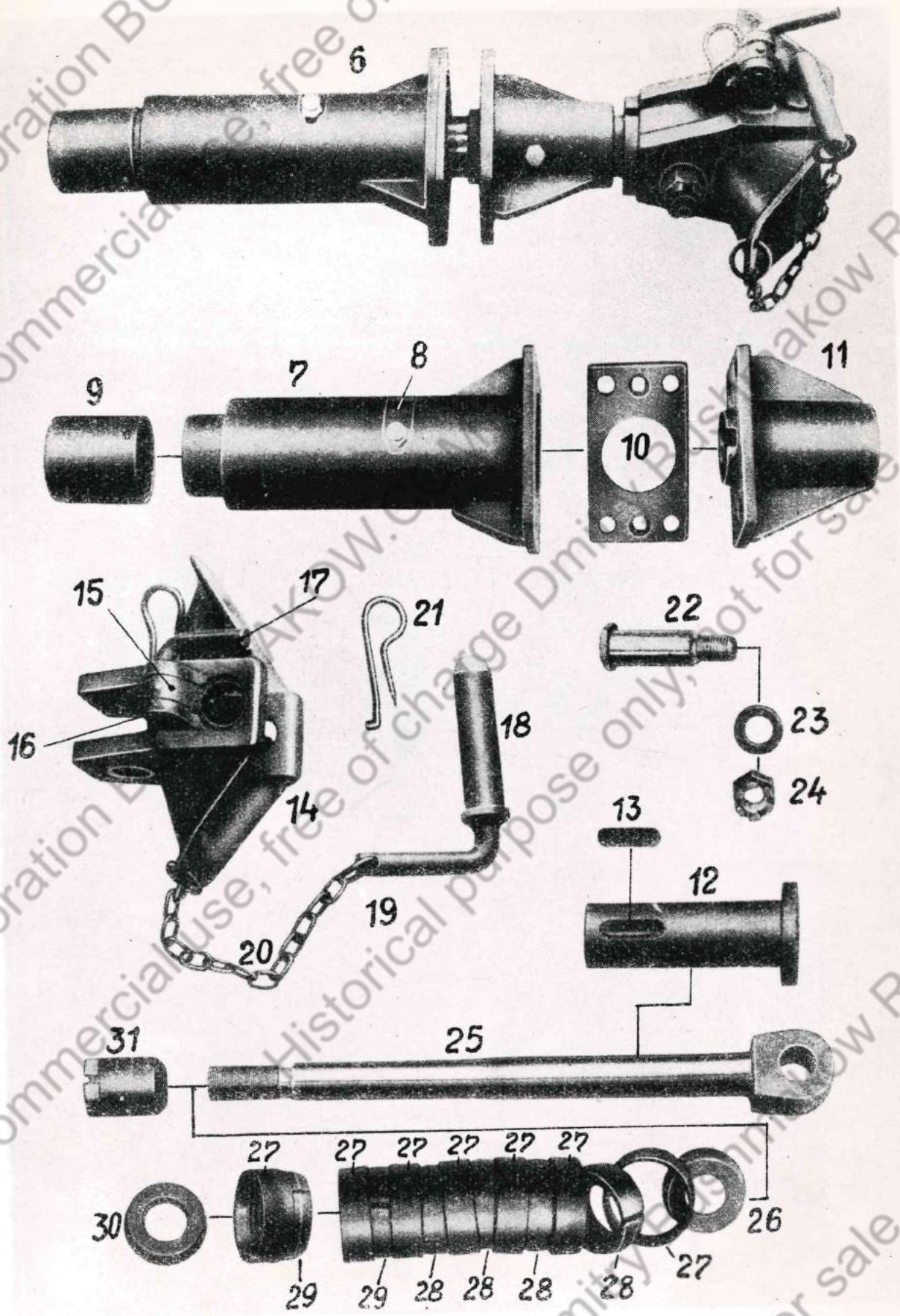

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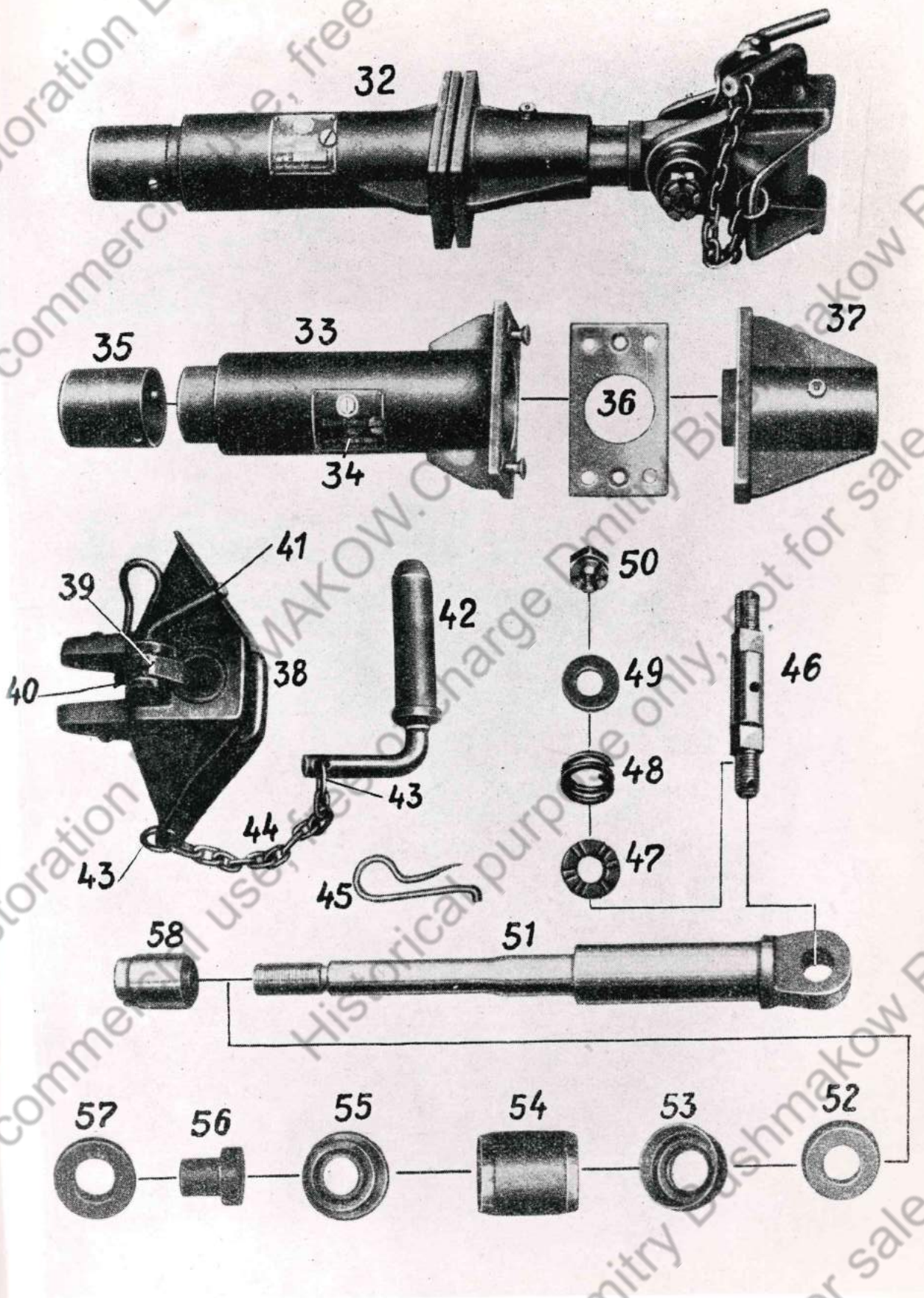

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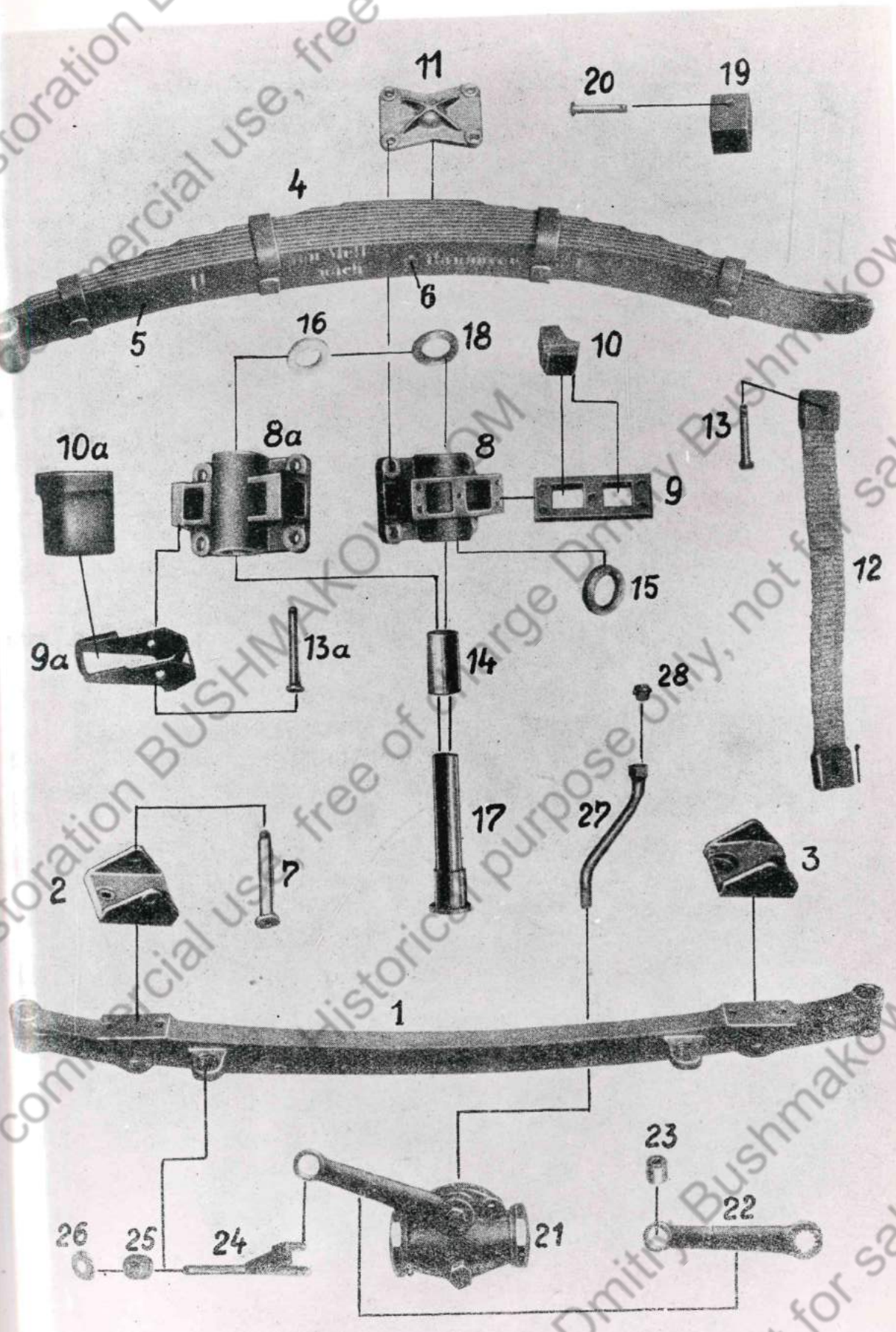

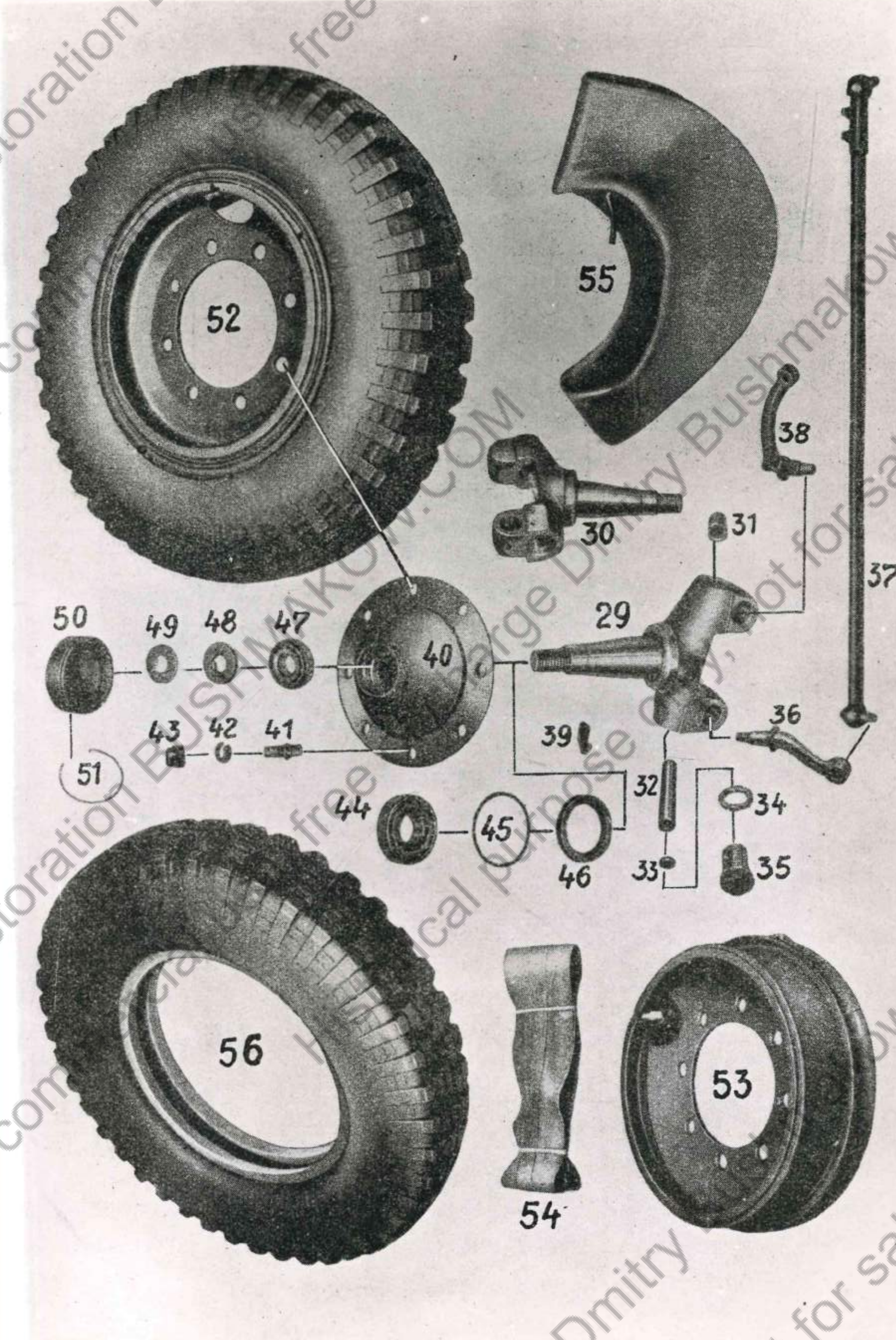

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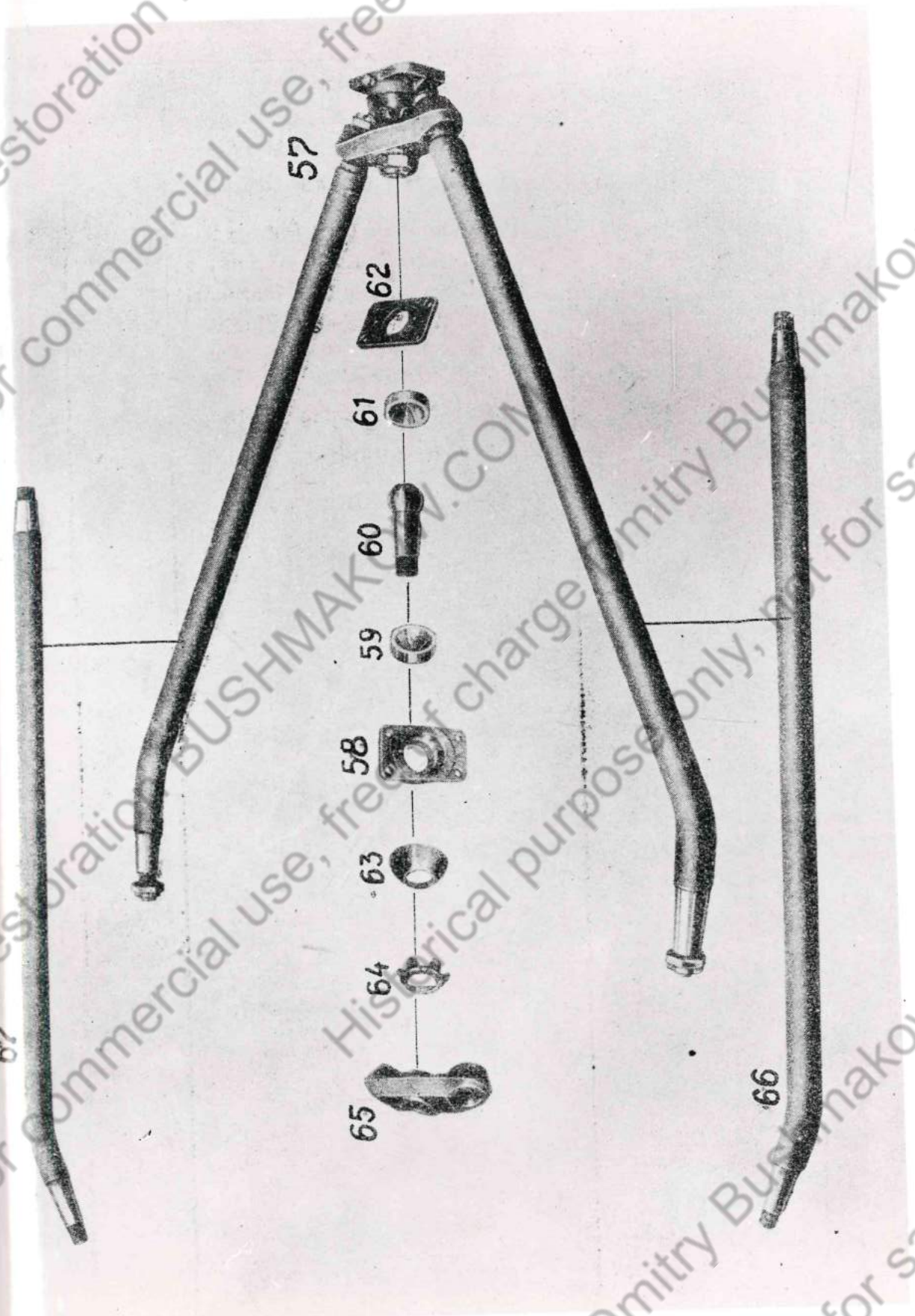

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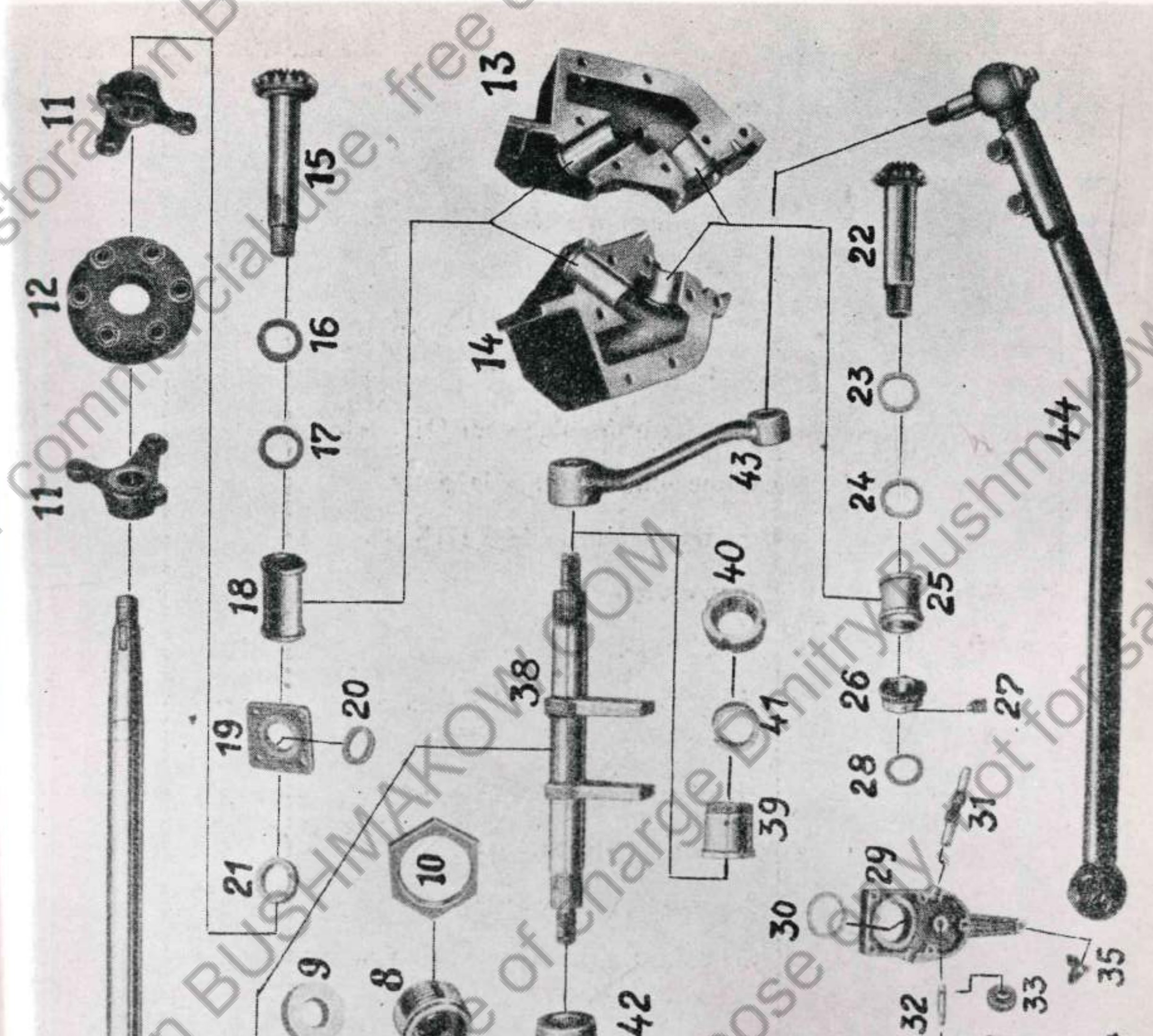
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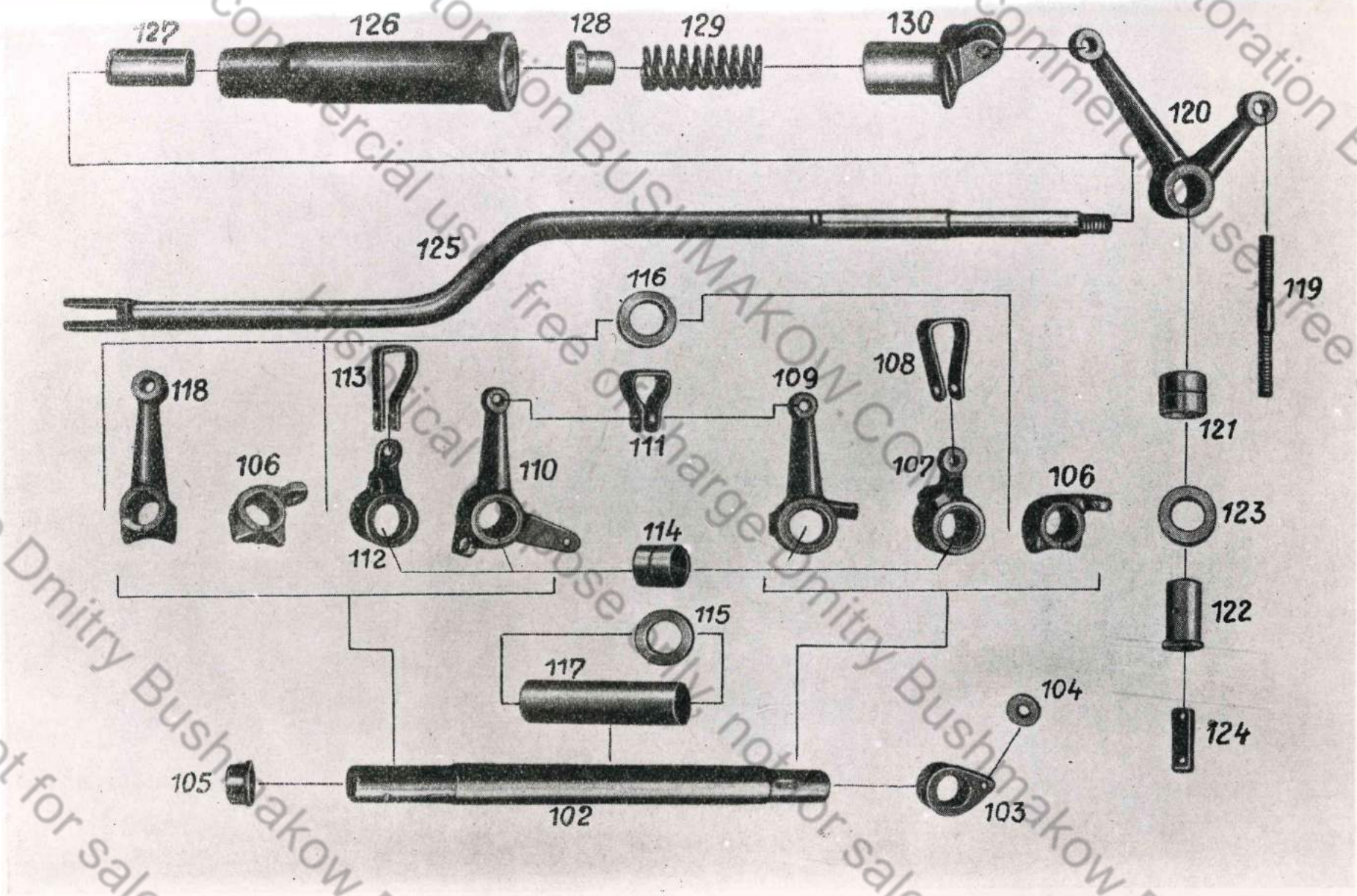
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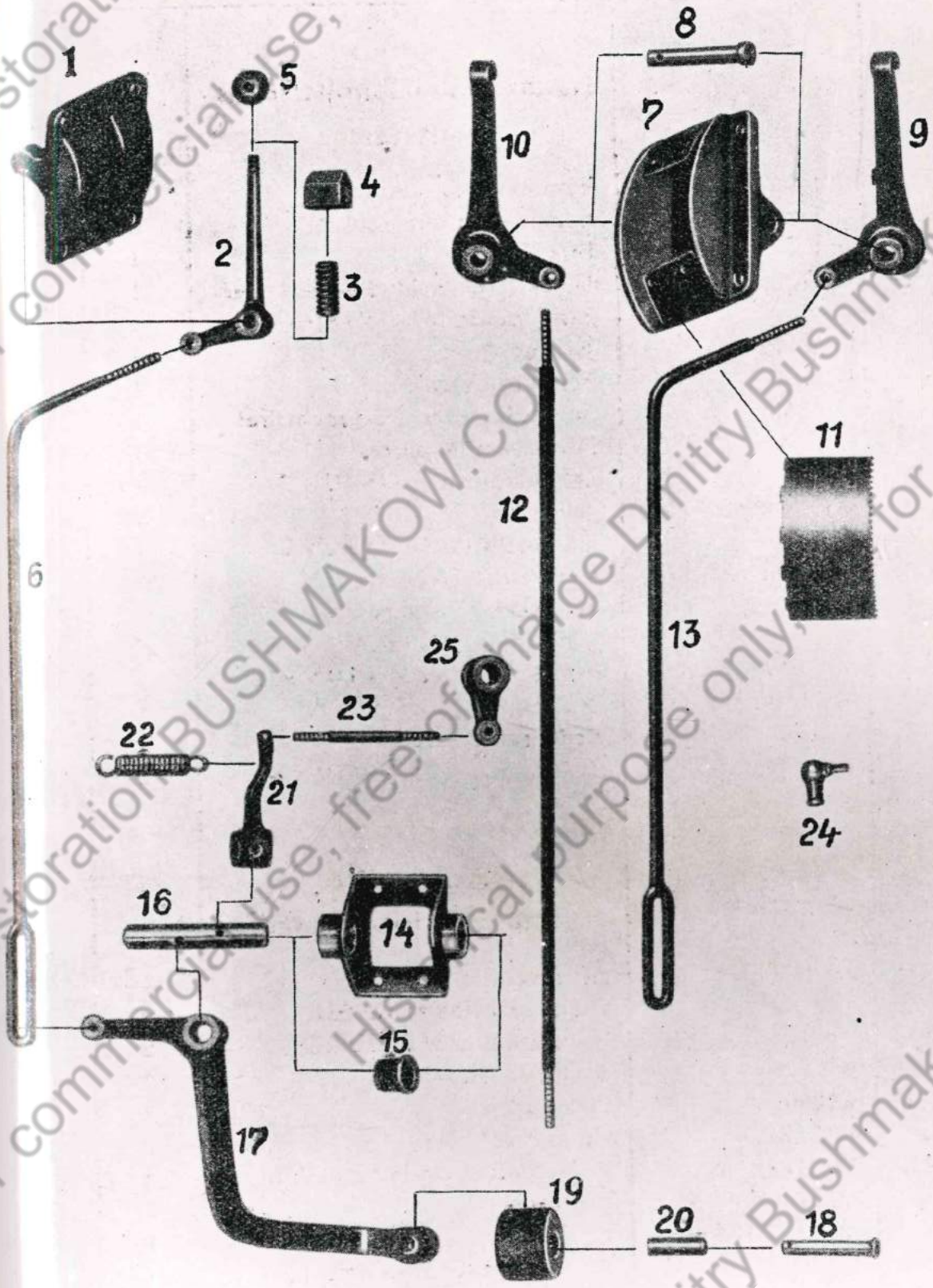

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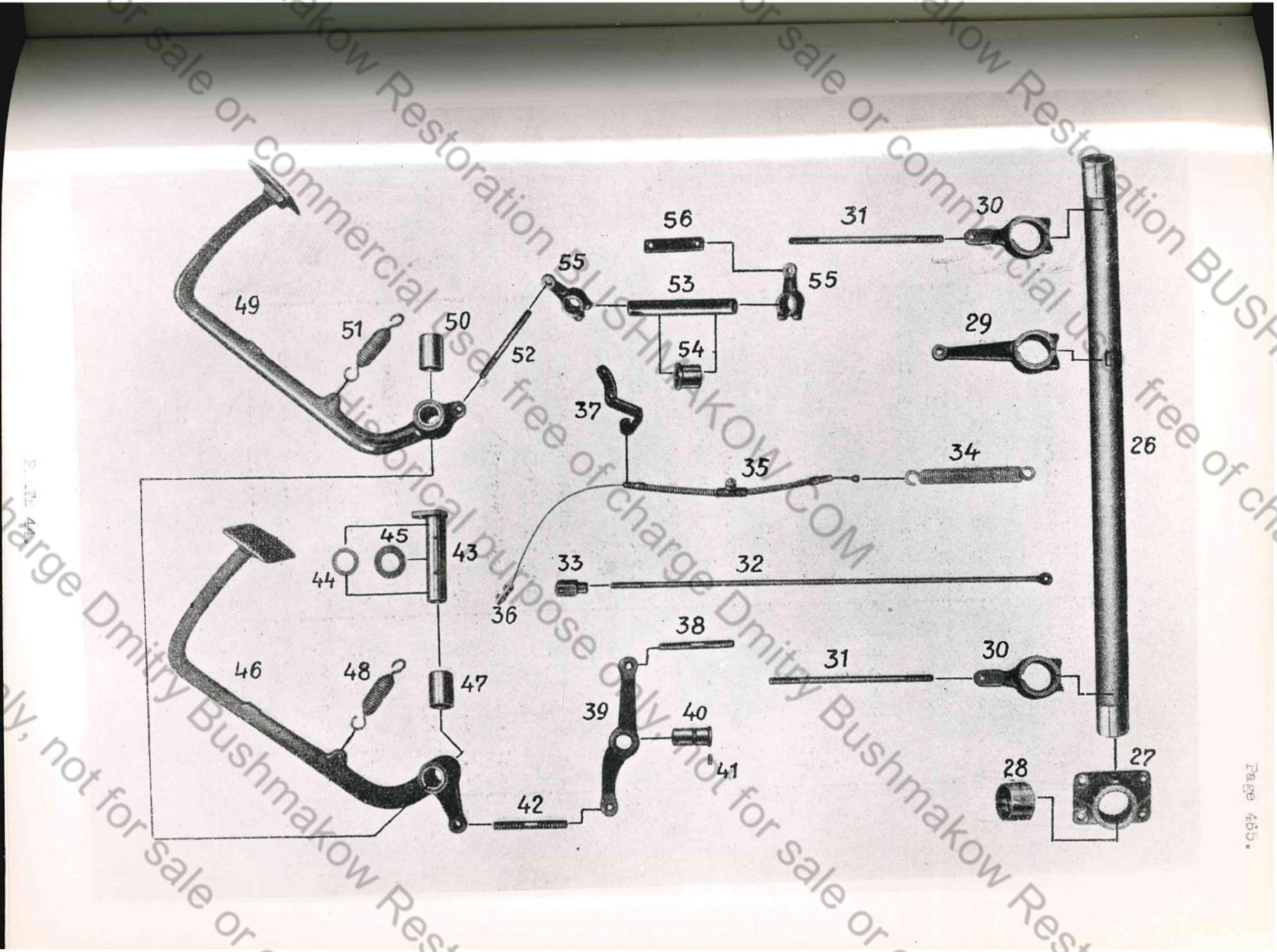

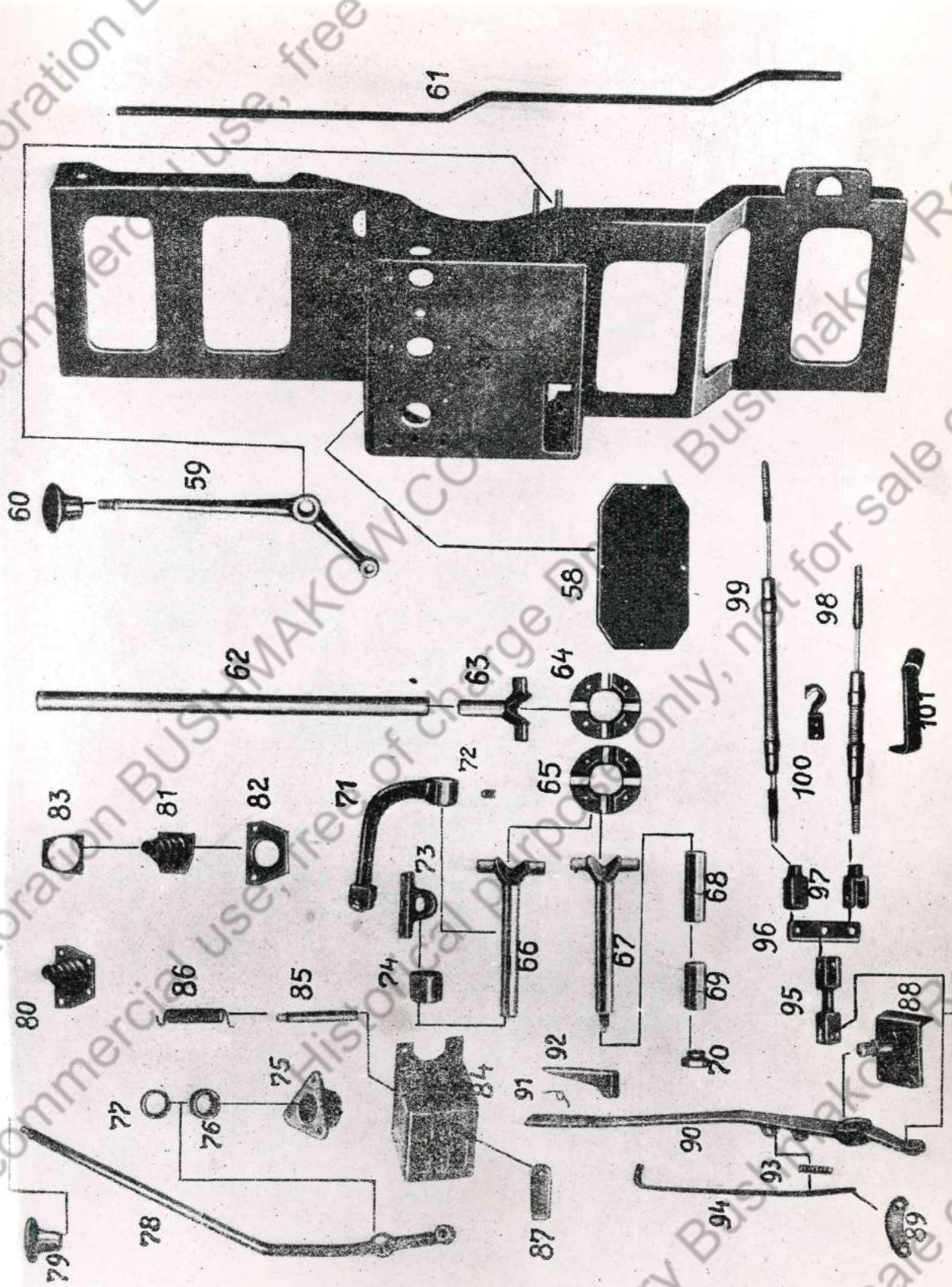

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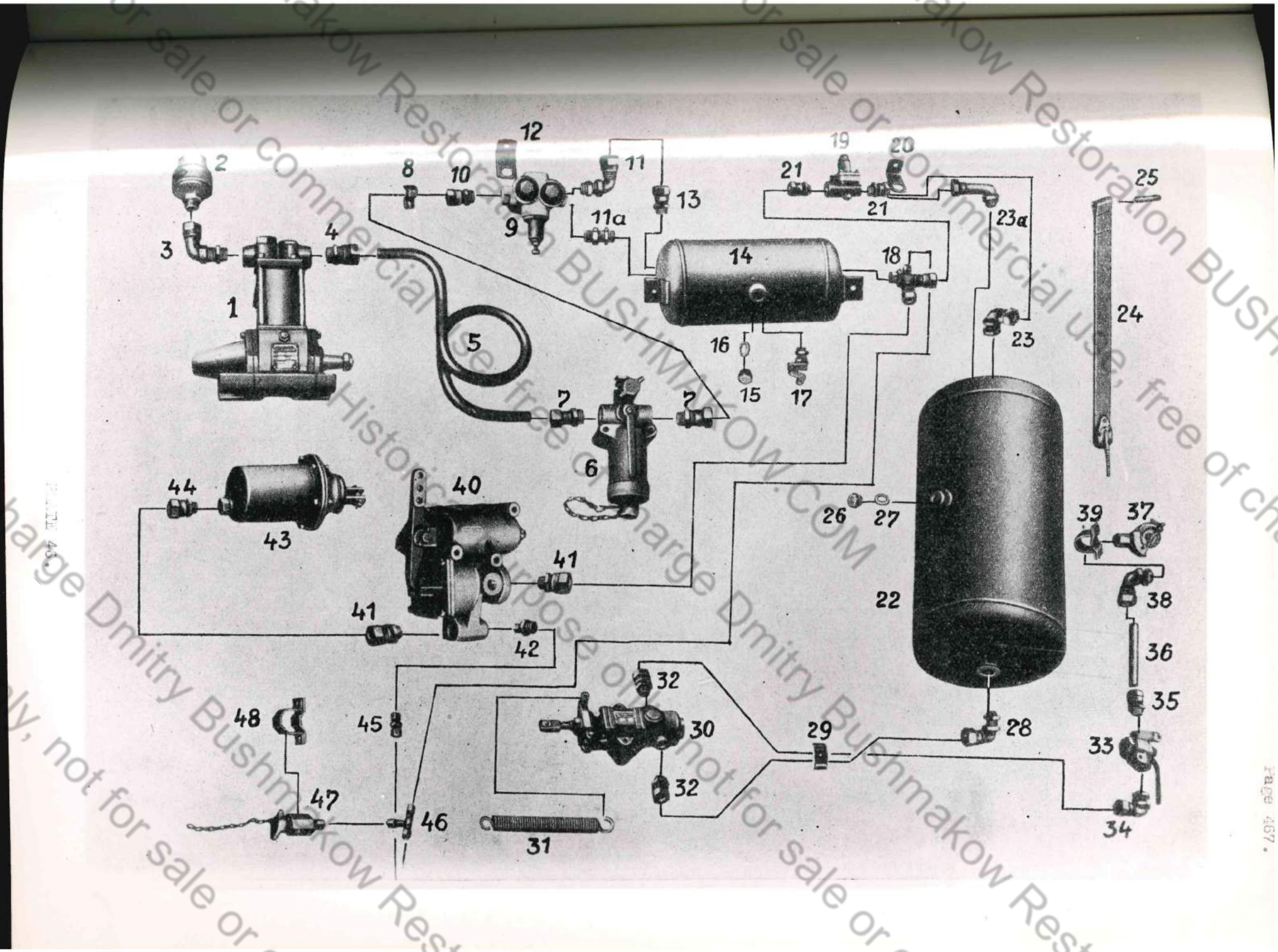
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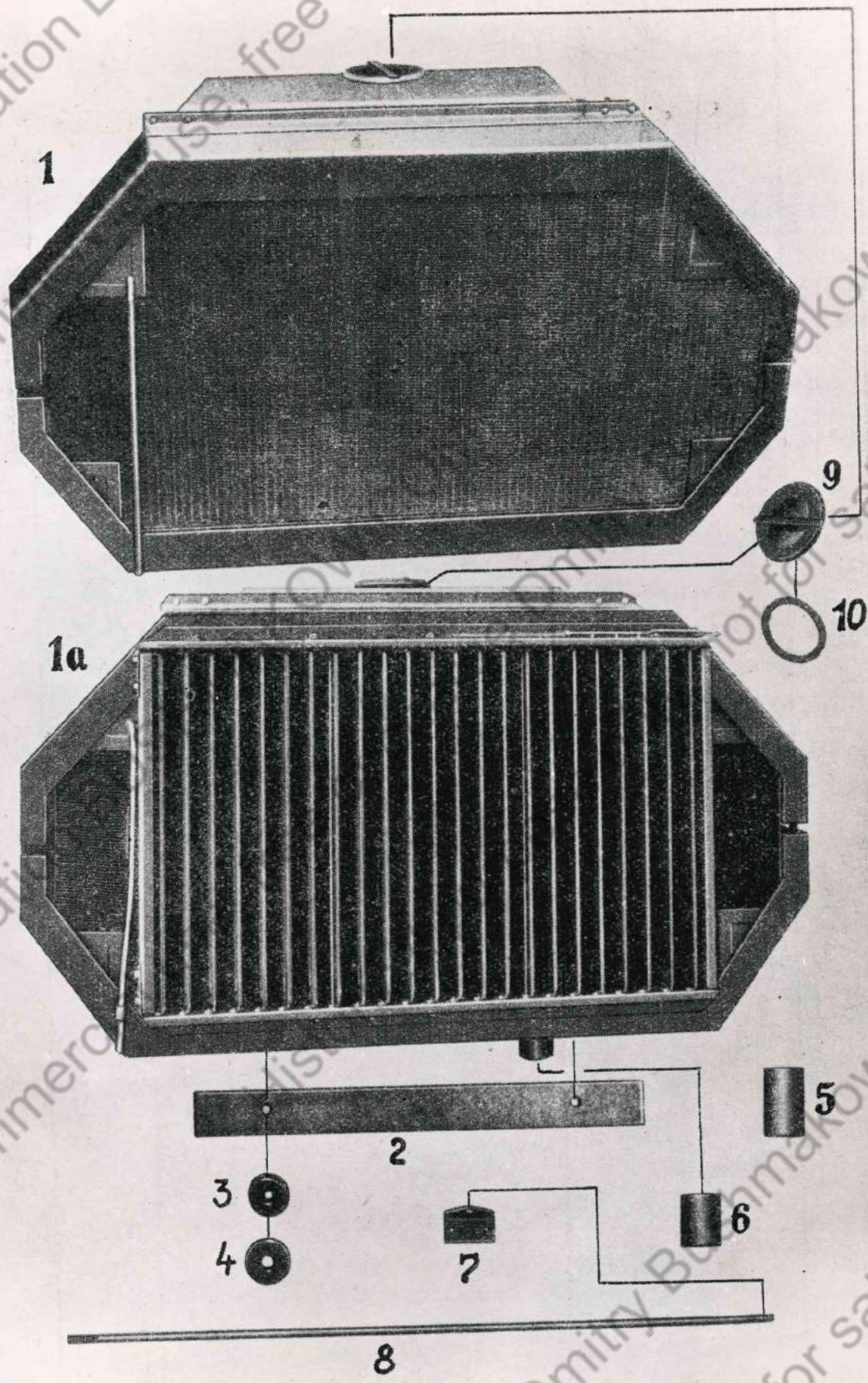

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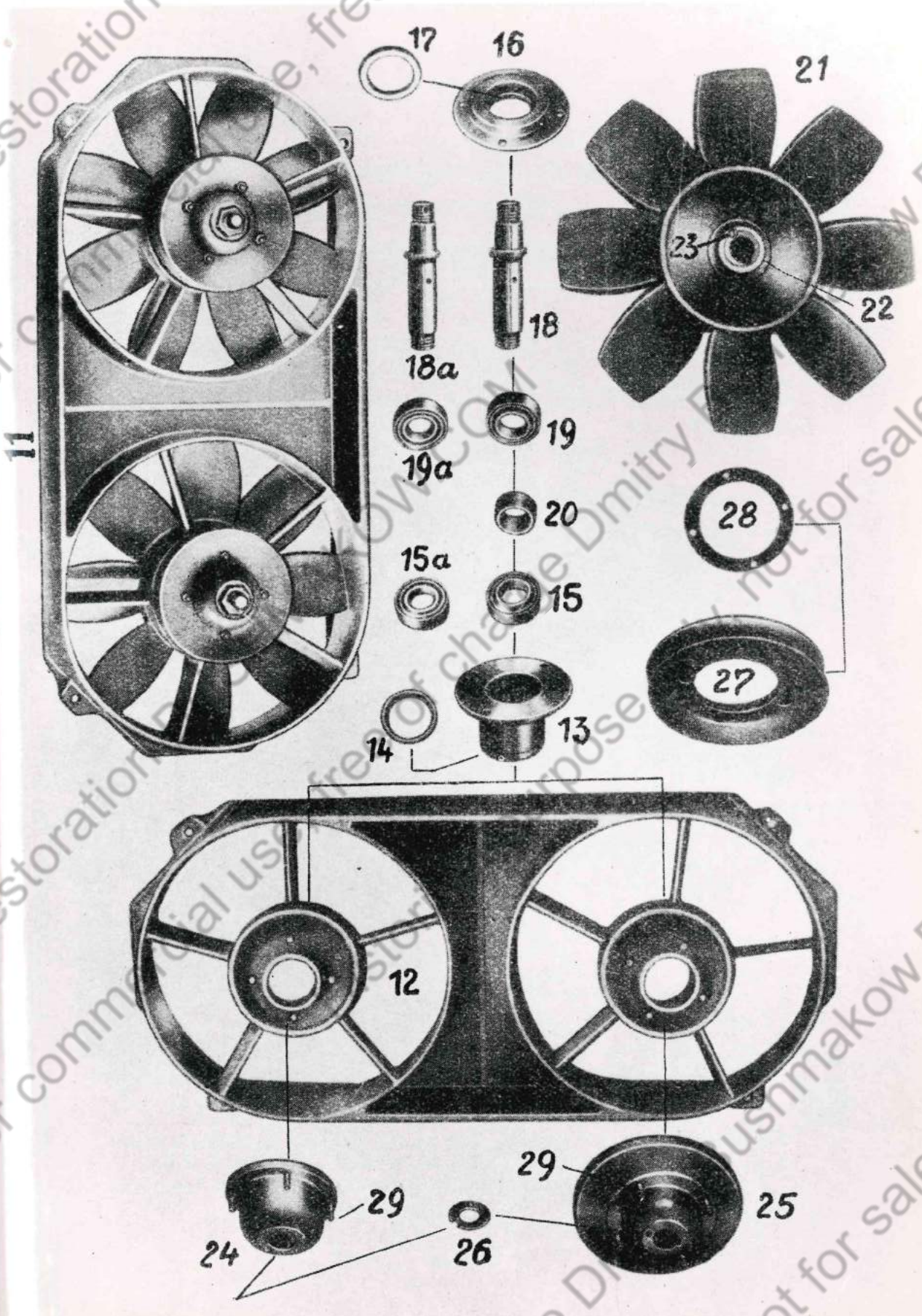

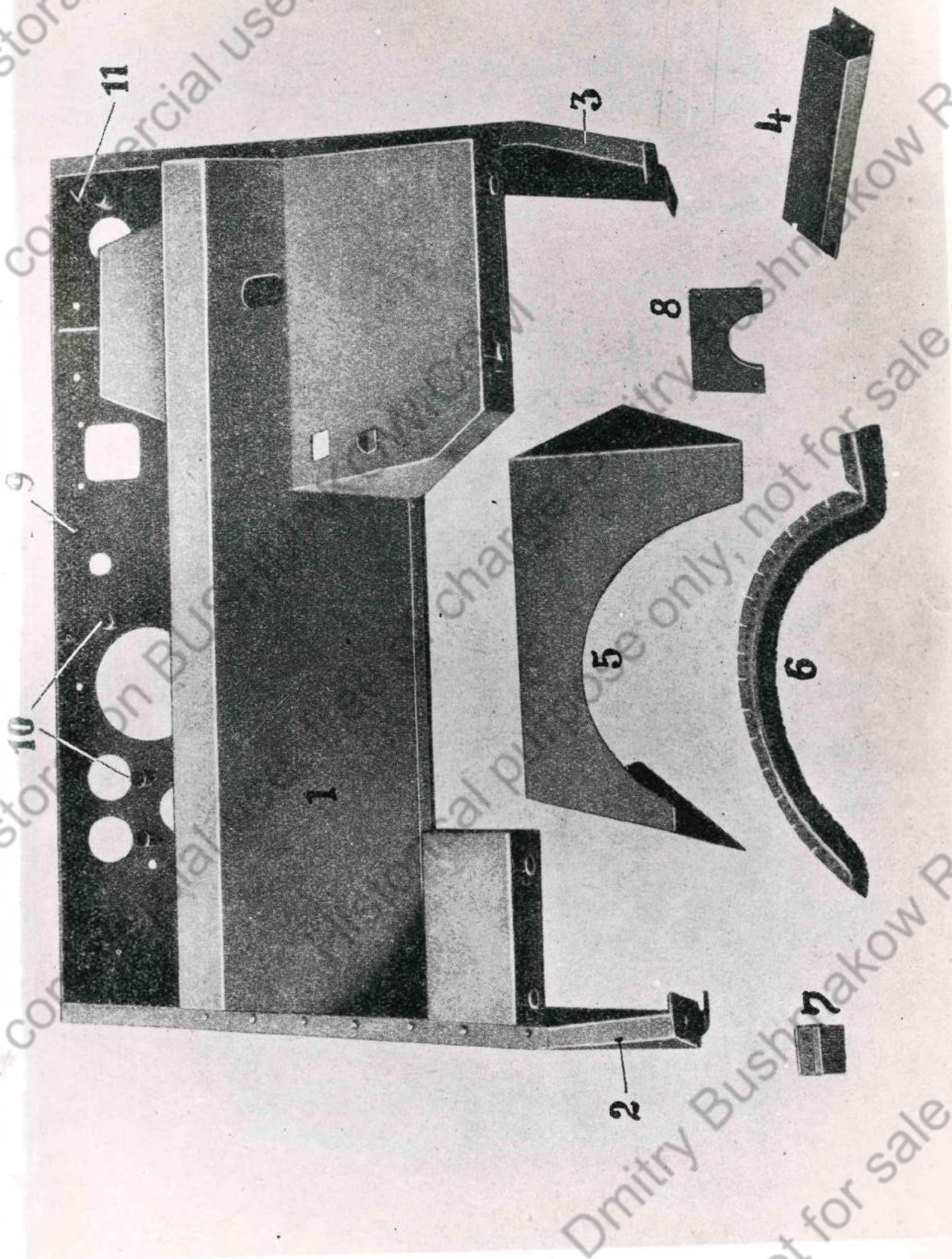

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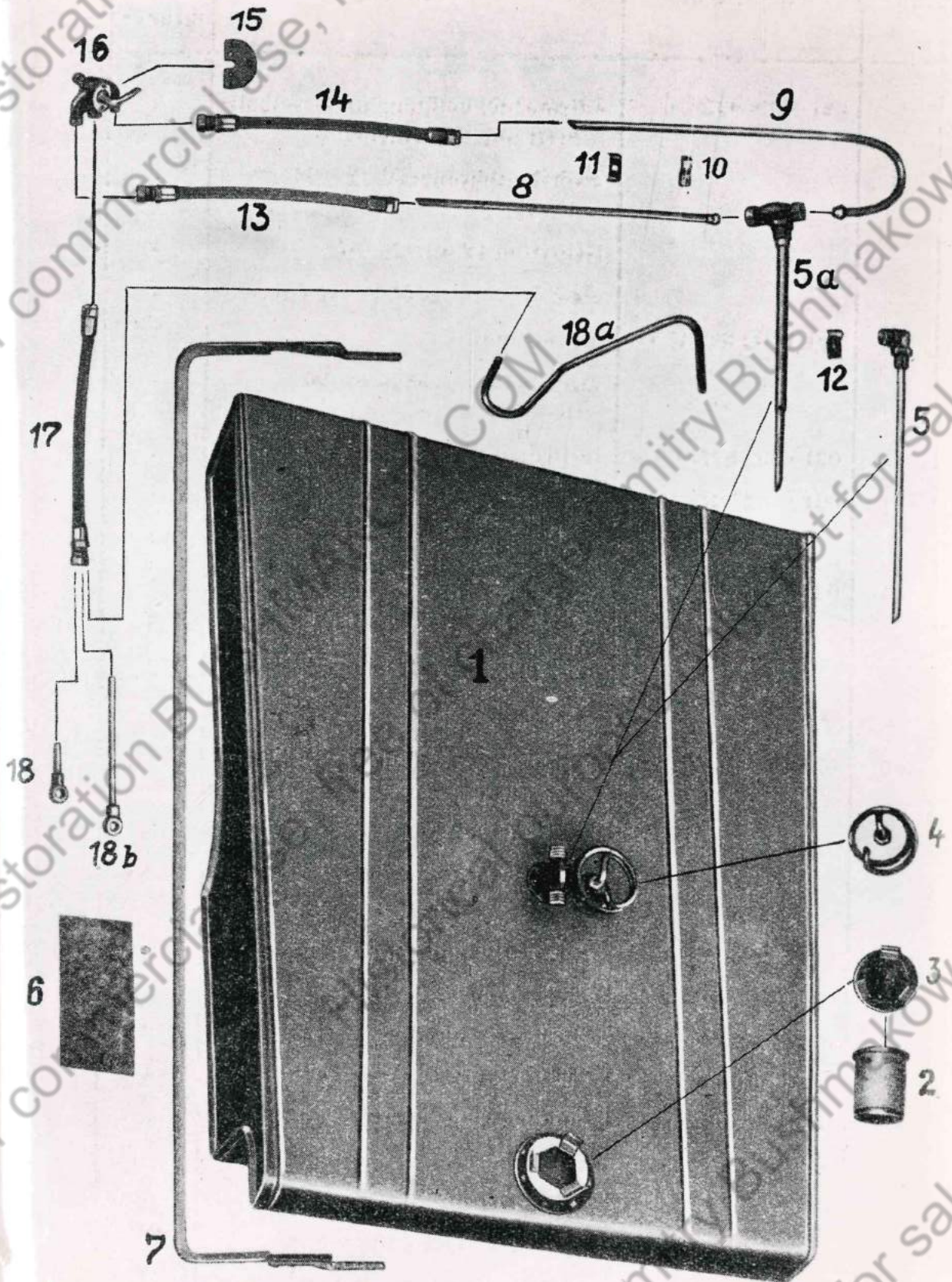

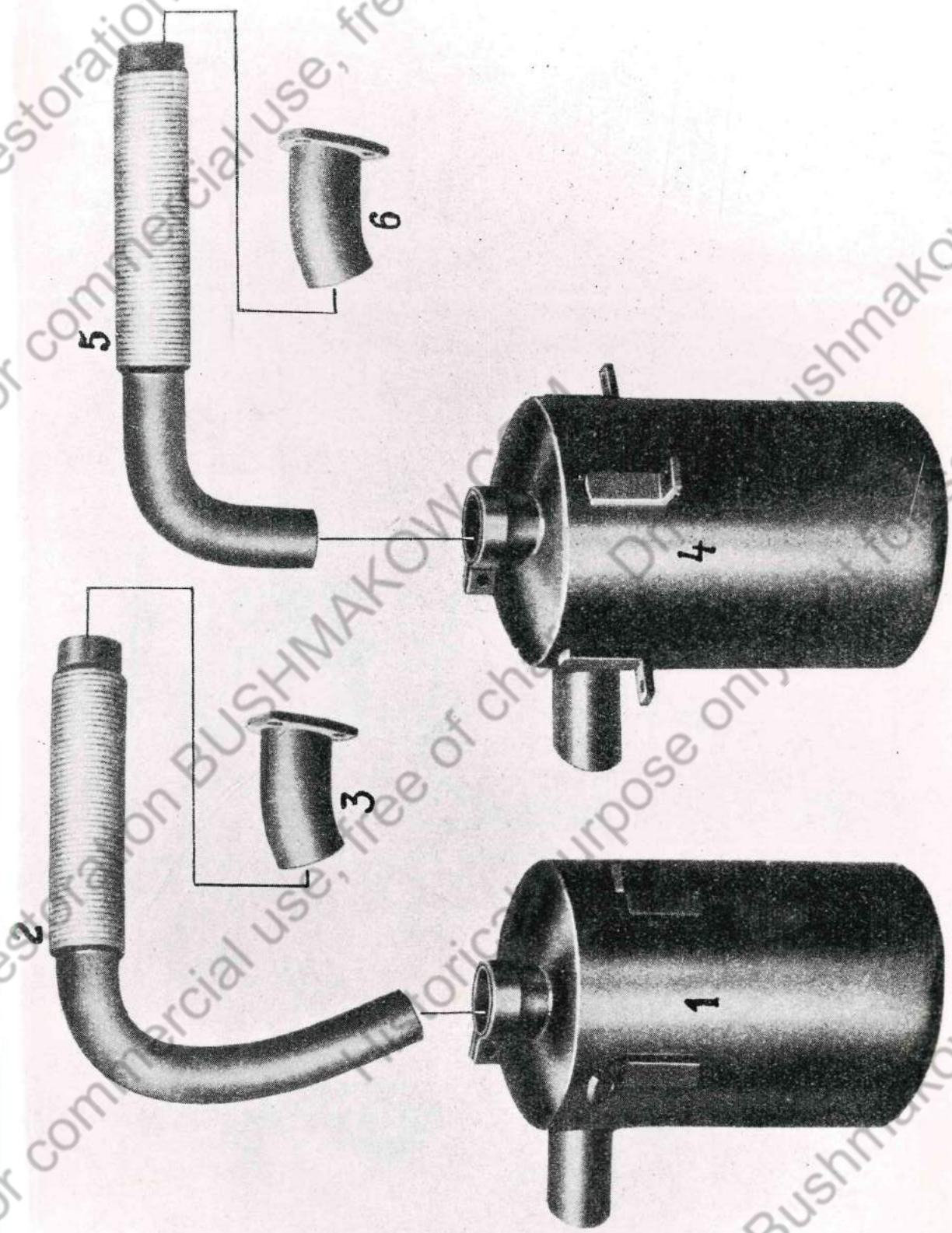
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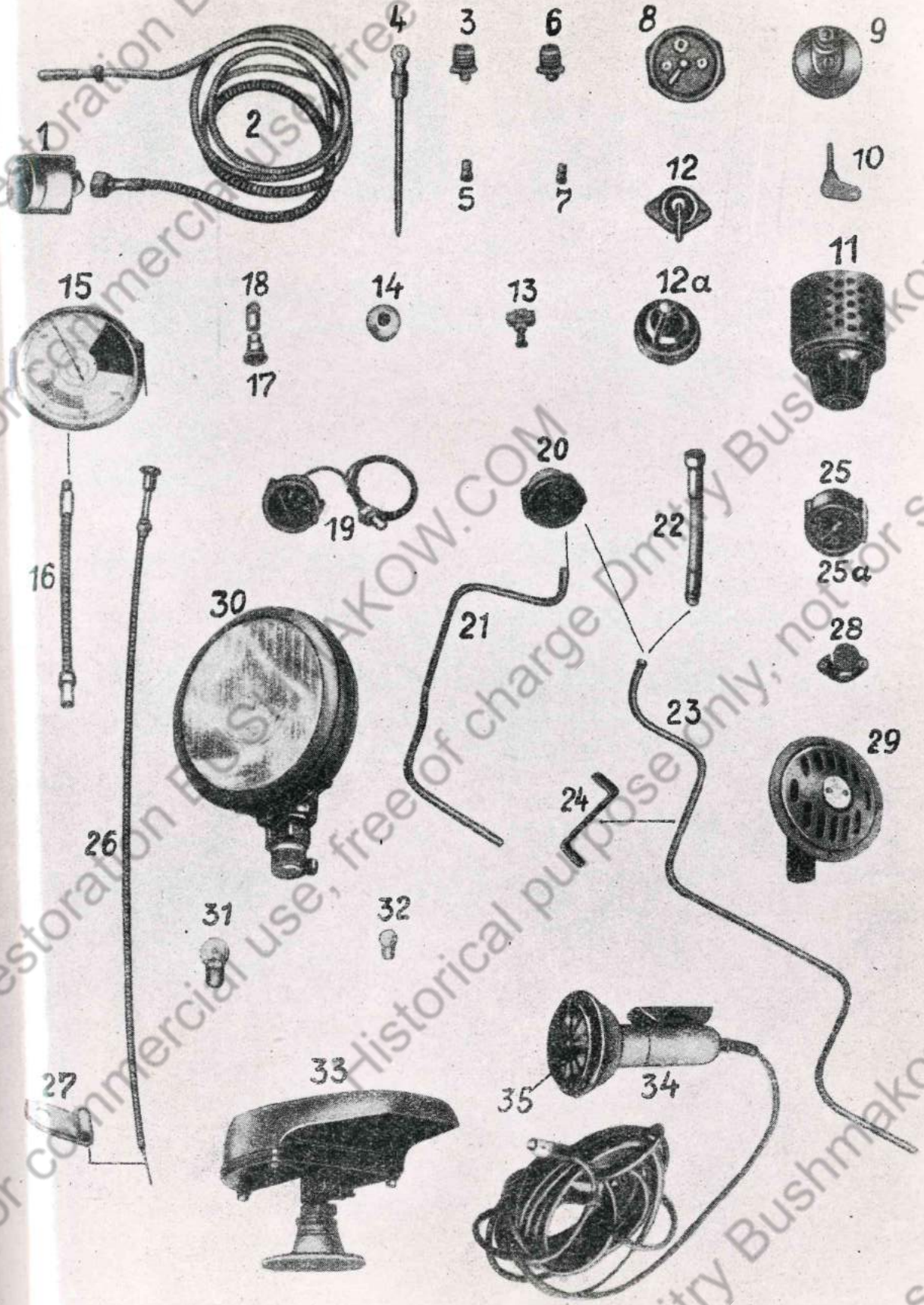

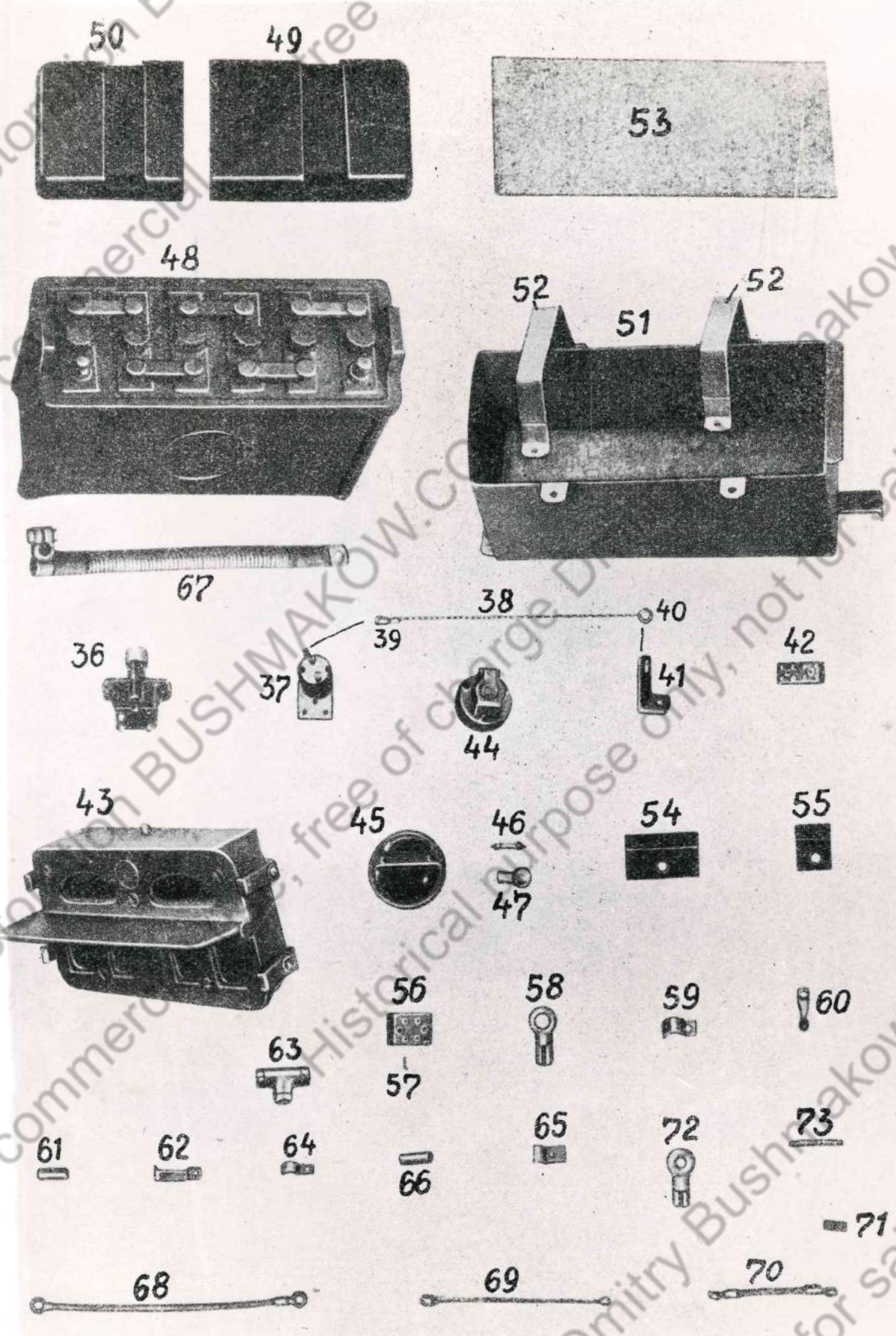

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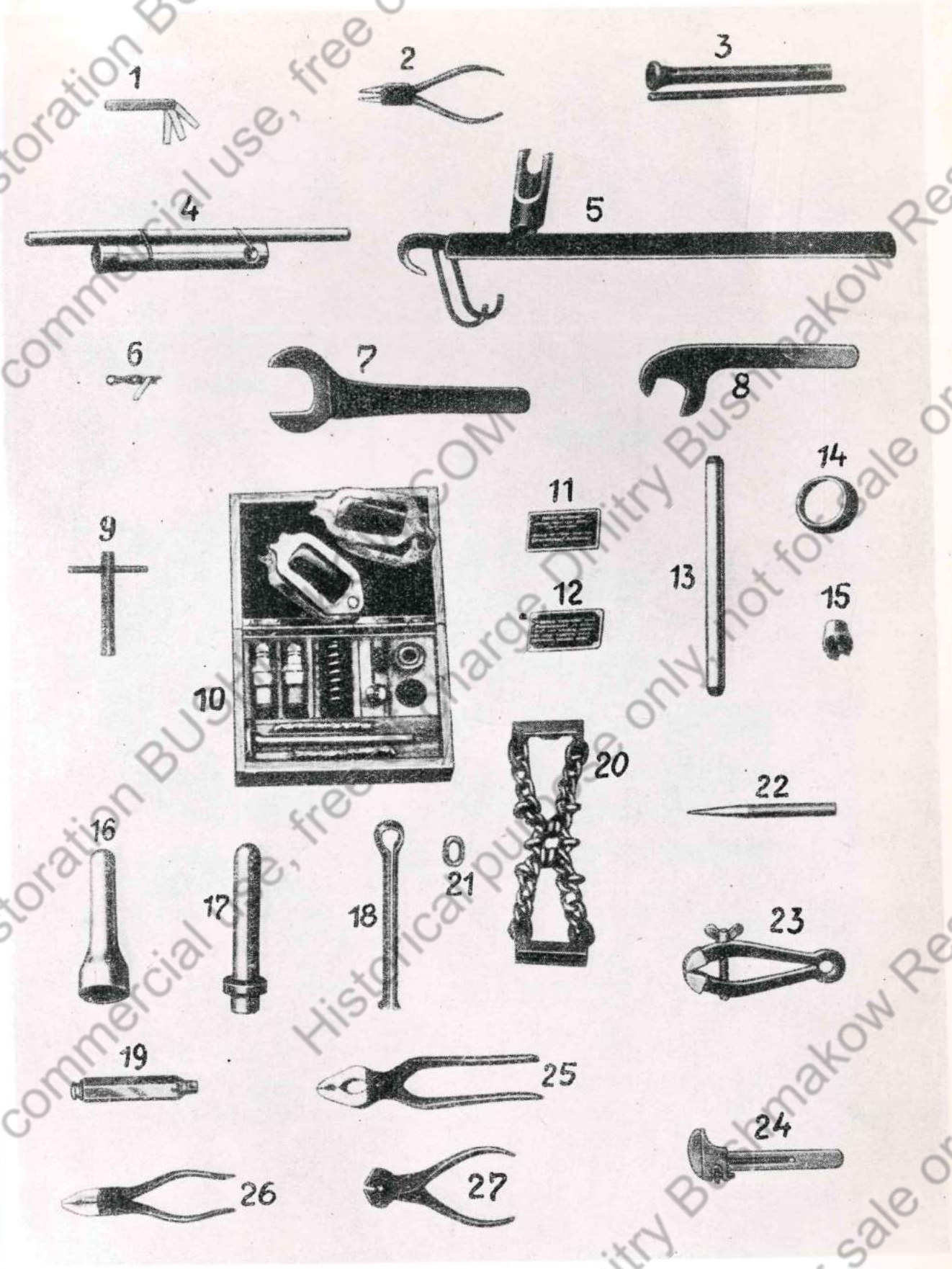

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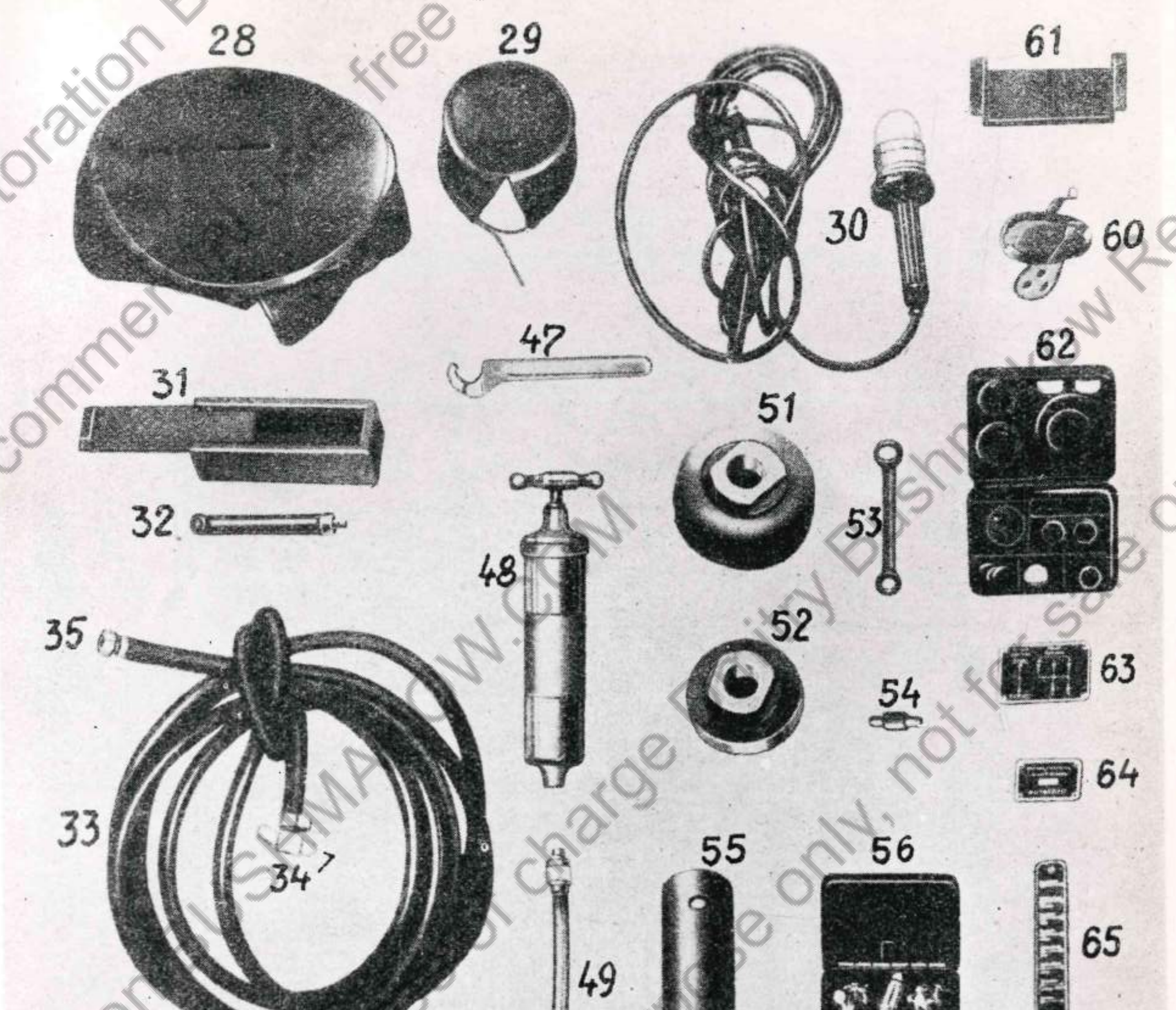

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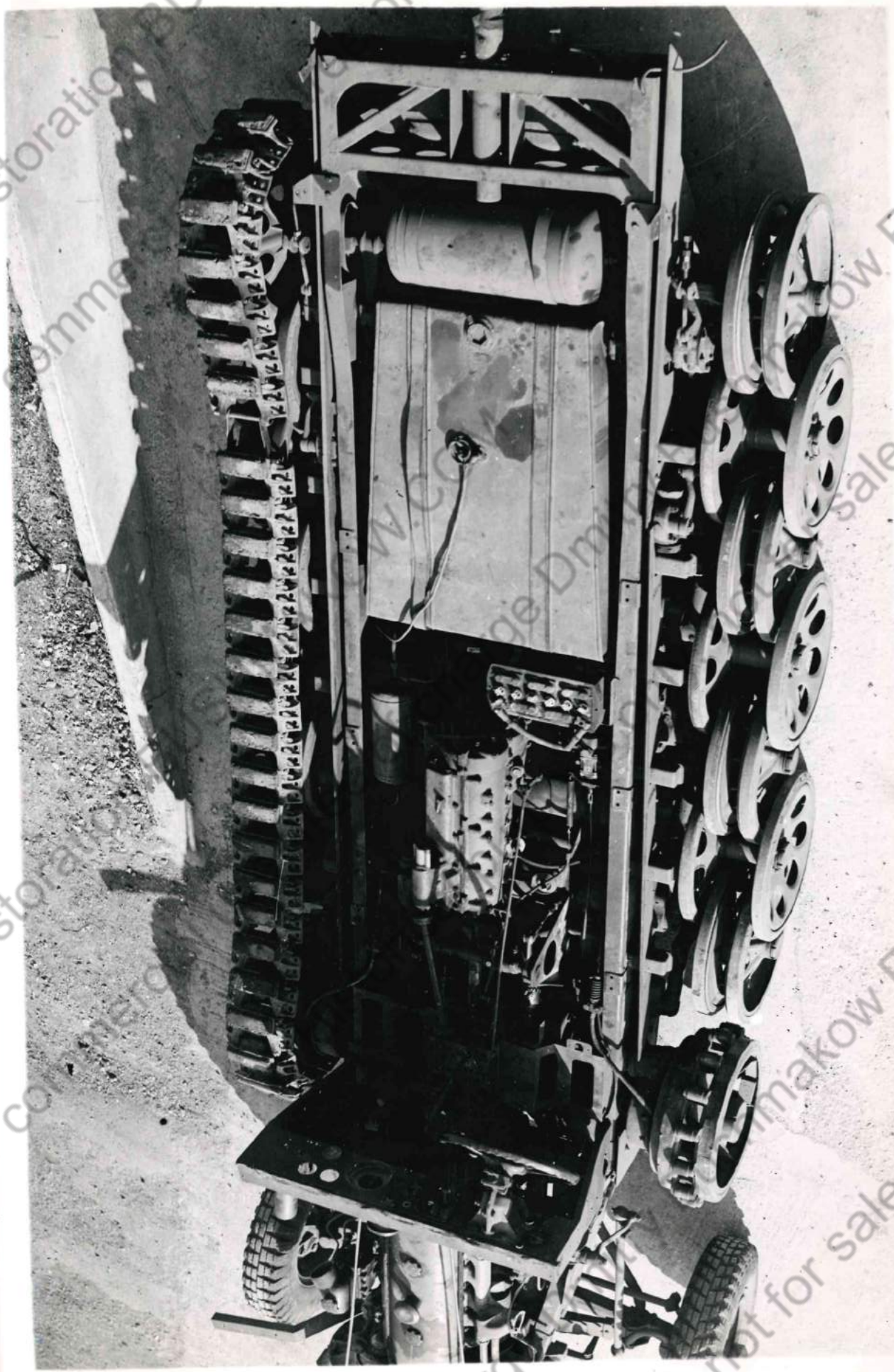

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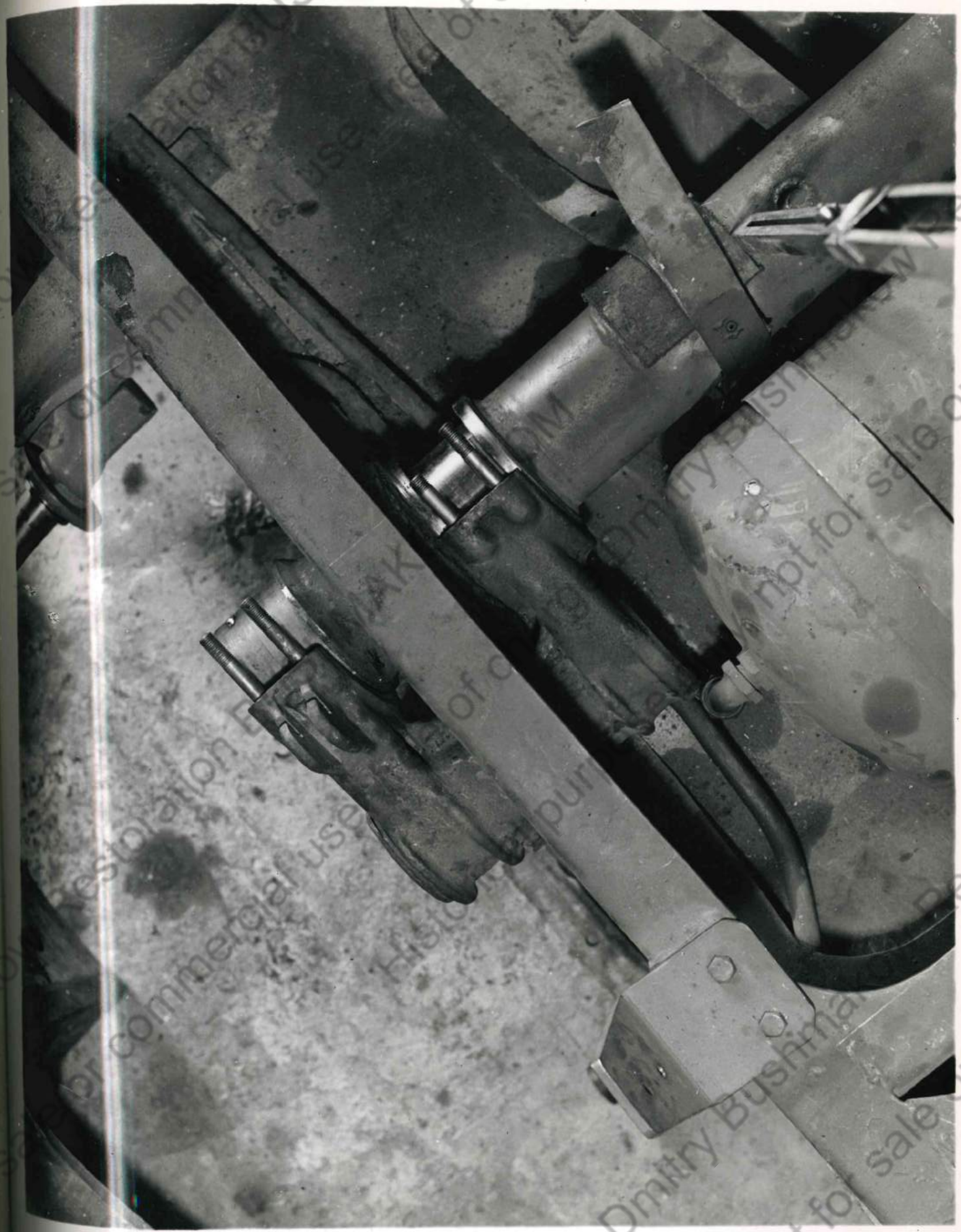

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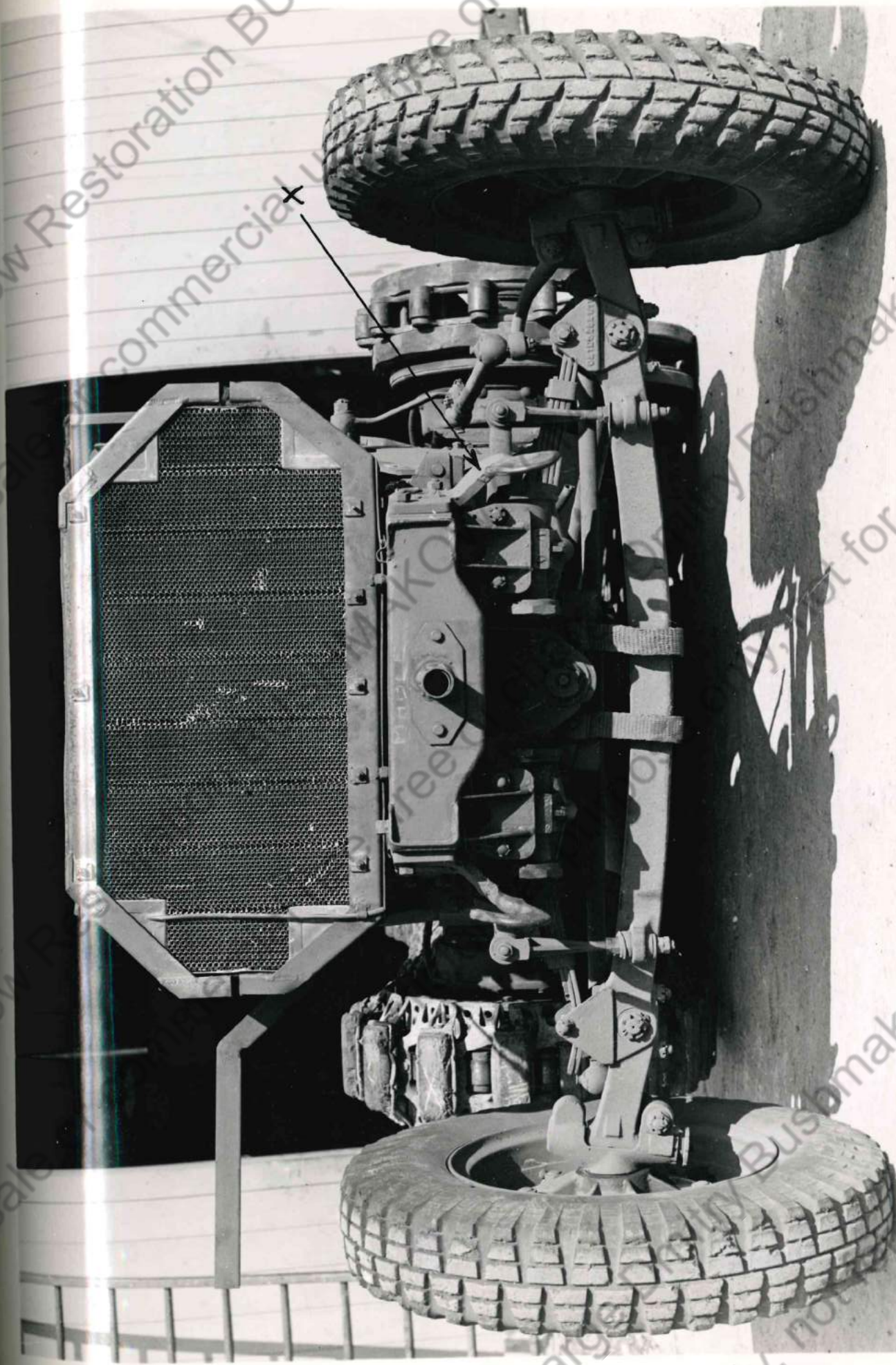

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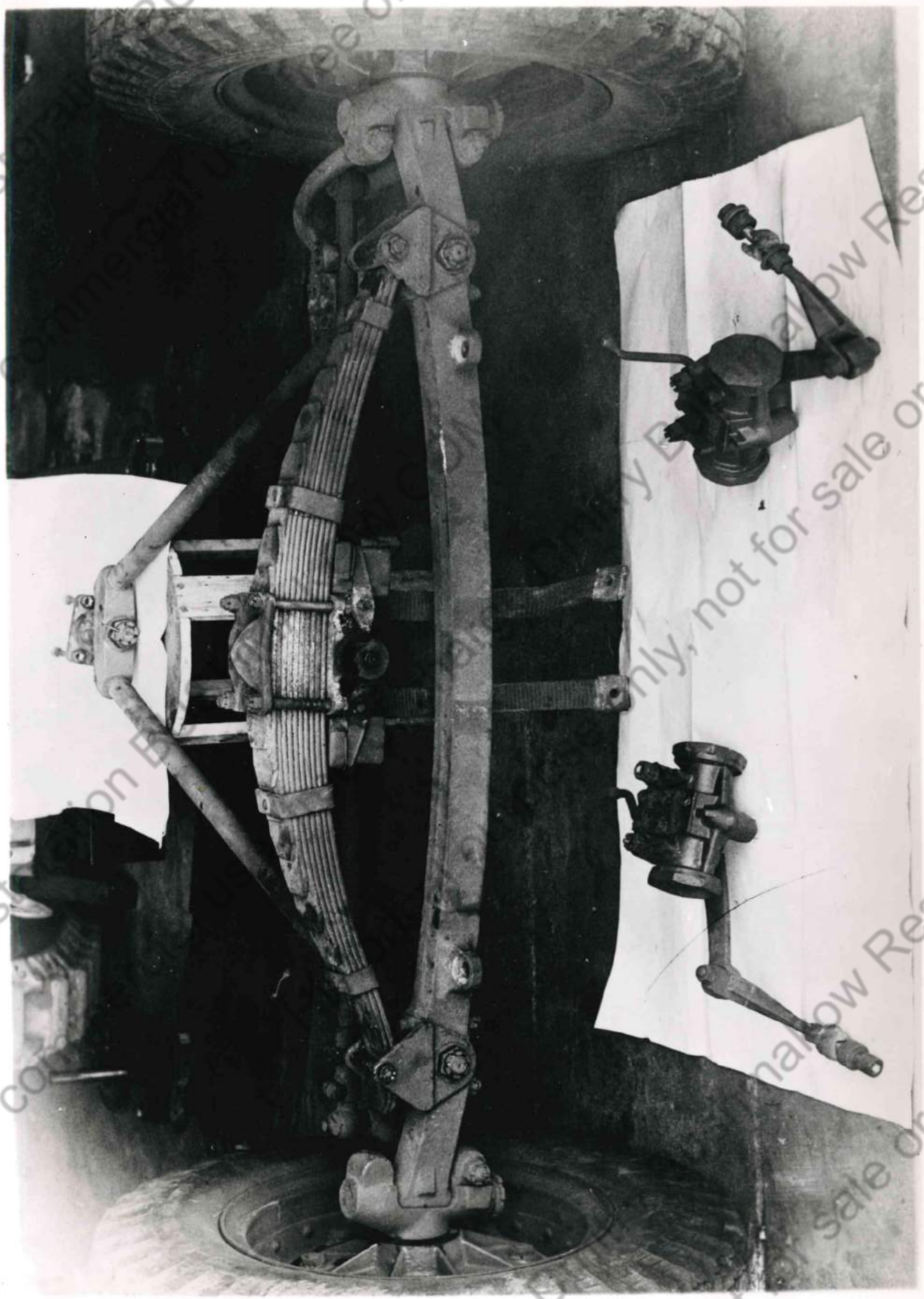

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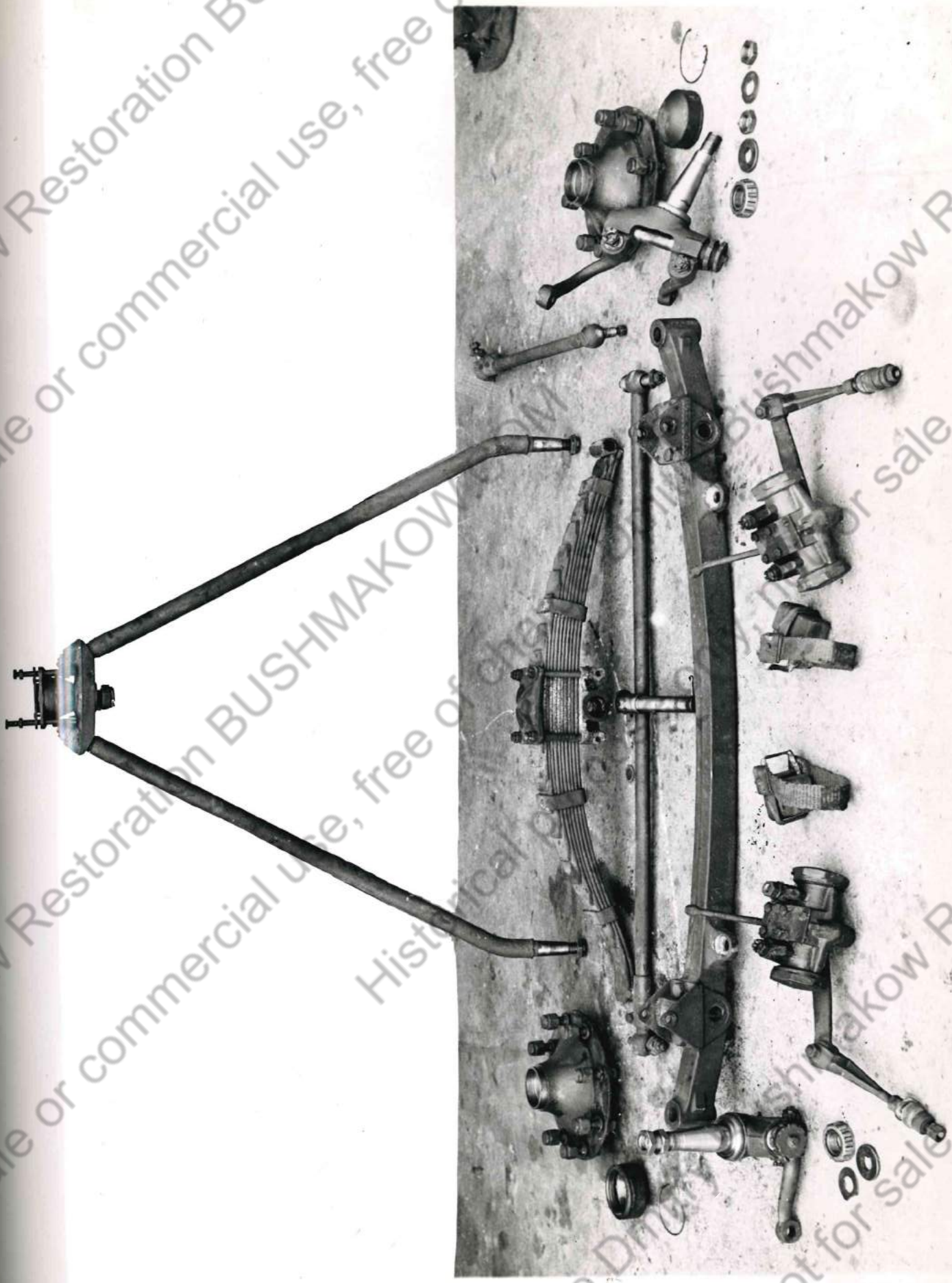
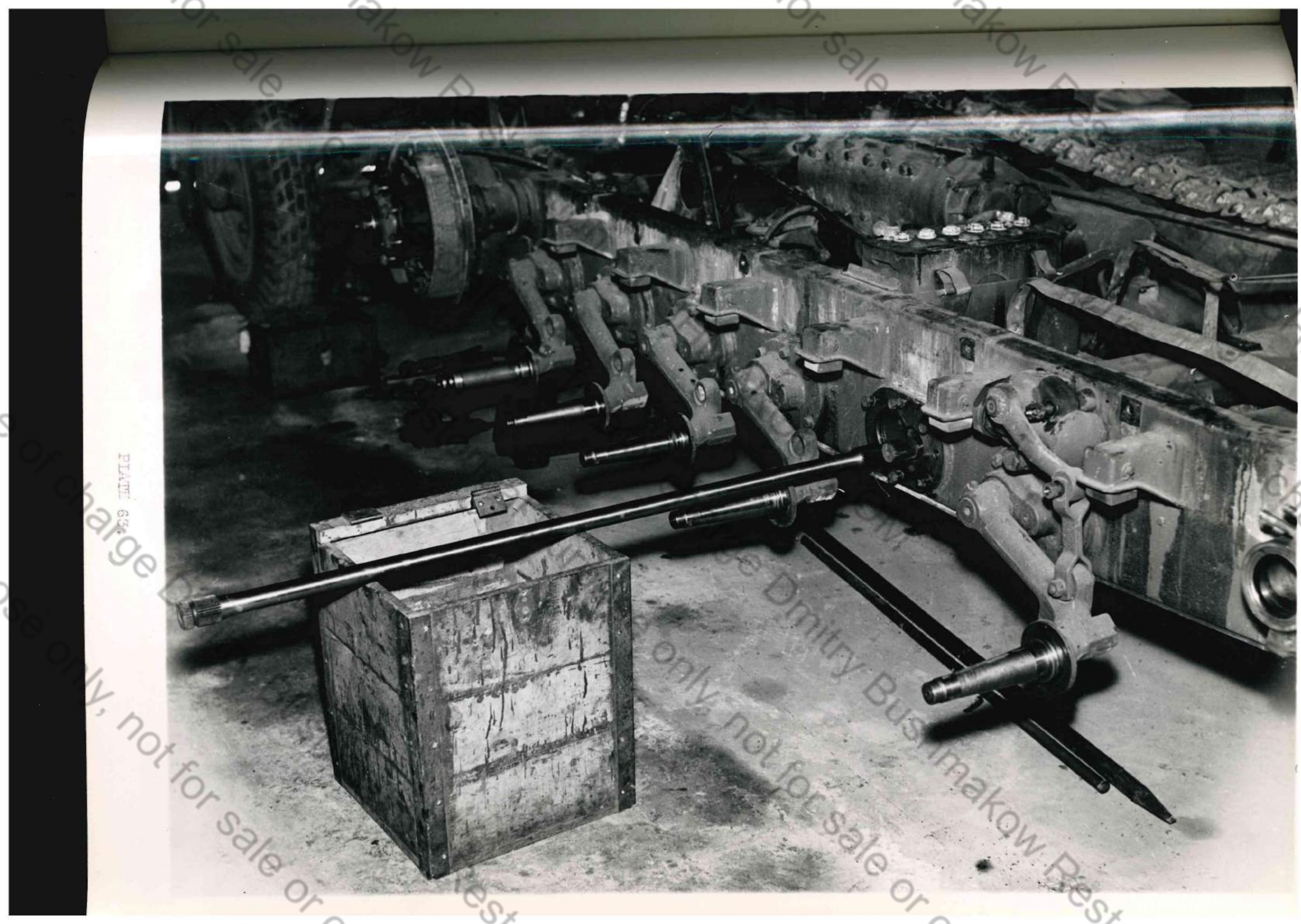


PLATE 61.

PLATE 62.



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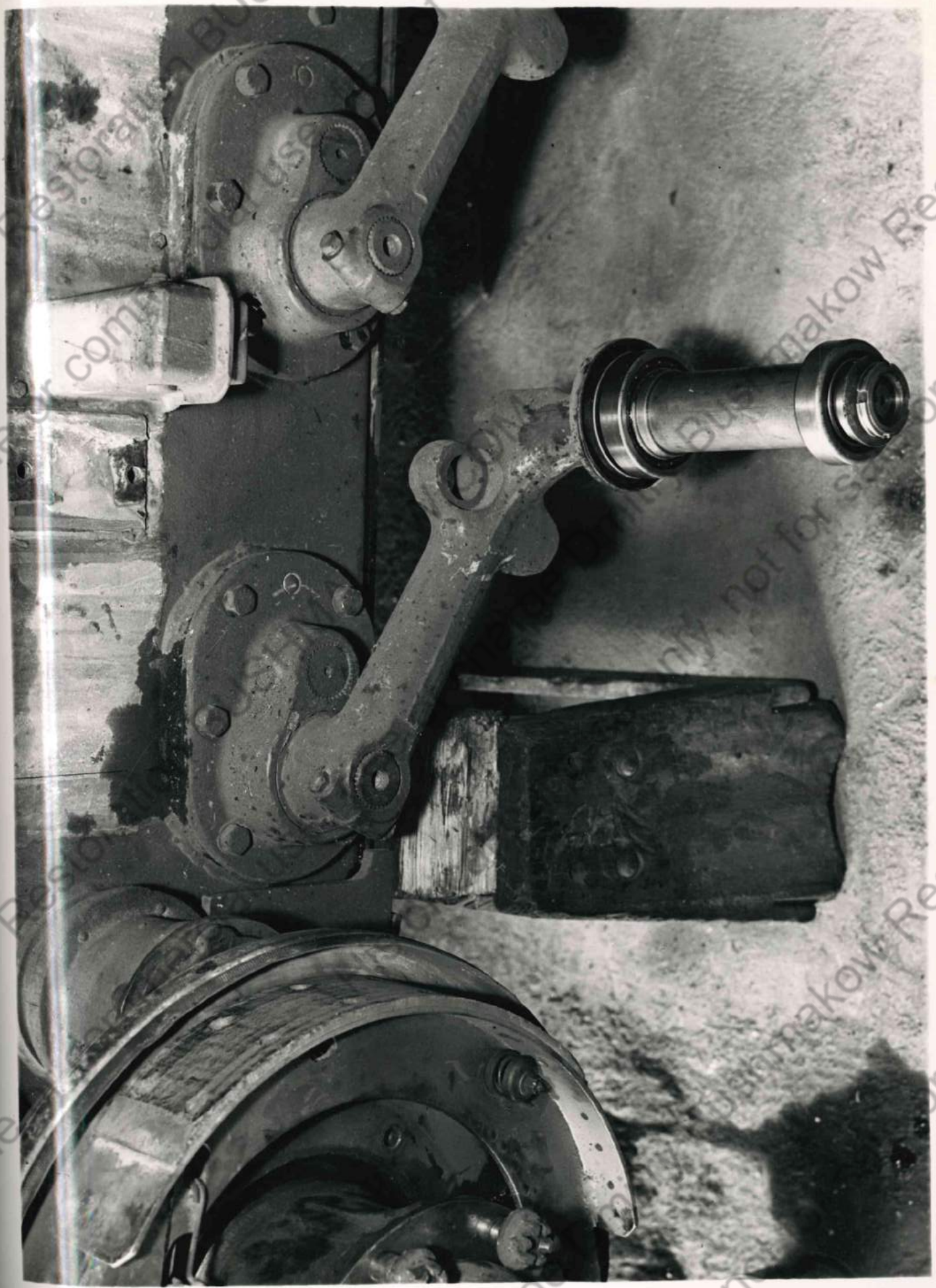

PLATE 64.

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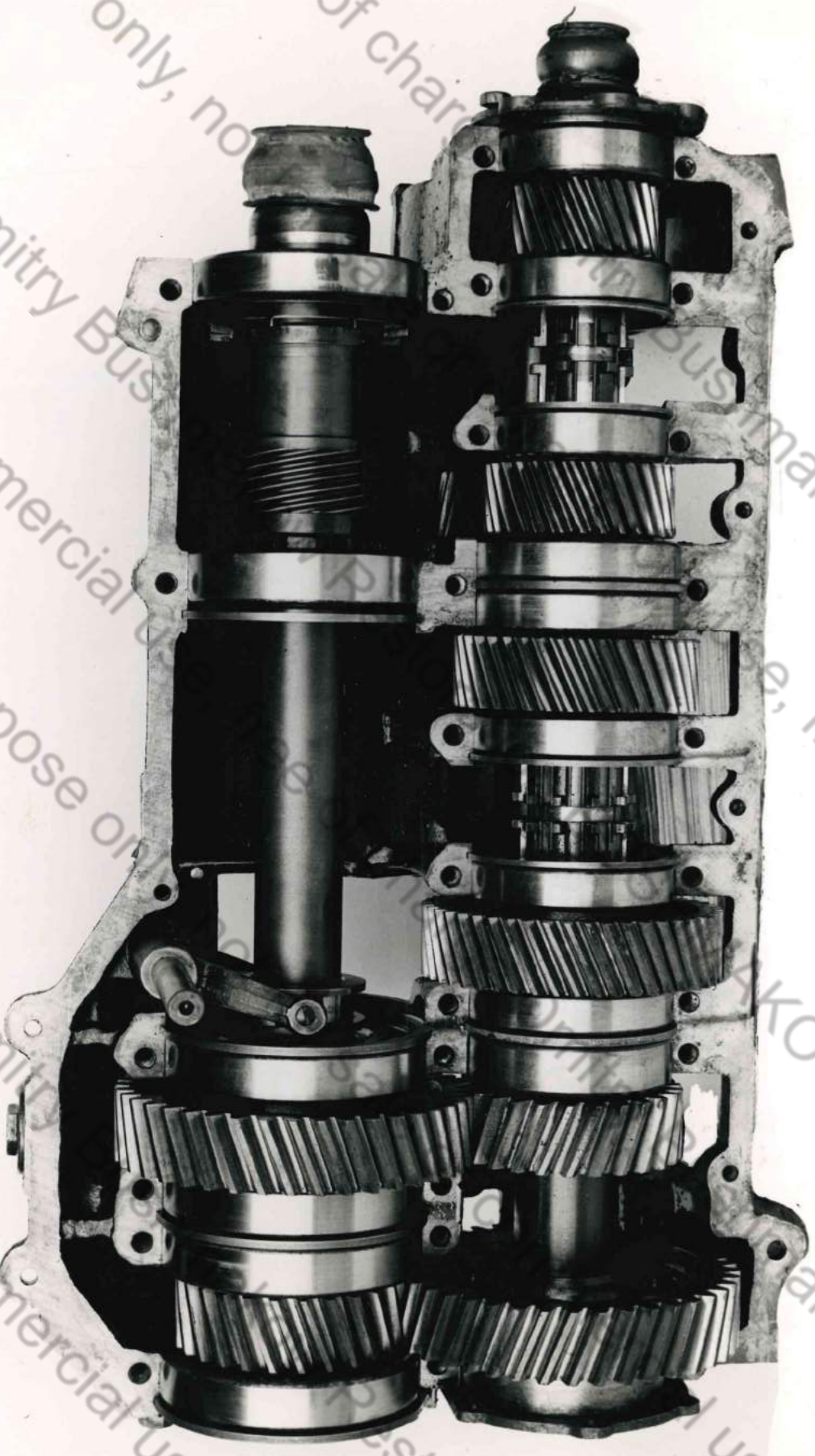

PLATE 69.

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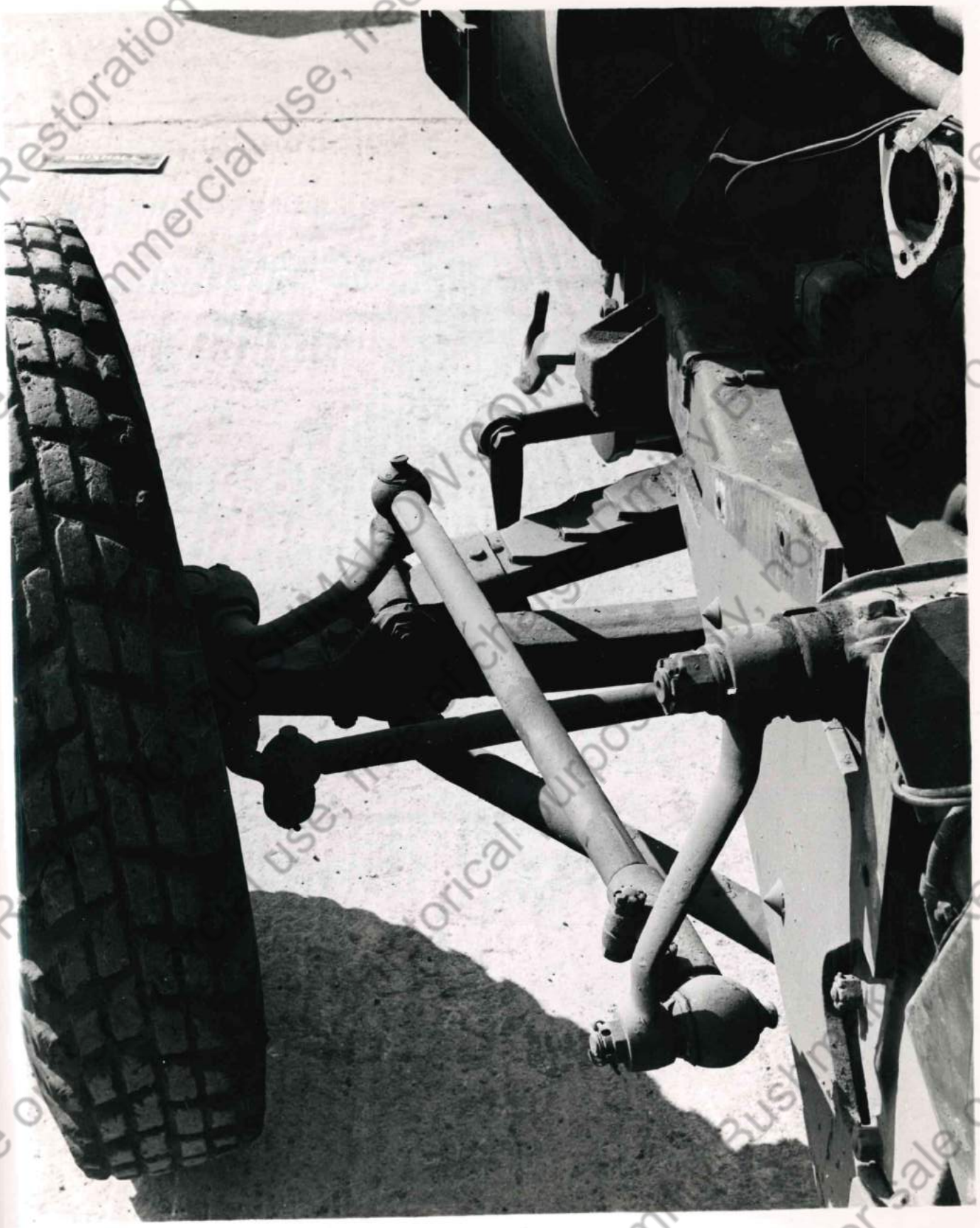

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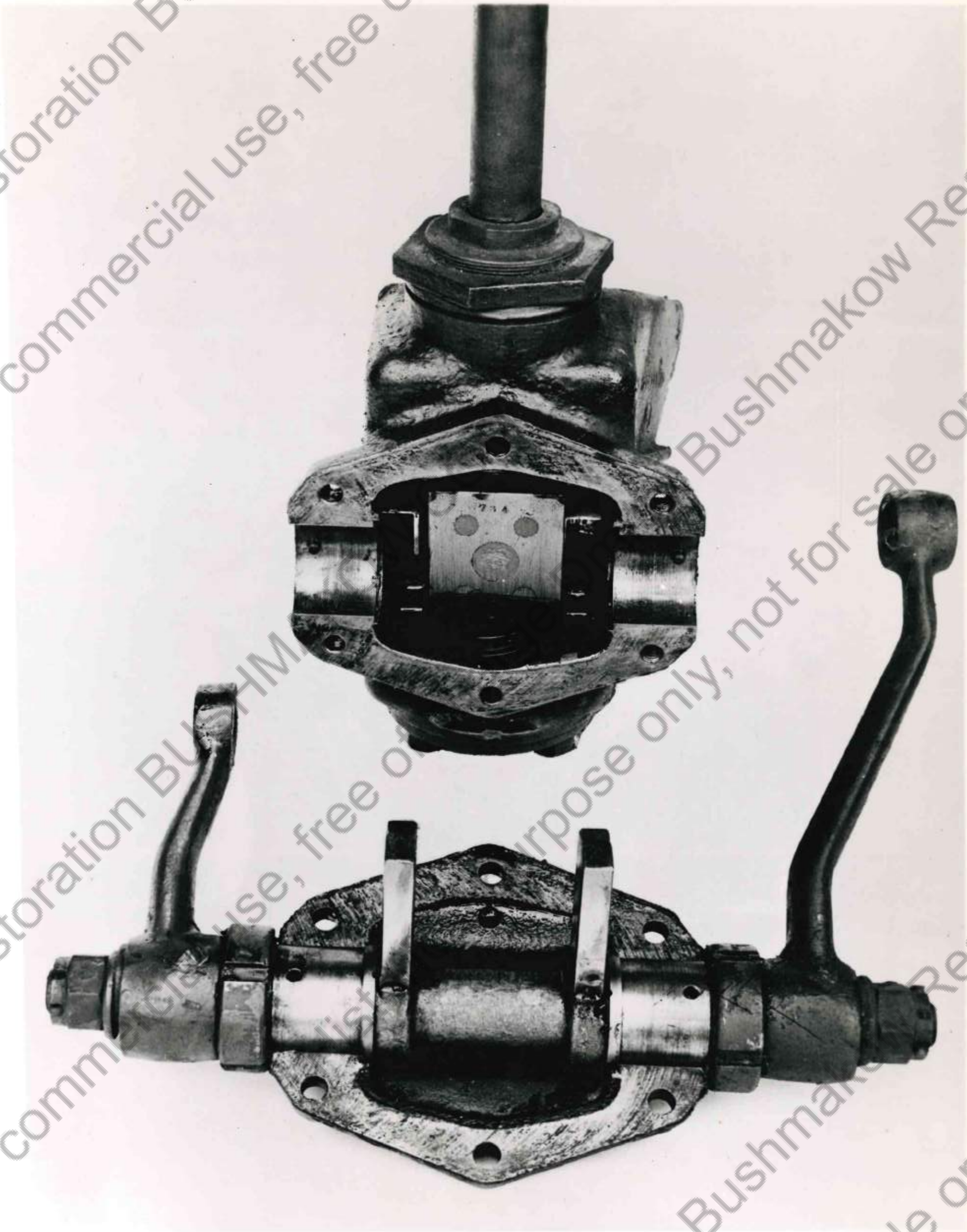

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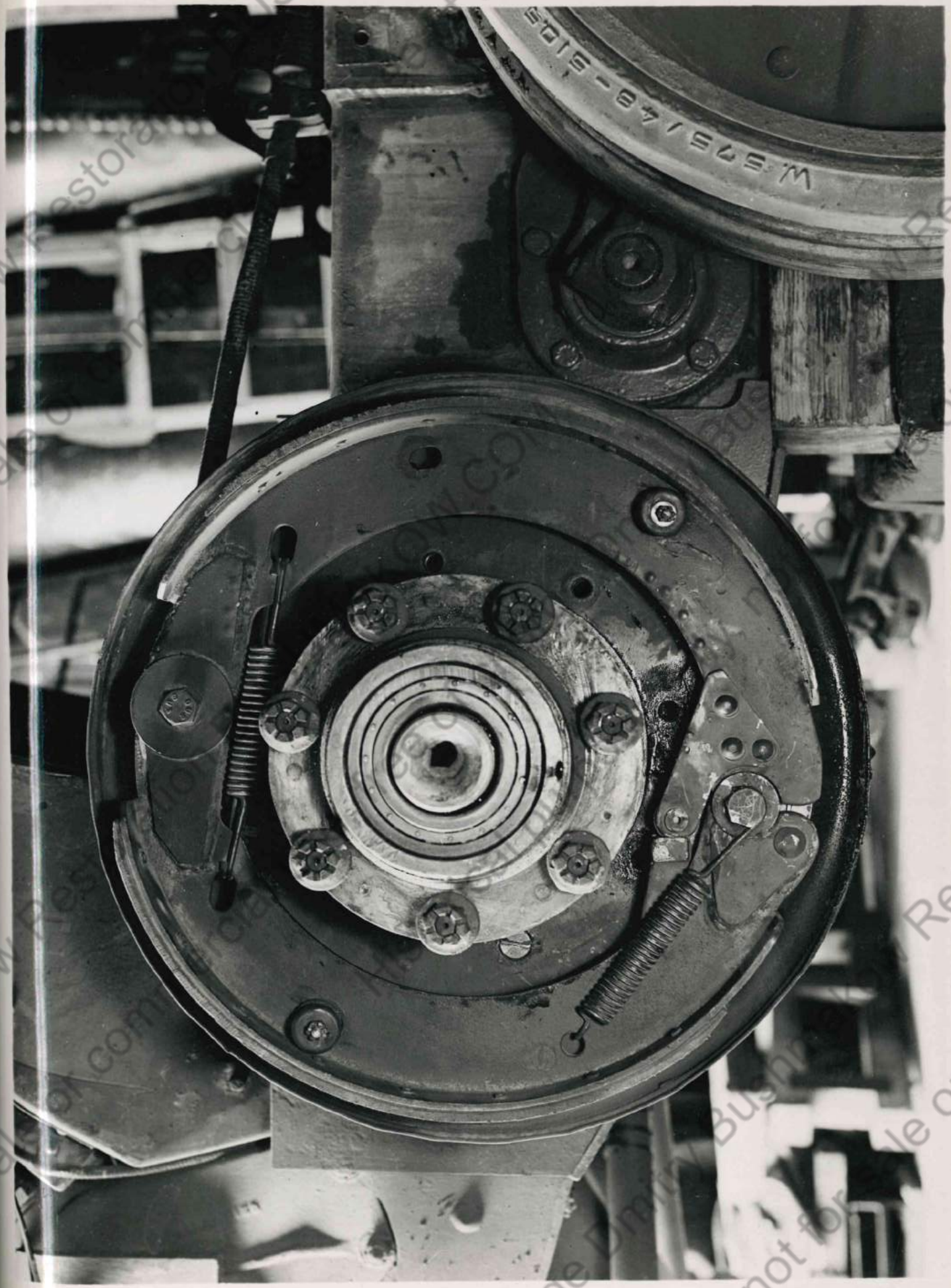

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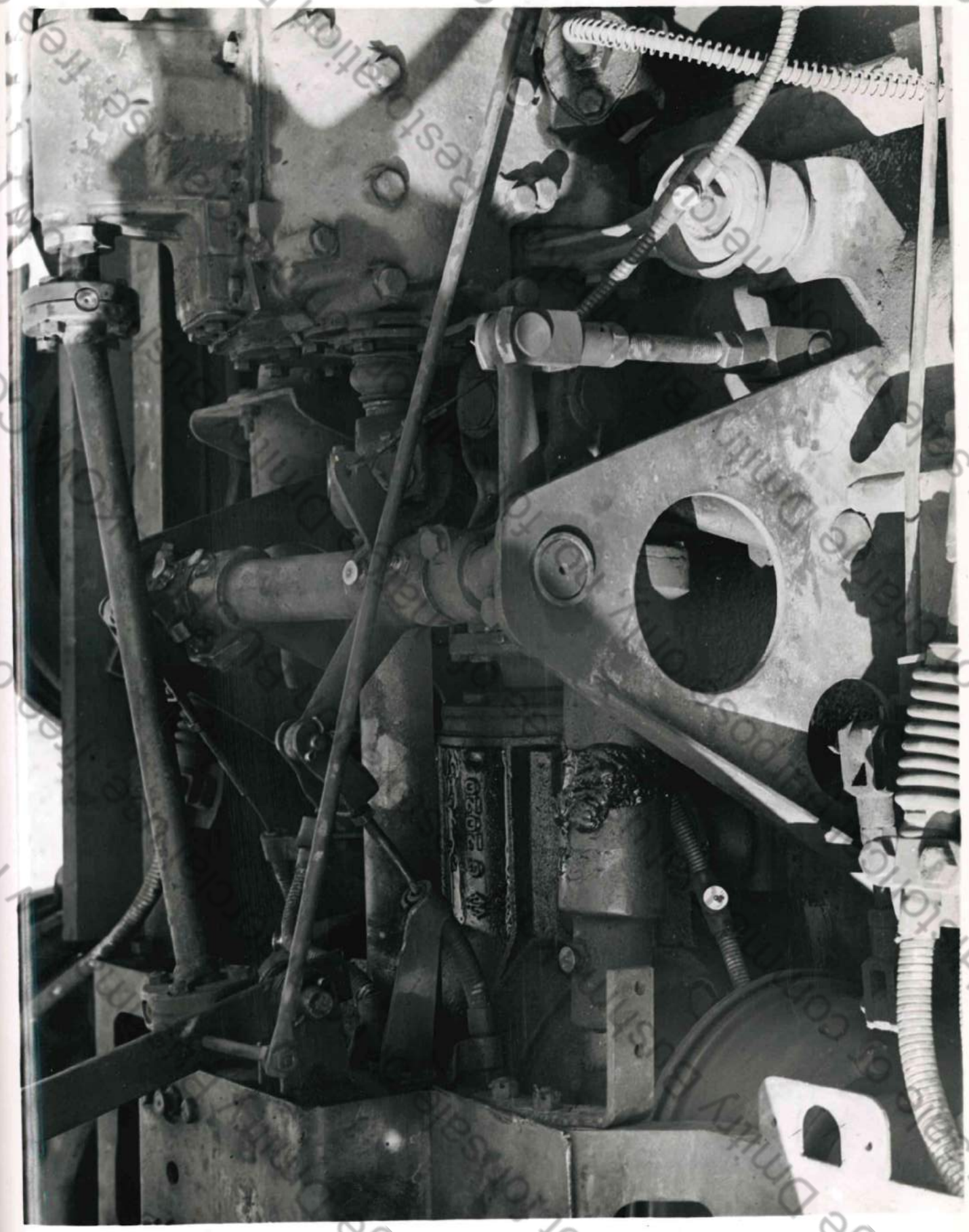

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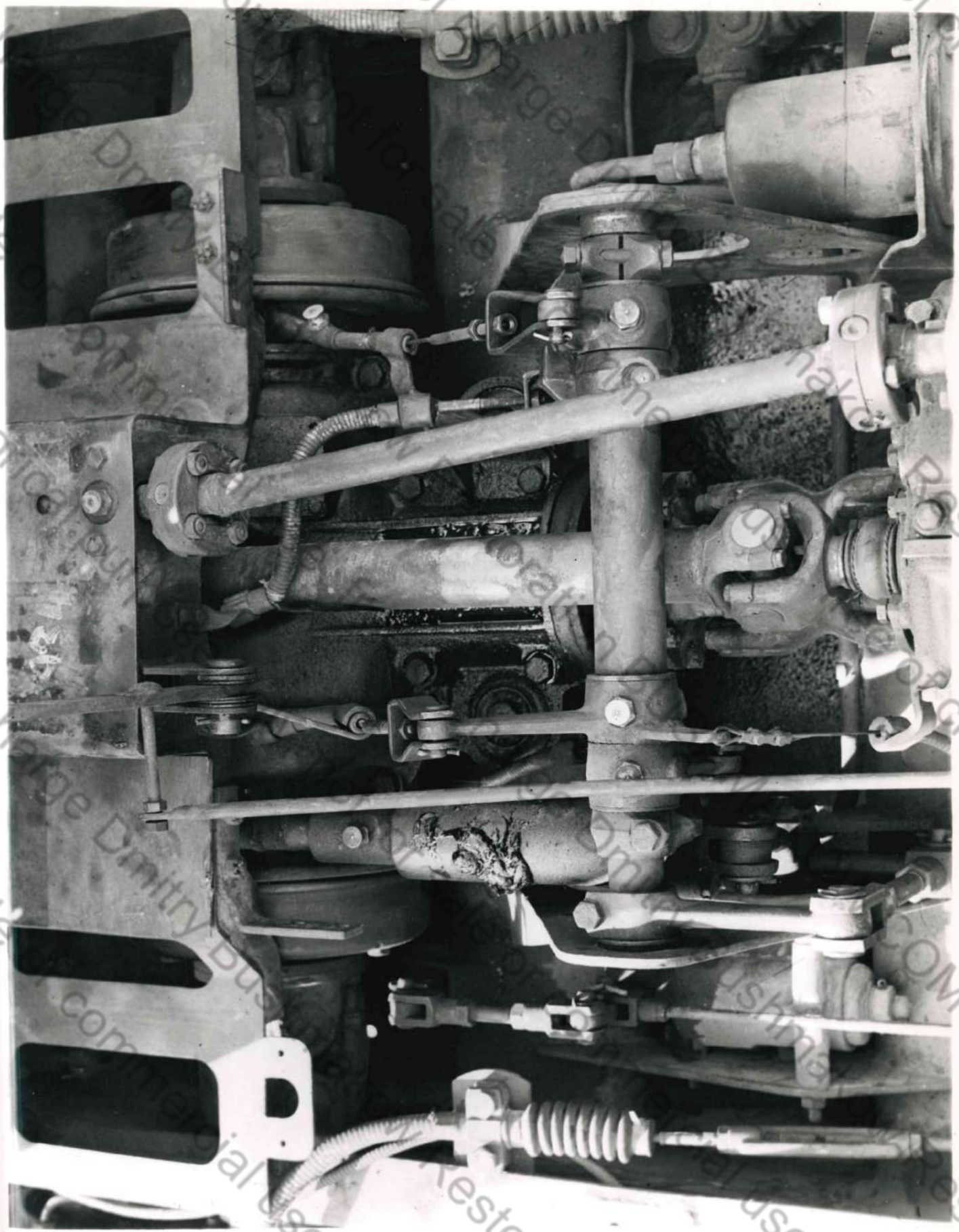

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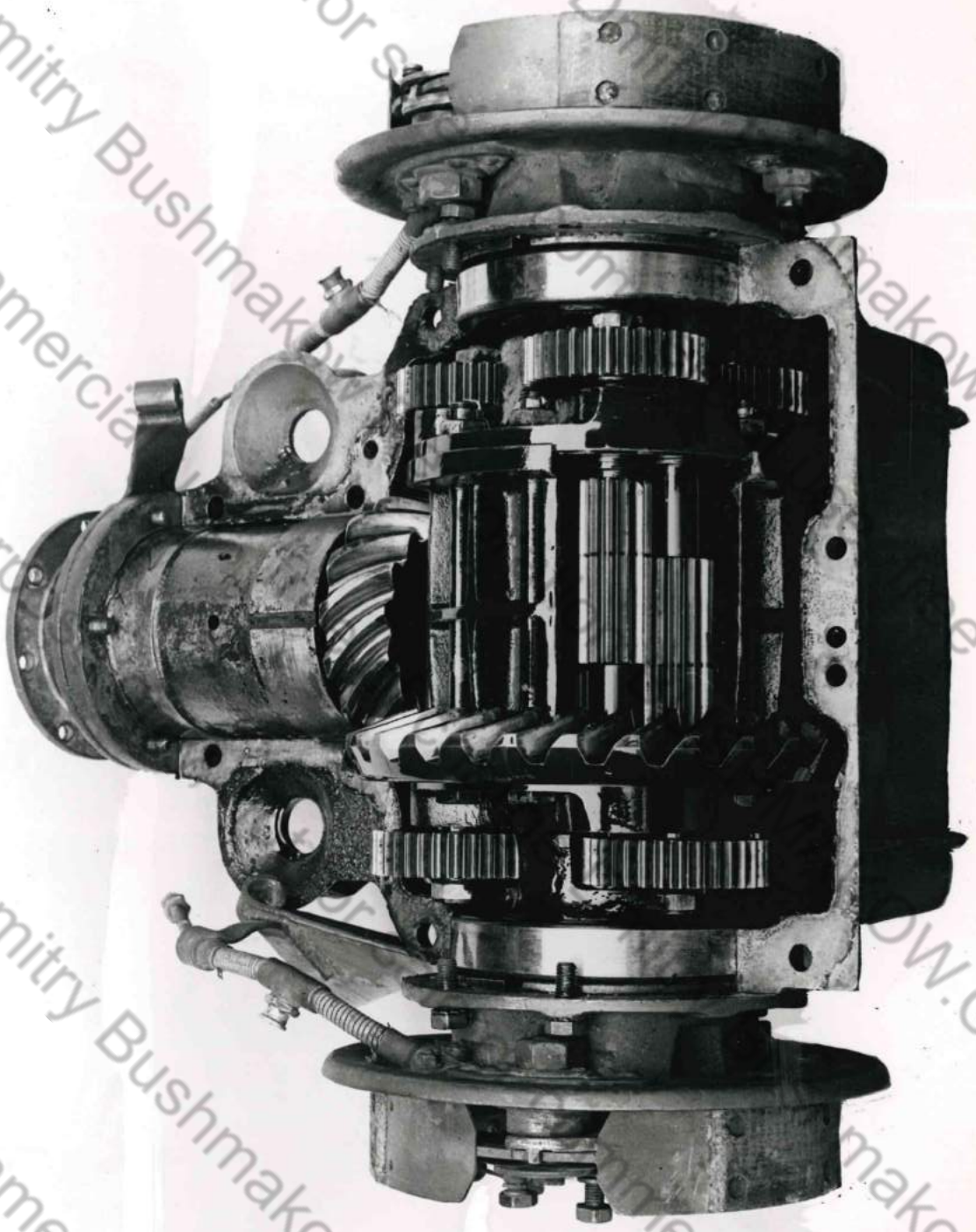

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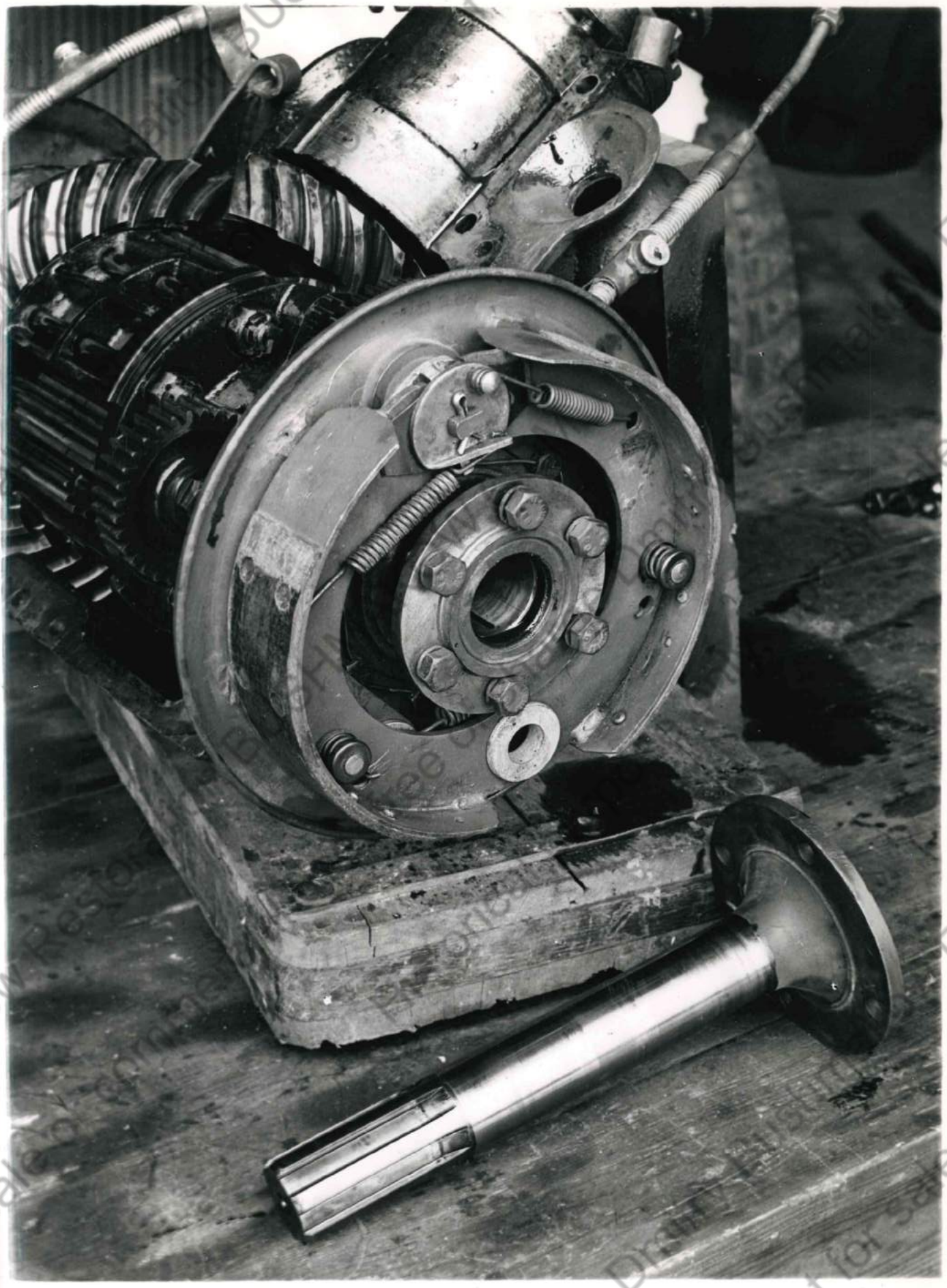

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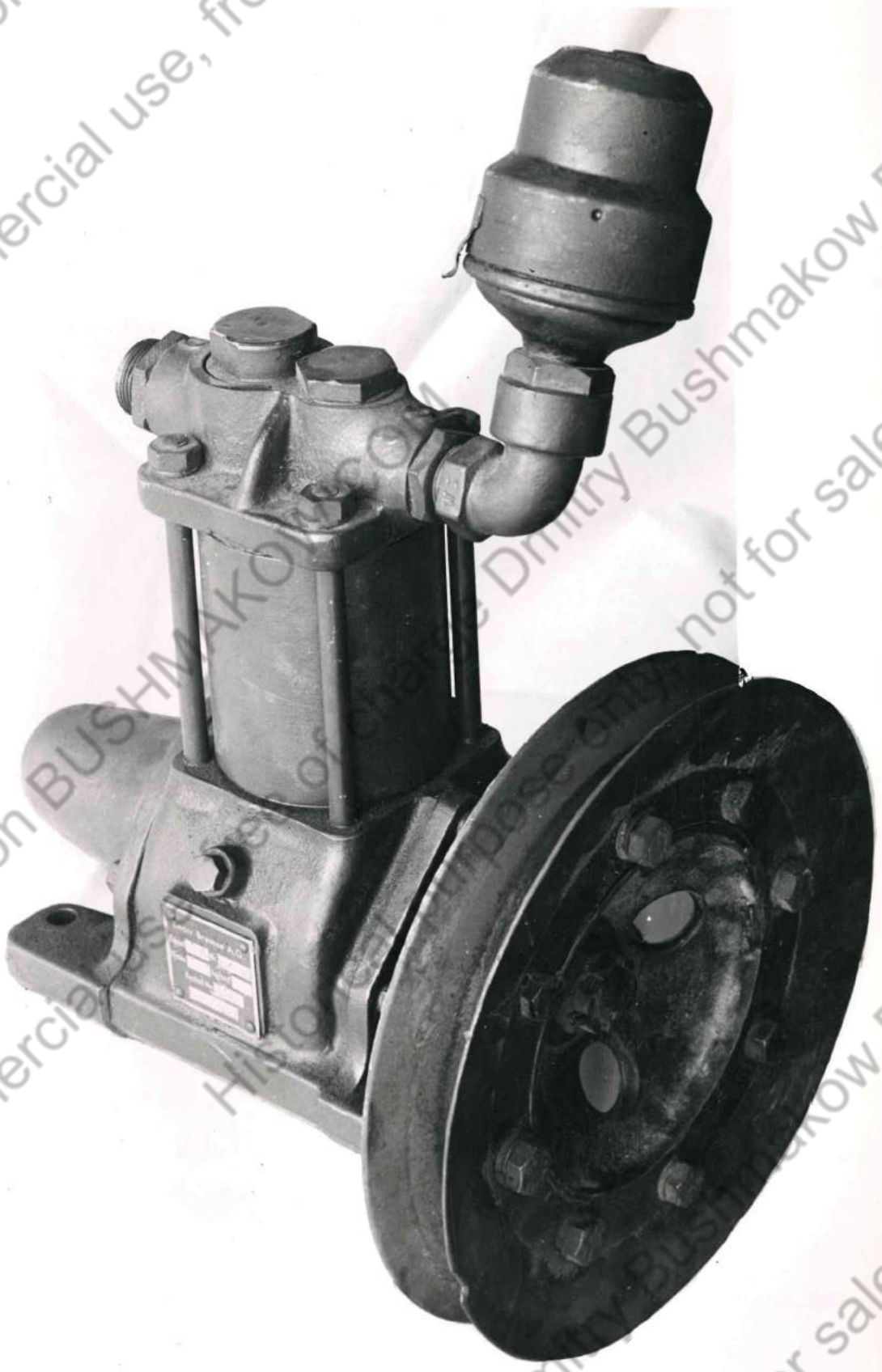
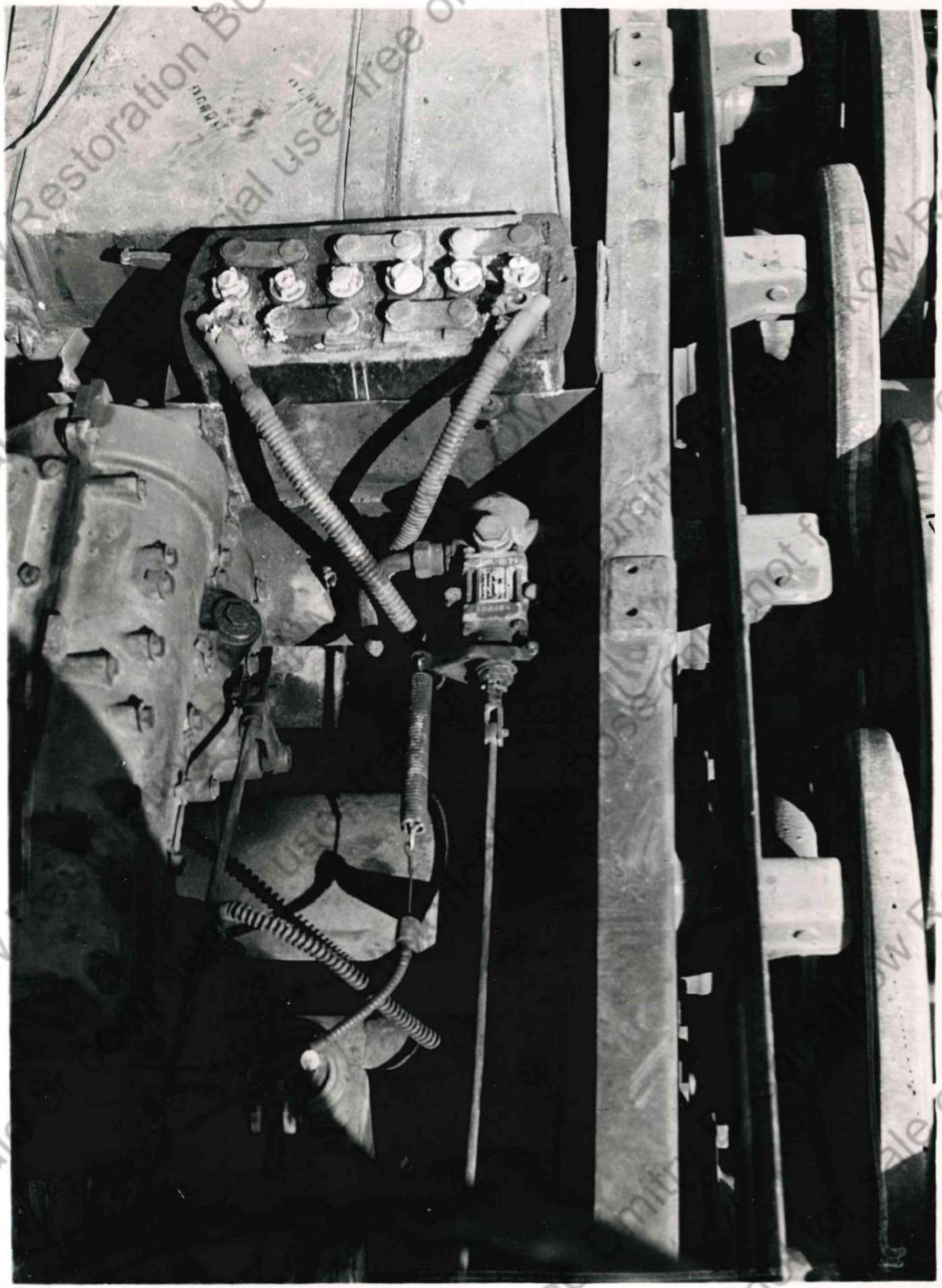


PLATE 86.

PLATE 87.



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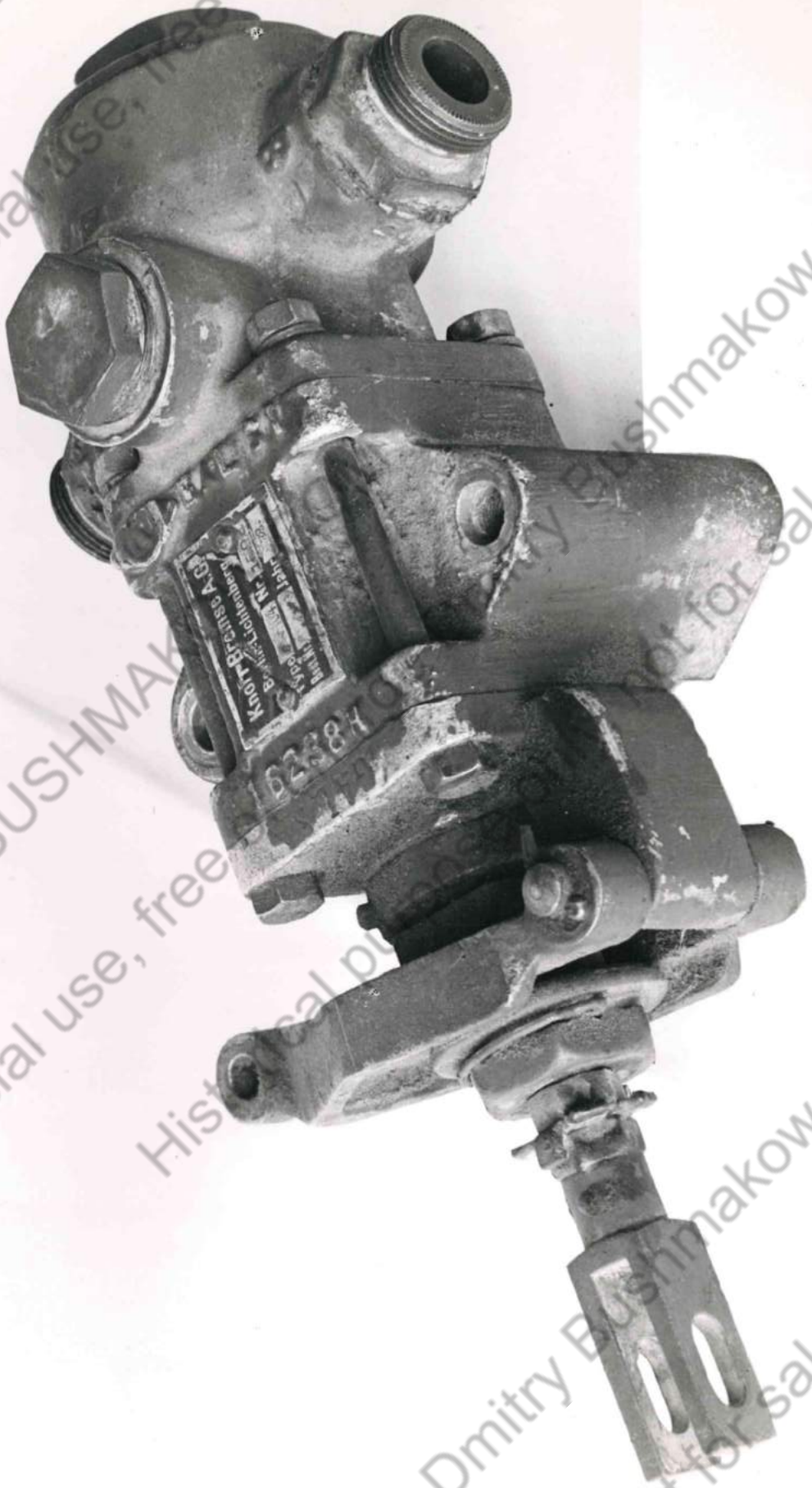
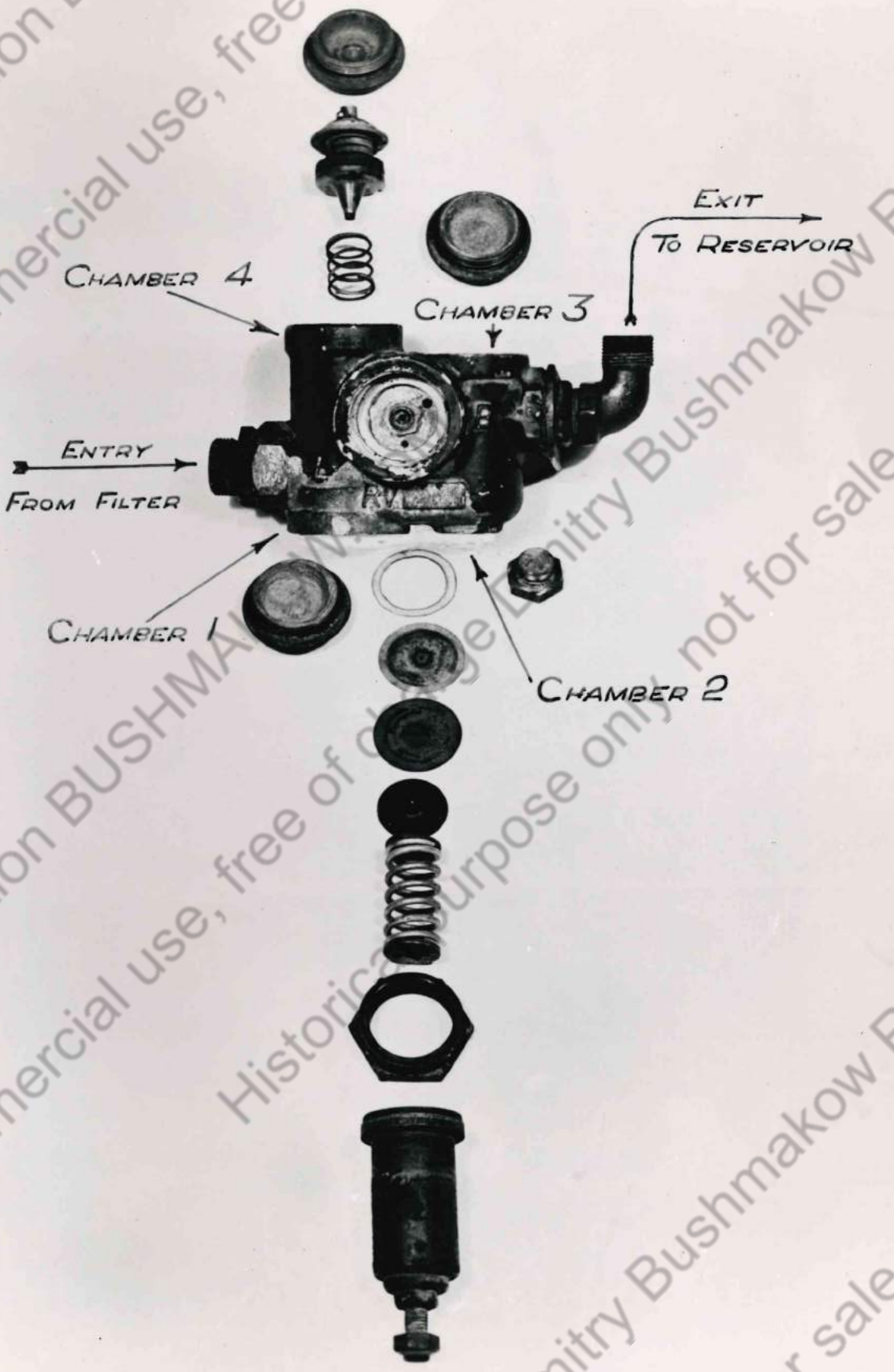


PLATE 89.

PLATE 90.



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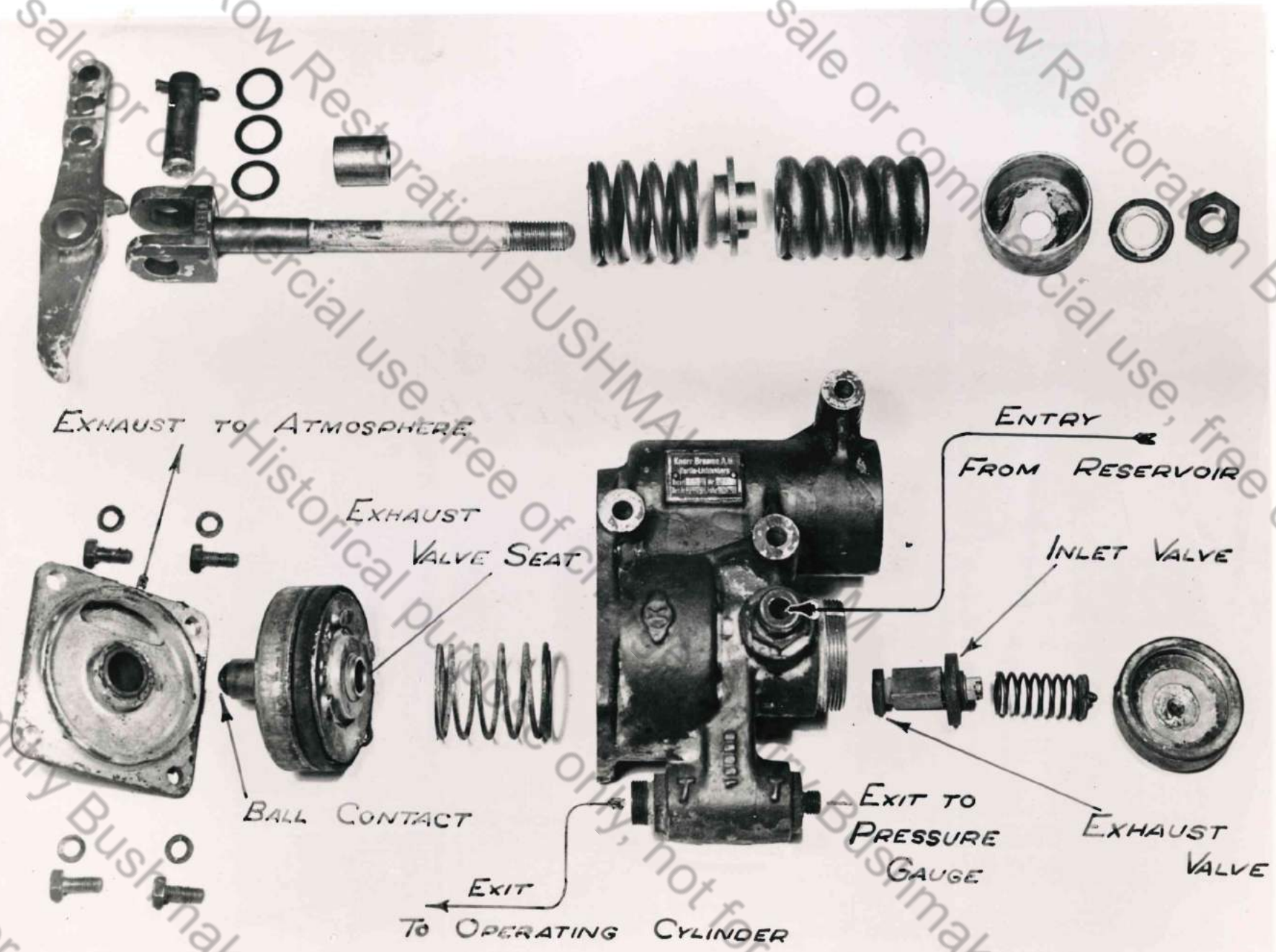

EXHAUST TO ATMOSPHERE
EXHAUST VALVE SEAT
BALL CONTACT
ENTRY FROM RESERVOIR
INLET VALVE
EXIT TO PRESSURE GAUGE
EXHAUST VALVE
EXIT TO OPERATING CYLINDER

PLATE 93.

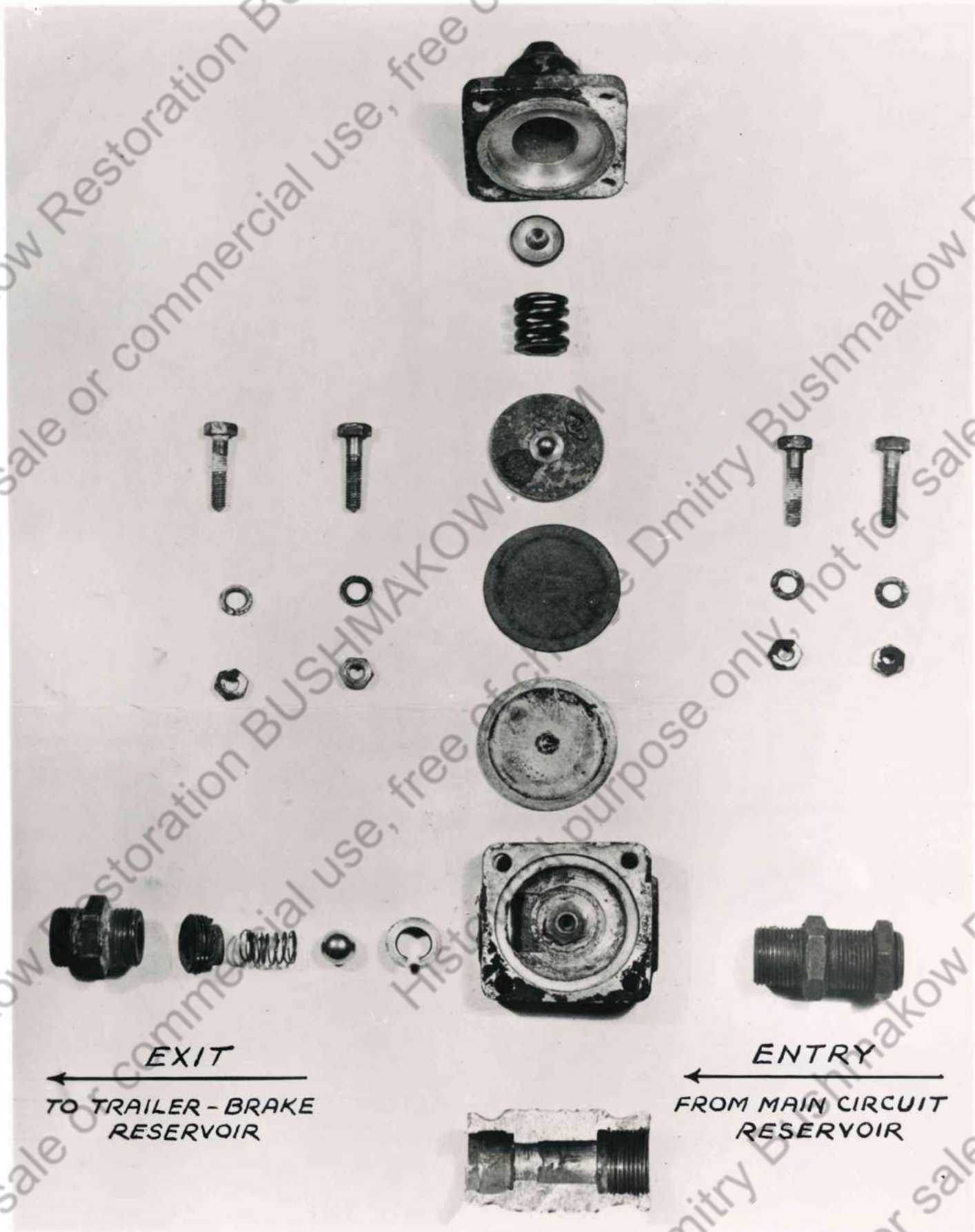


PLATE 94.

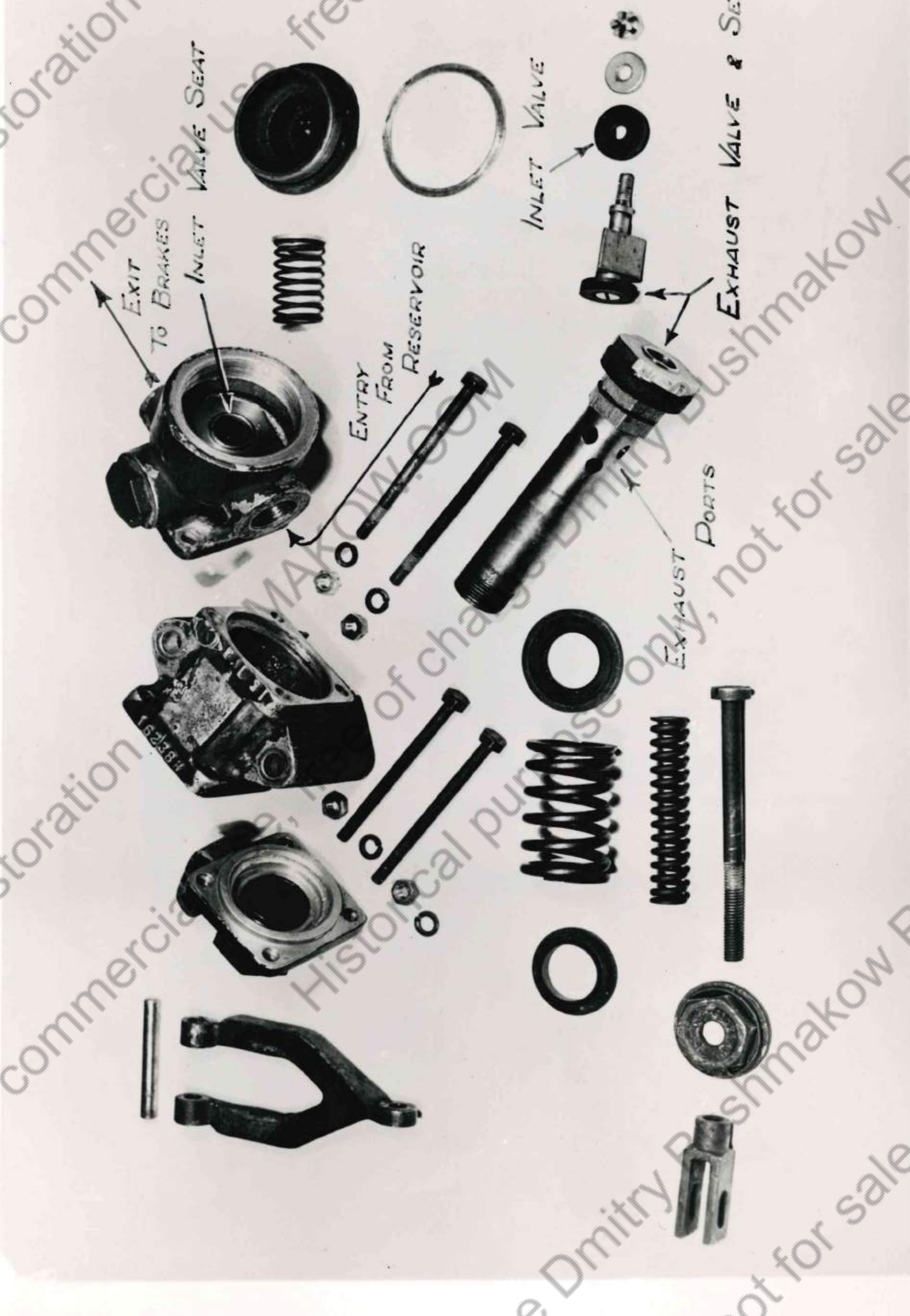
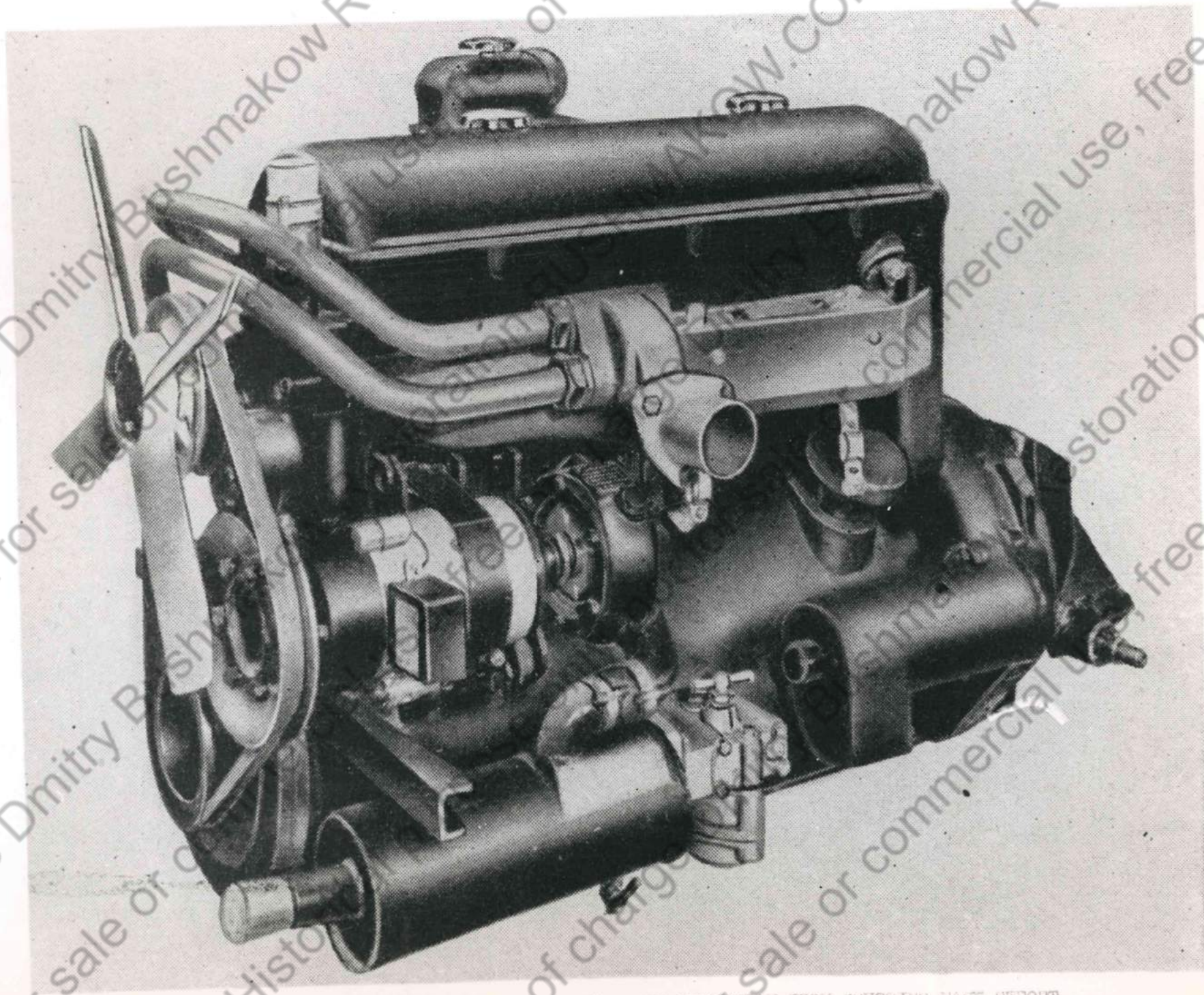
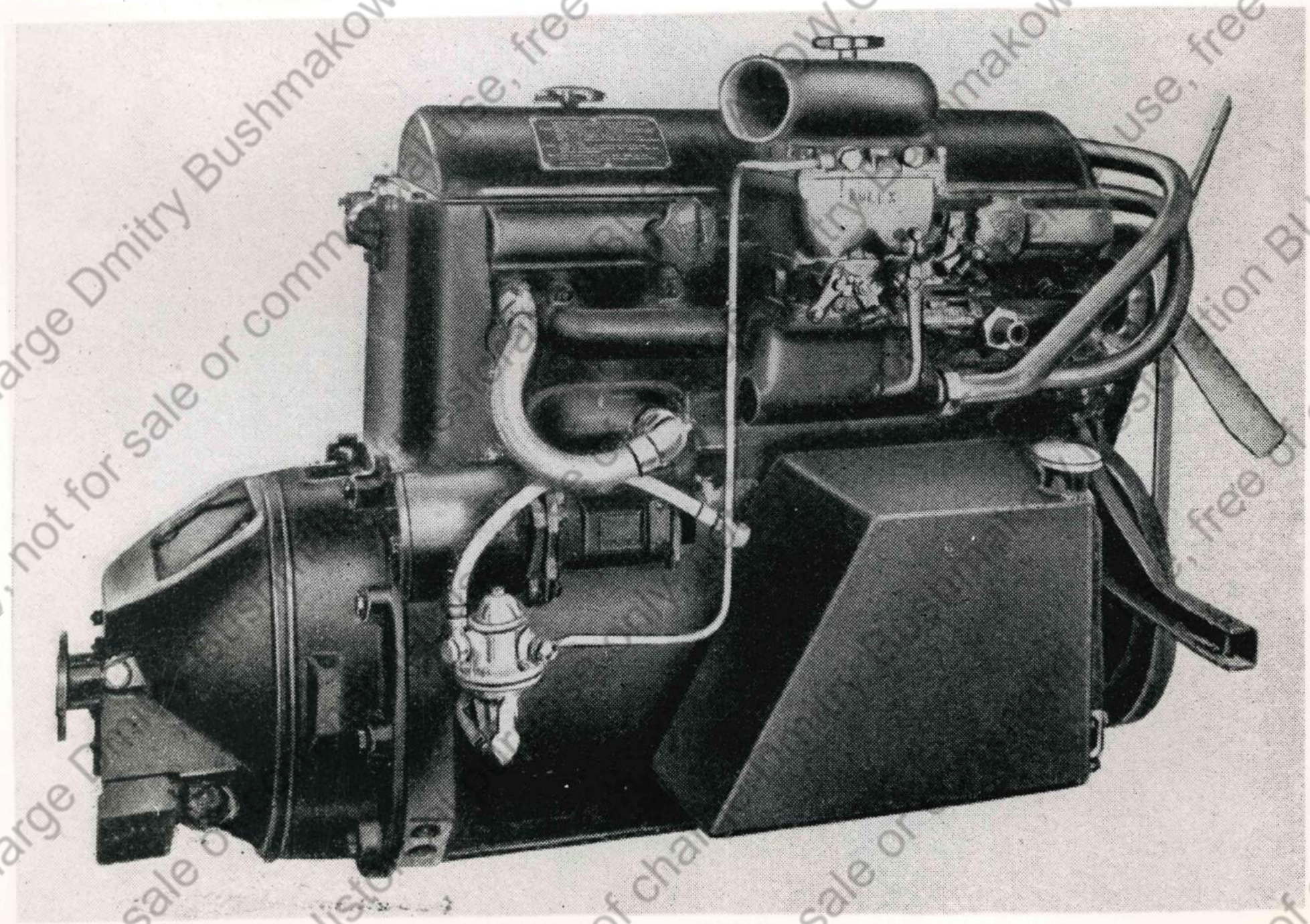


PLATE 95[illegible]

PLATE 96.

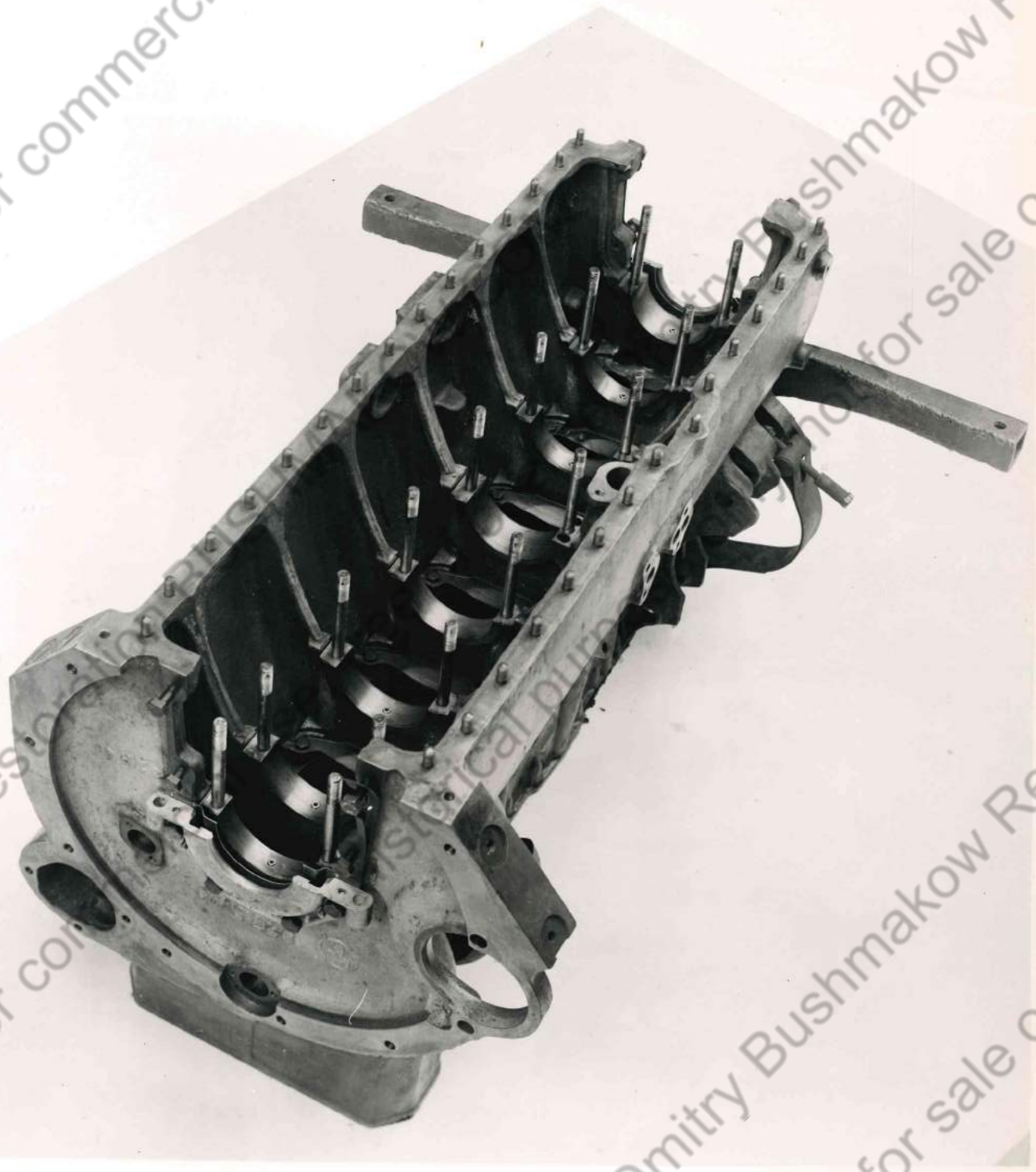


ZGKW 1.4 ENGINE (EXHAUST SIDE). REPRODUCTION FROM "BUSSING NAG" REPORT.



ZGKW 1.5 ENGINE (CARBURETTOR SIDE). REPRODUCTION FROM "BUSSING NAG" REPORT.

ZGKW 1.t ENGINE. REPRODUCTION FROM "BUSSING NAG" REPORT.



ZGKW 1.t ENGINE. REPRODUCTION FROM "BUSSING NAG" REPORT.

PLATE 108.