CONTENTS

1. STRUCTURE

This service manual has been prepared as an aid to improve the quality of repairs by giving the serviceman an accurate understanding of the product and by showing him the correct way to perform repairs and make judgements. Make sure you understand the contents of this manual and use it to full effect at every opportunity.
This service manual mainly contains the necessary technical information for operations performed in a service workshop.
For ease of understanding, the manual is divided into the following sections.

SECTION 1 GENERAL
This section gives the general information of the machine and explains the safety hints for maintenance.

SECTION 2 REMOVAL & INSTALLATION OF UNIT
This section explains the procedures and techniques of removal and installation of each component.

SECTION 3 POWER TRAIN SYSTEM
This section explains the structure of the transmission as well as control valve and drive axle.

SECTION 4 BRAKE SYSTEM
This section explains the brake piping, each component and operation.

SECTION 5 STEERING SYSTEM
This section explains the structure of the steering unit, priority valve, trail axle as well as steering circuit and operation.

SECTION 6 HYDRAULIC SYSTEM
This section explains the structure of the gear pump, main control valve as well as work equipment circuit, each component and operation.

SECTION 7 ELECTRICAL SYSTEM
This section explains the electrical circuit and each component.
It serves not only to give an understanding electrical system, but also serves as reference material for troubleshooting.

SECTION 8 MAST
This section explains the structure of mast, carriage, backrest and forks.

The specifications contained in this service manual are subject to change at any time and without any advance notice. Contact your HYUNDAI distributor for the latest information.

2. HOW TO READ THE SERVICE MANUAL

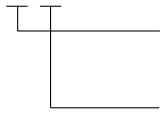
Distribution and updating

Any additions, amendments or other changes will be sent to HYUNDAI distributors.

Get the most up-to-date information before you start any work.

Filing method

1. See the page number on the bottom of the page.
   File the pages in correct order.
2. Following examples shows how to read the page number.
   Example 1



Item number(2. Structure and Function)

Consecutive page number for each item.

3. Additional pages : Additional pages are indicated by a hyphen(-) and number after the page number. File as in the example.

10 - 4
10 - 4 - 1 ┐
10 - 4 - 2 ┘ Added pages
10 - 5

Revised edition mark(①②③…)

When a manual is revised, an edition mark is recorded on the bottom outside corner of the pages.

Revisions

Revised pages are shown at the **list of revised pages** on the between the contents page and section 1 page.

Symbols

So that the shop manual can be of ample practical use, important places for safety and quality are marked with the following symbols.

Symbol	Item	Remarks
	Safety	Special safety precautions are necessary when performing the work.
		Extra special safety precautions are necessary when performing the work because it is under internal pressure.
※	Caution	Special technical precautions or other precautions for preserving standards are necessary when performing the work.

3. CONVERSION TABLE

Method of using the Conversion Table

The Conversion Table in this section is provided to enable simple conversion of figures. For details of the method of using the Conversion Table, see the example given below.

Example

1. Method of using the Conversion Table to convert from millimeters to inches
   Convert 55mm into inches.

   (1) Locate the number 50in the vertical column at the left side, take this as ⓐ, then draw a horizontal line from ⓐ.

   (2) Locate the number 5in the row across the top, take this as ⓑ, then draw a perpendicular line down from ⓑ.

   (3) Take the point where the two lines cross as ⓒ. This point ⓒ gives the value when converting from millimeters to inches. Therefore, 55mm = 2.165 inches.

2. Convert 550mm into inches.

   (1) The number 550 does not appear in the table, so divide by 10(Move the decimal point one place to the left) to convert it to 55mm.

   (2) Carry out the same procedure as above to convert 55mm to 2.165 inches.

   (3) The original value(550mm) was divided by 10, so multiply 2.165 inches by 10(Move the decimal point one place to the right) to return to the original value.
   This gives 550mm = 21.65 inches.

Millimeters to inches

1mm = 0.03937 in

	0	1	2	3	4	5 ⓑ	6	7	8	9
0		0.039	0.079	0.118	0.157	0.197	0.236	0.276	0.315	0.354
10	0.394	0.433	0.472	0.512	0.551	0.591	0.630	0.669	0.709	0.748
20	0.787	0.827	0.866	0.906	0.945	0.984	1.024	1.063	1.102	1.142
30	1.181	1.220	1.260	1.299	1.339	1.378	1.417	1.457	1.496	1.536
40	1.575	1.614	1.654	1.693	1.732	1.772	1.811	1.850	1.890	1.929
ⓐ 50	1.969	2.008	2.047	2.087	2.126	ⓒ 2.165	2.205	2.244	2.283	2.323
60	2.362	2.402	2.441	2.480	2.520	2.559	2.598	2.638	2.677	2.717
70	2.756	2.795	2.835	2.874	2.913	2.953	2.992	3.032	3.071	3.110
80	3.150	3.189	3.228	3.268	3.307	3.346	3.386	3.425	3.465	3.504
90	3.543	3.583	3.622	3.661	3.701	3.740	3.780	3.819	3.858	3.898

Millimeters to inches

1mm = 0.03937in

	0	1	2	3	4	5	6	7	8	9
0		0.039	0.079	0.118	0.157	0.197	0.236	0.276	0.315	0.354
10	0.394	0.433	0.472	0.512	0.551	0.591	0.630	0.669	0.709	0.748
20	0.787	0.827	0.866	0.906	0.945	0.984	1.024	1.063	1.102	1.142
30	1.181	1.220	1.260	1.299	1.339	1.378	1.417	1.457	1.496	1.536
40	1.575	1.614	1.654	1.693	1.732	1.772	1.811	1.850	1.890	1.929
50	1.969	2.008	2.047	2.087	2.126	2.165	2.205	2.244	2.283	2.323
60	2.362	2.402	2.441	2.480	2.520	2.559	2.598	2.638	2.677	2.717
70	2.756	2.795	2.835	2.874	2.913	2.953	2.992	3.032	3.071	3.110
80	3.150	3.189	3.228	3.268	3.307	3.346	3.386	3.425	3.465	3.504
90	3.543	3.583	3.622	3.661	3.701	3.740	3.780	3.819	3.858	3.898

Kilogram to Pound

1kg = 2.2046lb

	0	1	2	3	4	5	6	7	8	9
0		2.20	4.41	6.61	8.82	11.02	13.23	15.43	17.64	19.84
10	22.05	24.25	26.46	28.66	30.86	33.07	35.27	37.48	39.68	41.89
20	44.09	46.30	48.50	50.71	51.91	55.12	57.32	59.5.	61.73	63.93
30	66.14	68.34	70.55	72.75	74.96	77.16	79.37	81.57	83.78	85.98
40	88.18	90.39	92.59	94.80	97.00	99.21	101.41	103.62	105.82	108.03
50	110.23	112.44	114.64	116.85	119.05	121.25	123.46	125.66	127.87	130.07
60	132.28	134.48	136.69	138.89	141.10	143.30	145.51	147.71	149.91	152.12
70	154.32	156.53	158.73	160.94	163.14	165.35	167.55	169.76	171.96	174.17
80	176.37	178.57	180.78	182.98	185.19	187.39	189.60	191.80	194.01	196.21
90	198.42	200.62	202.83	205.03	207.24	209.44	211.64	213.85	216.05	218.26

Liter to U.S. Gallon

1 l = 0.2642 U.S.Gal

	0	1	2	3	4	5	6	7	8	9
0		0.264	0.528	0.793	1.057	1.321	1.585	1.849	2.113	2.378
10	2.642	2.906	3.170	3.434	3.698	3.963	4.227	4.491	4.755	5.019
20	5.283	5.548	5.812	6.6076	6.340	6.604	6.869	7.133	7.397	7.661
30	7.925	8.189	8.454	8.718	8.982	9.246	9.510	9.774	10.039	10.303
40	10.567	10.831	11.095	11.359	11.624	11.888	12.152	12.416	12.680	12.944
50	13.209	13.473	13.737	14.001	14.265	14.529	14.795	15.058	15.322	15.586
60	15.850	16.115	16.379	16.643	16.907	17.171	17.435	17.700	17.964	18.228
70	18.492	18.756	19.020	19.285	19.549	19.813	20.077	20.341	20.605	20.870
80	21.134	21.398	21.662	21.926	22.190	22.455	22.719	22.983	23.247	23.511
90	23.775	24.040	24.304	24.568	24.832	25.096	25.631	25.625	25.889	26.153

Liter to U.K. Gallon

1 l = 0.21997 U.K.Gal

	0	1	2	3	4	5	6	7	8	9
0		0.220	0.440	0.660	0.880	1.100	1.320	1.540	1.760	1.980
10	2.200	2.420	2.640	2.860	3.080	3.300	3.520	3.740	3.950	4.179
20	4.399	4.619	4.839	5.059	5.279	5.499	5.719	5.939	6.159	6.379
30	6.599	6.819	7.039	7.259	7.479	7.969	7.919	8.139	8.359	8.579
40	8.799	9.019	9.239	9.459	9.679	9.899	10.119	10.339	10.559	10.778
50	10.998	11.281	11.438	11.658	11.878	12.098	12.318	12.528	12.758	12.978
60	13.198	13.418	13.638	13.858	14.078	14.298	14.518	14.738	14.958	15.178
70	15.398	15.618	15.838	16.058	16.278	16.498	16.718	16.938	17.158	17.378
80	17.598	17.818	18.037	18.257	18.477	18.697	18.917	19.137	19.357	19.577
90	19.797	20.017	20.237	20.457	20.677	20.897	21.117	21.337	21.557	21.777

kgf · m to lbf · ft

1kgf · m = 7.233lbf · ft

	0	1	2	3	4	5	6	7	8	9
		7.2	14.5	21.7	28.9	36.2	43.4	50.6	57.9	65.1
10	72.3	79.6	86.8	94.0	101.3	108.5	115.7	123.0	130.2	137.4
20	144.7	151.9	159.1	166.4	173.6	180.8	188.1	195.3	202.5	209.8
30	217.0	224.2	231.5	238.7	245.9	253.2	260.4	267.6	274.9	282.1
40	289.3	396.6	303.8	311.0	318.3	325.5	332.7	340.0	347.2	354.4
50	361.7	368.9	376.1	383.4	390.6	397.8	405.1	412.3	419.5	426.8
60	434.0	441.2	448.5	455.7	462.9	470.2	477.4	484.6	491.8	499.1
70	506.3	513.5	520.8	528.0	535.2	542.5	549.7	556.9	564.2	571.4
80	578.6	585.9	593.1	600.3	607.6	614.8	622.0	629.3	636.5	643.7
90	651.0	658.2	665.4	672.7	679.9	687.1	694.4	701.6	708.8	716.1
100	723.3	730.5	737.8	745.0	752.2	759.5	766.7	773.9	781.2	788.4
110	795.6	802.9	810.1	817.3	824.6	831.8	839.0	846.3	853.5	860.7
120	868.0	875.2	882.4	889.7	896.9	904.1	911.4	918.6	925.8	933.1
130	940.3	947.5	954.8	962.0	969.2	976.5	983.7	990.9	998.2	10005.4
140	1012.6	1019.9	1027.1	1034.3	1041.5	1048.8	1056.0	1063.2	1070.5	1077.7
150	1084.9	1092.2	1099.4	1106.6	1113.9	1121.1	1128.3	1135.6	1142.8	1150.0
160	1157.3	1164.5	1171.7	1179.0	1186.2	1193.4	1200.7	1207.9	1215.1	1222.4
170	1129.6	1236.8	1244.1	1251.3	1258.5	1265.8	1273.0	1280.1	1287.5	1294.7
180	1301.9	1309.2	1316.4	1323.6	1330.9	1338.1	1345.3	1352.6	1359.8	1367.0
190	1374.3	1381.5	1388.7	1396.0	1403.2	1410.4	1417.7	1424.9	1432.1	1439.4

kgf/cm² to lbf/in²

1kgf / cm² = 14.2233lbf / in²

	0	1	2	3	4	5	6	7	8	9
		14.2	28.4	42.7	56.9	71.1	85.3	99.6	113.8	128.0
10	142.2	156.5	170.7	184.9	199.1	213.4	227.6	241.8	256.0	270.2
20	284.5	298.7	312.9	327.1	341.4	355.6	369.8	384.0	398.3	412.5
30	426.7	440.9	455.1	469.4	483.6	497.8	512.0	526.3	540.5	554.7
40	568.9	583.2	597.4	611.6	625.8	640.1	654.3	668.5	682.7	696.9
50	711.2	725.4	739.6	753.8	768.1	782.3	796.5	810.7	825.0	839.2
60	853.4	867.6	881.8	896.1	910.3	924.5	938.7	953.0	967.2	981.4
70	995.6	1010	1024	1038	1053	1067	1081	1095	1109	1124
80	1138	1152	1166	1181	1195	1209	1223	1237	1252	1266
90	1280	1294	1309	1323	1337	1351	1365	1380	1394	1408
100	1422	1437	1451	1465	1479	1493	1508	1522	1536	1550
110	1565	1579	1593	1607	1621	1636	1650	1664	1678	1693
120	1707	1721	1735	1749	1764	1778	1792	1806	1821	1835
130	1849	2863	1877	1892	1906	1920	1934	1949	1963	1977
140	1991	2005	2020	2034	2048	2062	2077	2091	2105	2119
150	2134	2148	2162	2176	2190	2205	2219	2233	2247	2262
160	2276	2290	2304	2318	2333	2347	2361	2375	2389	2404
170	2418	2432	2446	2460	2475	2489	2503	2518	2532	2546
180	2560	2574	2589	5603	2617	2631	2646	2660	2674	2688
200	2845	2859	2873	2887	2901	2916	2930	2944	2958	2973
210	2987	3001	3015	3030	3044	3058	3072	3086	3101	3115
220	3129	3143	3158	3172	3186	3200	3214	3229	3243	3257
230	3271	3286	3300	3314	3328	3343	3357	3371	3385	3399
240	3414	3428	3442	3456	3470	3485	3499	3513	3527	3542

TEMPERATURE

Fahrenheit-Centigrade Conversion.

A simple way to convert a fahrenheit temperature reading into a centigrade temperature reading or vice verse is to enter the accompanying table in the center or boldface column of figures.

These figures refer to the temperature in either Fahrenheit or Centigrade degrees.

If it is desired to convert from Fahrenheit to Centigrade degrees, consider the center column as a table of Fahrenheit temperatures and read the corresponding Centigrade temperature in the column at the left.

If it is desired to convert from Centigrade to Fahrenheit degrees, consider the center column as a table of Centigrade values, and read the corresponding Fahrenheit temperature on the right.

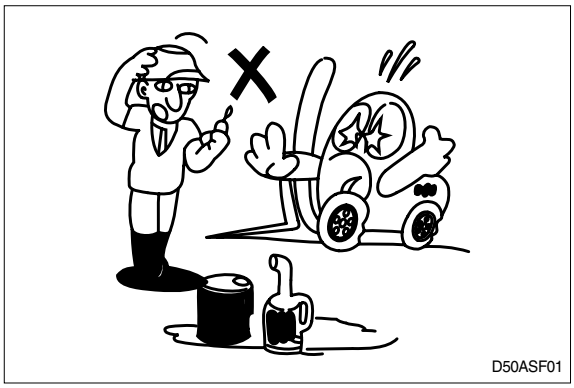
°C		°F	°C		°F	°C		°F	°C		°F
-40.4	-40	-40.0	-11.7	11	51.8	7.8	46	114.8	27.2	81	117.8
-37.2	-35	-31.0	-11.1	12	53.6	8.3	47	116.6	27.8	82	179.6
-34.4	-30	-22.0	-10.6	13	55.4	8.9	48	118.4	28.3	83	181.4
-31.7	-25	-13.0	-10.0	14	57.2	9.4	49	120.2	28.9	84	183.2
-28.9	-20	-4.0	-9.4	15	59.0	10.0	50	122.0	29.4	85	185.0
-28.3	-19	-2.2	-8.9	16	60.8	10.6	51	123.8	30.0	86	186.8
-27.8	-18	-0.4	-8.3	17	62.6	11.1	52	125.6	30.6	87	188.6
-27.2	-17	1.4	-7.8	18	64.4	11.7	53	127.4	31.1	88	190.4
-26.7	-16	3.2	-6.7	20	68.0	12.8	55	131.0	32.2	90	194.0
-26.1	-15	5.0	-6.7	20	68.0	12.8	55	131.0	32.2	90	194.0
-25.6	-14	6.8	-6.1	21	69.8	13.3	56	132.8	32.8	91	195.8
-25.0	-13	8.6	-5.6	22	71.6	13.9	57	134.6	33.3	92	197.6
-24.4	-12	10.4	-5.0	23	73.4	14.4	58	136.4	33.9	93	199.4
-23.9	-11	12.2	-4.4	24	75.2	15.0	59	138.2	34.4	94	201.2
-23.3	-10	14.0	-3.9	25	77.0	15.6	60	140.0	35.0	95	203.0
-22.8	-9	15.8	-3.3	26	78.8	16.1	61	141.8	35.6	96	204.8
-22.2	-8	17.6	-2.8	27	80.6	16.7	62	143.6	36.1	97	206.6
-21.7	-7	19.4	-2.2	28	82.4	17.2	63	145.4	36.7	98	208.4
-21.1	-6	21.2	-1.7	29	84.2	17.8	64	147.2	37.2	99	210.2
-20.6	-5	23.0	-1.1	35	95.0	21.1	70	158.0	51.7	125	257.0
-20.0	-4	24.8	-0.6	31	87.8	18.9	66	150.8	40.6	105	221.0
-19.4	-3	26.6	0	32	89.6	19.4	67	152.6	43.3	110	230.0
-18.9	-2	28.4	0.6	33	91.4	20.0	68	154.4	46.1	115	239.0
-18.3	-1	30.2	1.1	34	93.2	20.6	69	156.2	48.9	120	248.0
-17.8	0	32.0	1.7	35	95.0	21.1	70	158.0	51.7	125	257.0
-17.2	1	33.8	2.2	36	96.8	21.7	71	159.8	54.4	130	266.0
-16.7	2	35.6	2.8	37	98.6	22.2	72	161.6	57.2	135	275.0
-16.1	3	37.4	3.3	38	100.4	22.8	73	163.4	60.0	140	284.0
-15.6	4	39.2	3.9	39	102.2	23.3	74	165.2	62.7	145	293.0
-15.0	5	41.0	4.4	40	104.0	23.9	75	167.0	65.6	150	302.0
-14.4	6	42.8	5.0	41	105.8	24.4	76	168.8	68.3	155	311.0
-13.9	7	44.6	5.6	42	107.6	25.0	77	170.6	71.1	160	320.0
-13.3	8	46.4	6.1	43	109.4	25.6	78	172.4	73.9	165	329.0
-12.8	9	48.2	6.7	44	111.2	26.1	79	174.2	76.7	170	338.0
-12.2	10	50.0	7.2	45	113.0	26.7	80	176.0	79.4	172	347.0

SECTION 1 GENERAL

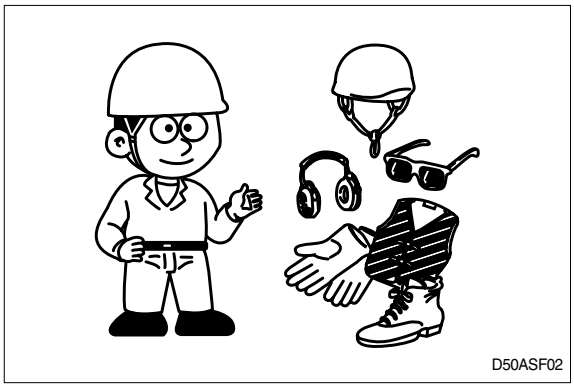
GROUP 1 SAFETY HINTS

Careless performing of the easy work may cause injuries.
Take care to always perform work safely, at least observing the following.

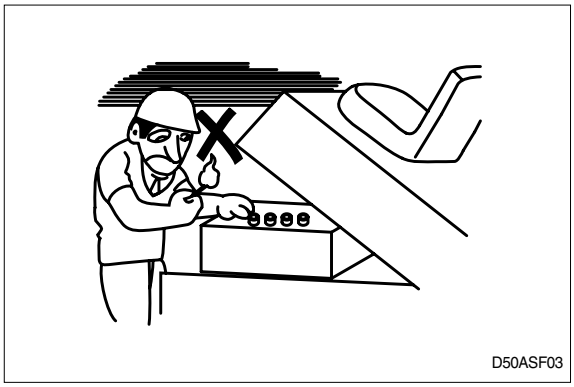
- Oil is a dangerous substance. Never handle oil, grease or oily clothes in places where there is any fire of flame.
  As preparation in case of fire, always know the location and directions for use of fire extinguishers and other fire fighting equipment.


D50ASF01

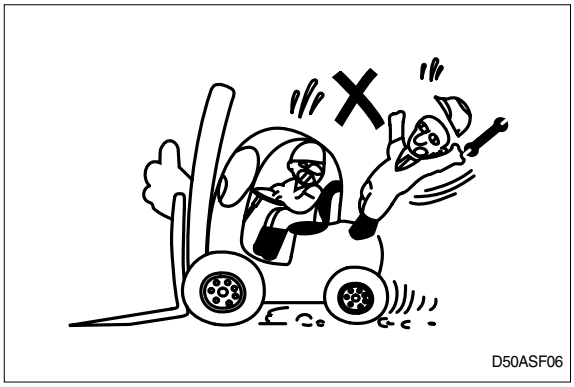
- Wear well-fitting helmet, safety shoes and working clothes. When drilling, grinding or hammering, always wear protective goggles.
  Always do up safety clothes properly so that they do not catch on protruding parts of machines. Do not wear oily clothes.
  When checking, always release battery plug.


D50ASF02

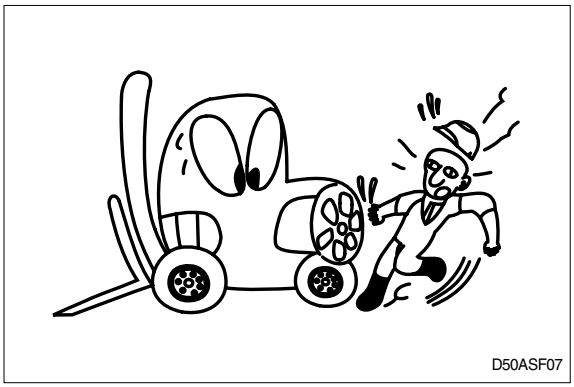
- Flames should never be used instead of lamps. Never use a naked flame to check leaks or the level of oil or electrolyte.


D50ASF03

- When working on top of the machine, be careful not to lose your balance and fall.

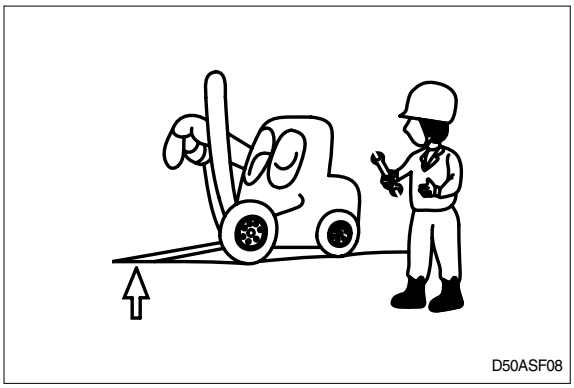

D50ASF06

- Hand a caution sign in the operator's compartment (For example **Do not start** or **Maintenance in progress**).
  This will prevent anyone from starting or moving the machine by mistake.

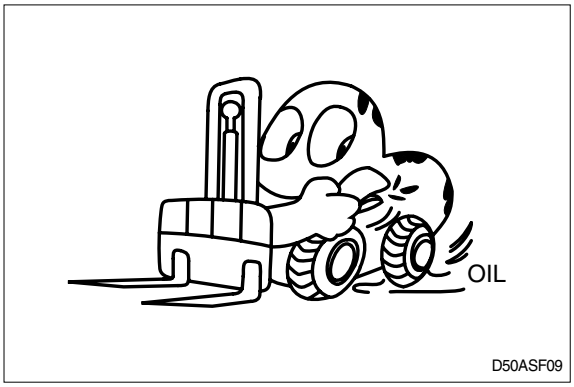

D50ASF07

When inspecting running parts or near such parts, always stop the machine first.
Before checking or servicing accumulator or piping, depress brake pedal repeatedly to release pressure.

- Park the machine on firm, flat ground.
  Lower the fork to the ground and stop the engine.
  Return each lever to **NEUTRAL** and apply the brake lock.

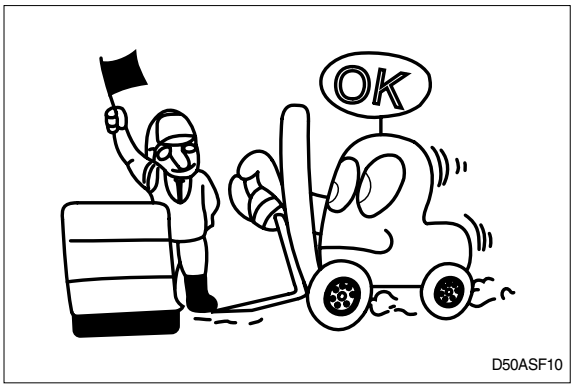

D50ASF08

- Immediately remove any oil or grease on the floor of the operator's compartment, or on the handrail. It is very dangerous if someone slips while on the machine.



D50ASF09

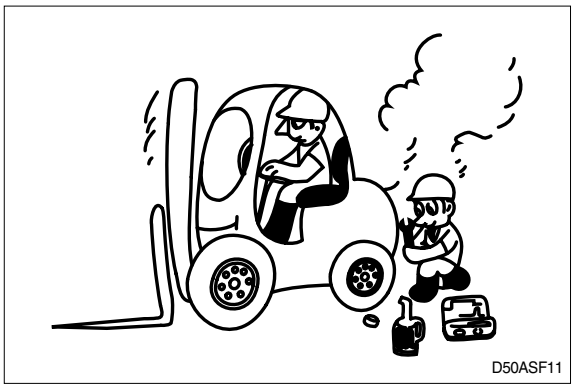
- When working with others, choose a group leader and work according to his instructions. Do not perform any maintenance beyond the agreed work.



D50ASF10

- Unless you have special instructions to the contrary, maintenance should always be carried out with the machine stopped. If maintenance is carried out with the machine running, there must be two men present : one sitting in the operator's seat and the other one performing the maintenance. In such a case, never touch any moving part.

- Always remember that the hydraulic oil circuit is under pressure. When feeding or draining the oil or carrying out inspection and maintenance, release the pressure first.

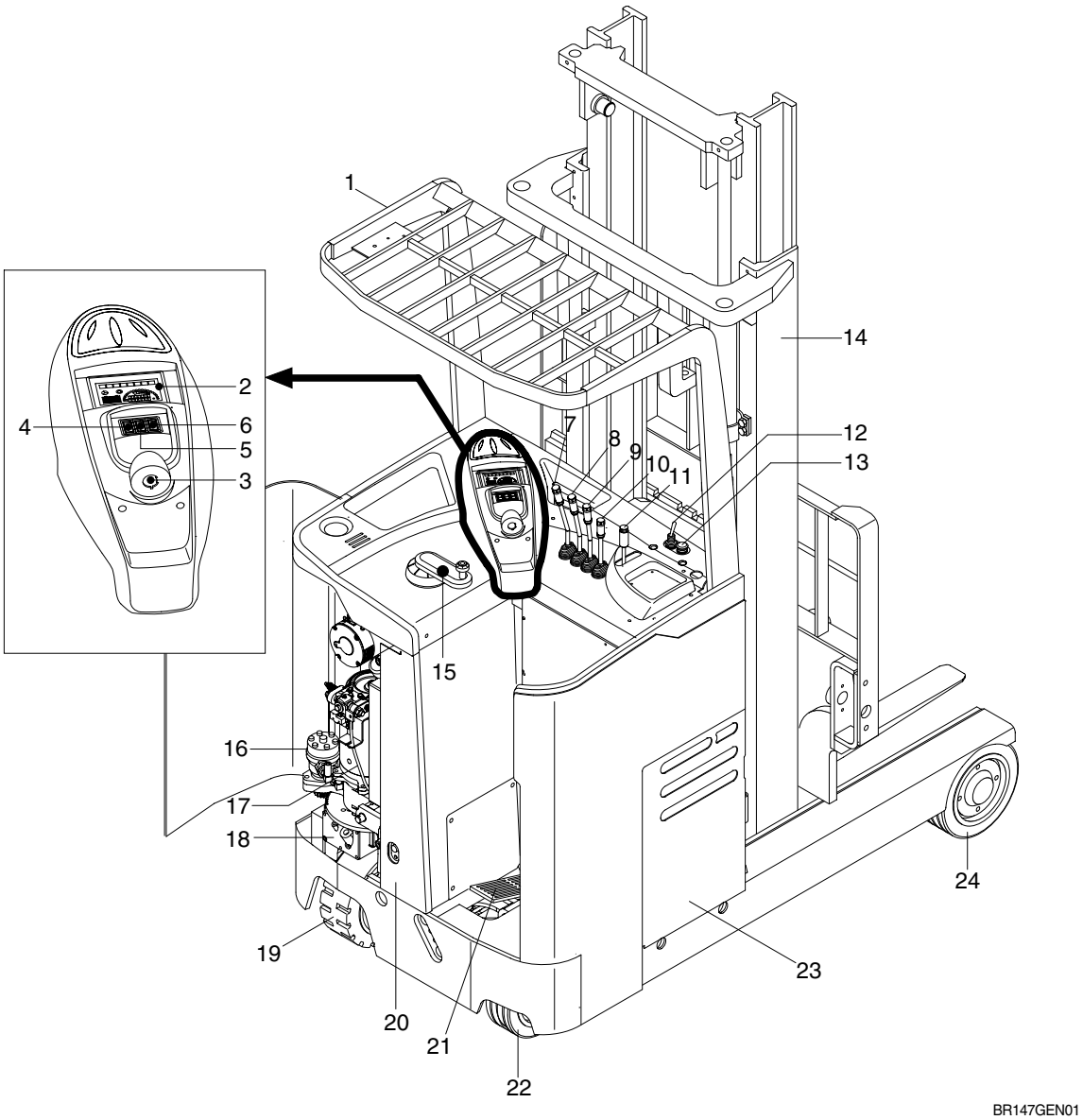


- Thoroughly clean the machine. In particular, be careful to clean the filler caps, grease fittings and the area around the dipsticks. Be careful not to let any dirt or dust into the system.
- Always use HYUNDAI Forklift genuine parts for replacement.
- Always use the grades of grease and oil recommended by HYUNDAI Forklift.
  Choose the viscosity specified for the ambient temperature.
- Always use pure oil or grease, and be sure to use clean containers.
- When checking or changing the oil, do it in a place free of dust, and prevent any dirt from getting into the oil.
- Before draining the oil, warm it up to a temperature of 30 to 40°C.
- After replacing oil, filter element or strainer, bleed the air from circuit.
- When the strainer is located in the oil filler, the strainer must not be removed while adding oil.
- When changing the oil filter, check the drained oil and filter for any signs of excessive metal particles or other foreign materials.
- When removing parts containing O-ring, gaskets or seals, clean the mounting surface and replace with new sealing parts.
- After injecting grease, always wipe off the oil grease that was forced out.
- Do not handle electrical equipment while wearing wet places, as this can cause electric shock.
- During maintenance do not allow any unauthorized person to stand near the machine.
- Be sure you fully understand the contents of the operation. It is important to prepare necessary tools and parts and to keep the operating area clean.
- When checking an open gear case there is a risk of dropping things in. Before removing the covers to inspect such cases, empty everything from your pockets. Be particularly careful to remove wrenches and nuts.
- Way to use dipstick
  Push the dipstick fully into the guide, and then pull out.

  Carrying out other difficult maintenance work carelessly can cause unexpected accidents. If you consider the maintenance is too difficult, always request the HYUNDAI Forklift distributor to carry out it.

GROUP 2 SPECIFICATIONS

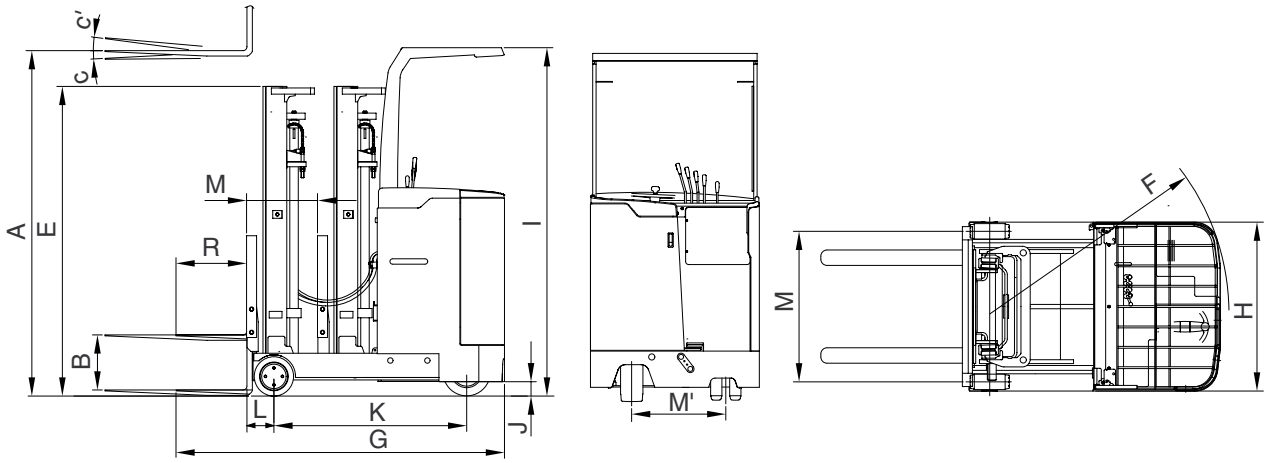
1. GENERAL LOCATIONS



1	Head guard	9	Reach lever	17	Drive motor
2	Monitor panel	10	Attachment lever	18	Drive unit
3	Key switch	11	Accelerator	19	Drive wheel
4	Head lamp switch	12	Dircection indication lamp switch	20	Hydraulic oil tank
5	Work lamp switch(Opt)	13	Hazard lamp switch	21	Brake pedal
6	Beacon lamp switch(Opt)	14	Mast	22	Caster wheel
7	Lift lever	15	Steering wheel	23	Battery cover
8	Tilt lever	16	EPS motor	24	Load wheel

2. SPECIFICATIONS

1) HBR14/15/18-7

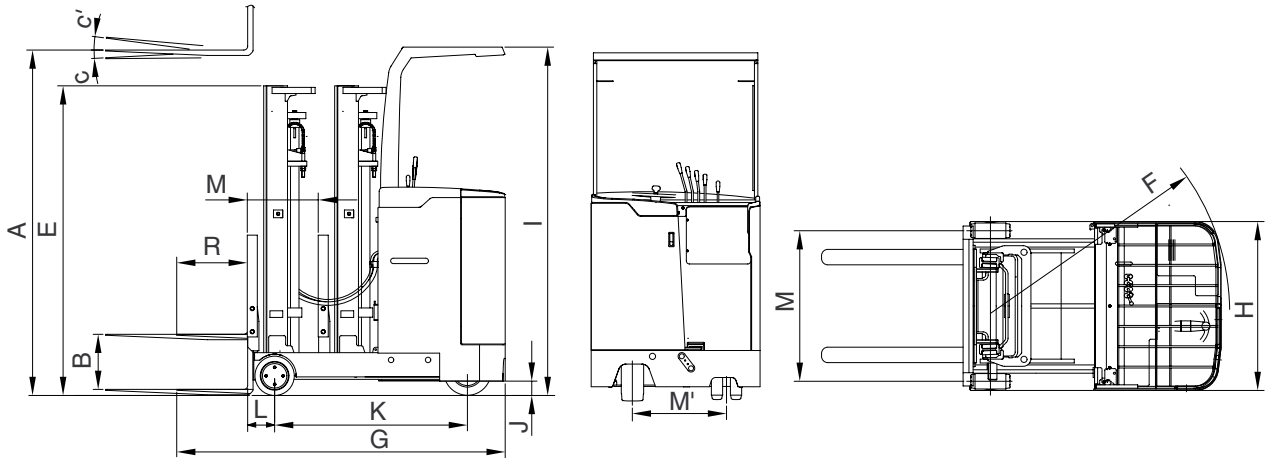


BR147SP01

Model			Unit	HBR 14-7	HBR 15-7	HBR 18-7
Capacity			kg	1350	1500	1800
Load center		R	mm	500	←	←
Weight(Unloaded, with battery)			kg	2210	2290	2350
Fork	Lifting height	A	mm	3000	←	←
	Free lift	B	mm	357	←	←
	Lifting speed(Unload/Load)		mm/sec	480/300	480/290	480/280
	Lowering speed(Unload/Load)		mm/sec	450/500	←	←
	L×W×T	L,W,T	mm	90×100×35	←	←
Mast	Tilt angle (forward/backward)	C/C'	degree	3/5	←	←
	Max height	D	mm	4025	←	←
	Min height	E	mm	2003	←	←
Body	Travel speed(Unload/Load)		km/h	10.9/9.6	10.7/9.2	10.2/9.0
	Gradeability(Unload/Load)		degree	12.8/15.8	12.5/15.1	11.8/13.4
	Min turning radius(Outside)	F	mm	1550	1640	1775
ETC	Max hydraulic pressure		kgf/cm²	175	←	←
	Hydraulic oil tank		ℓ	18	←	←
Overall length(With fork)		G	mm	2085	←	←
Overall width(Load wheel)		H	mm	1095	←	←
Overhead guard height		I	mm	2258	←	←
Ground clearance		J	mm	85	←	←
Wheel base		K	mm	1250	1350	1500
Wheel tread(Front/rear)		M, M'	mm	976 *1003/610	←	←
Reach stroke		O	mm	485	585	735

* Rubber tire

2) HBR20/25-7



BR147SP01

Model			Unit	HBR 20-7	HBR 25-7
Capacity			kg	2000	2500
Load center		R	mm	500	←
Weight(Unloaded, with battery)			kg	2920	3010
Fork	Lifting height	A	mm	3000	←
	Free lift	B	mm	415	←
	Lifting speed(Unload/Load)		mm/sec	430/280	430/260
	Lowering speed(Unload/Load)		mm/sec	450/500	←
	L×W×T	L,W,T	mm	1050×100×45	←
Mast	Tilt angle(Forward/backward)	C/C'	degree	3/5	3/5
	Max height	D	mm	4030	←
	Min height	E	mm	2040	←
Body	Travel speed(Unload/Load)		km/h	11.8/9.7	11.7/9.2
	Gradeability(Unload/Load)		degree	11.8/9.7	10.1/8.6
	Min turning radius(Outside)	F	mm	1795	1985
ETC	Max hydraulic pressure		kgf/cm²	175	←
	Hydraulic oil tank		ℓ	24	←
Overall length(With fork)		G	mm	2330	←
Overall width(Load wheel)		H	mm	1230	←
Overhead guard height		I	mm	2294	←
Ground clearance		J	mm	85	←
Wheel base		K	mm	1500	1700
Wheel tread(Front/rear)		M, M'	mm	1090/708	←
Reach stroke		O	mm	650	850

3. SPECIFICATION FOR MAJOR COMPONENTS

1) HBR14/15/18-7

(1) MOTOR

Item	Unit	Drive motor	Hydraulic pump motor
Model	-	KNAS4003	KNAQ4004
Type	-	SEM, self ventilated	DC series, self ventilated
Rated voltage	V	48	
Output	kW	5.0	9.5
Brush size	mm	16×32×30	16×20×25
Insulation	-	Class H	

(2) BATTERY

Item	Unit	HBR14/15-7(STD)	HBR14/15-7(OPT) HBR18-7(STD)
Model	-	VCF 280	VCI 335
Rated voltage	V	48	
Capacity	AH/hr	280/5	335/5
Electrolyte	-	WET	
Dimension(W×D×H)	mm	994×378×581.7	
Connector(CE spec)	-	SB350(SBE320)	
Weight	kg	480	560

(3) CHARGER

Item	Unit	HBR14/15/18-7
Type	-	Constant current, constant voltage
Battery capacity for charge	V-AH	48-280~335
AC input	V	Triple phase 410
		Single phase 220
		Triple phase 220/380
		Triple phase 440
DC output	V	62±1
Charge time	hr	8±2
Connector(CE spec)	-	SB 350(SBE320)

(4) GEAR PUMP

Item	Unit	Specification
Type	-	Fixed displacement gear pump
Capacity	cc/rev	22
Maximum operating pressure	bar	210
Rated speed(max/min)	rpm	3000/500

(5) MAIN CONTROL VALVE

Item	Unit	Specification
Type	-	3 spool, 4 spool
Operating method	-	Mechanical
Main relief valve pressure	bar	175

(6) DRIVE UNIT

Item		Unit	Specification
Gear ratio	G2 : G1	-	35 : 8 (4.375 : 1)
	G3 : G2	-	46 : 10 (4.6 : 1)
	Total	-	20.125
Oil quantity		l	1.6

(7) WHEELS

Item	Specification
Type(Load / Drive /Caster)	Urethane / Rubber / Rubber
Quantity(Load / Drive /Caster)	2 / 1 / 2
Load wheel	254×100
Drive wheel	305×145
Caster wheel	178×73

(8) BRAKES

Item	Specification
Brakes(Service & Parking)	Drive wheel, leading & trailing type drum brake.

2) HBR20/25-7

(1) MOTOR

Item	Unit	Drive motor	Hydraulic pump motor
Model	-	KNAS4005	KNAQ4004
Type	-	SEM, self ventilated	DC Series, self ventilated
Rated voltage	V	48	
Output	kW	5.0	9.5
Brush size	mm	16×32×30	16×20×25
Insulation	-	Class H	

(2) BATTERY

Item	Unit	HBR20/25-7
Model(Type)	-	VCI 335
Rated voltage	V	48
Capacity	AH/hr	335/5
Electrolyte	-	WET
Dimension(W×D×H)	mm	994×378×581.7
Connector(CE spec)	-	SB350(SBE320)
Weight	kg	560

(3) CHARGER

Item	Unit	HBR20/25-7
Type	-	Constant current, constant voltage
Battery capacity for charge	V-AH	48-280~335
AC input	V	Triple phase 410
		Single phase 220
		Triple phase 220/380
		Triple phase 440
DC output	V	62±1
Charge time	hr	8±2
Connector(CE spec)	-	SB 350(SBE320)

(4) GEAR PUMP

Item	Unit	Specification
Type	-	Fixed displacement gear pump
Capacity	cc/rev	22
Maximum operating pressure	bar	210
Rated speed(max/min)	rpm	3000/500

(5) MAIN CONTROL VALVE

Item	Unit	Specification
Type	-	3 spool, 4 spool
Operating method	-	Mechanical
Main relief valve pressure	bar	175

(6) DRIVE UNIT

Item		Unit	Specification
Max input torque		kgf · m	2200
Max input rpm		rpm	3500
Gear ratio	G2 : G1	-	42 : 7 (6.000 : 1)
	G3 : G2	-	80 : 23 (3.478 : 1)
	Total	-	20.870
Oil quantity		ℓ	4.4

(7) WHEELS

Item	Specification
Load / Drive / Caster	Urethane / Rubber / Rubber
Quantity(Load / Drive / Caster)	2 /1 /2
Load wheel	267×114
Drive wheel	382×142
Caster wheel	204×76

(8) BRAKES

Item	Specification
Brakes(Service & Parking)	Drive wheel, leading & trailing type drum brake.

4. TIGHTENING TORQUE FOR MAJOR COMPONENTS

1) HBR14/15/18-7

NO	Items		Size	kgf · m	lbf · ft
1	Electric system	Hyd pump motor mounting bolt	M10×1.5	6.9±1.4	50±10
2		Drive motor mounting bolt	M 8×1.25	2.0±0.2	14.4±1.4
3		Steering motor mounting bolt	M10×1.5	6.9±1.4	50±10
4	Hydraulic system	Hydraulic pump mounting bolt	M10×1.5	5±1.0	36.2±7.2
5		MCV mounting bolt, nut	M 8×1.25	2.5±0.5	18.1±3.6
6	Power train system	Drive wheel mounting nut	M16×1.5	20.5±1.5	148.3±10.8
7		Load wheel mounting nut	M40×1.5	5±0.5	36.2±3.6
8		Caster wheel mounting bolt	M12×2.75	10±2.0	72.3±14.4
9	Other	Head guard mounting bolt	M12×1.75	19±3.0	137.4±21.7

2) HBR20/25-7

NO	Items		Size	kgf · m	lbf · ft
1	Electric system	Hyd pump motor mounting bolt	M10×1.5	6.9±1.4	50±10
2		Drive motor mounting bolt	M 8×1.25	2.0±0.2	14.4±1.4
3		Steering motor mounting bolt	M10×1.5	6.9±1.4	50±10
4	Hydraulic system	Hydraulic pump mounting bolt	M10×1.5	5±1.0	36.2±7.2
5		MCV mounting bolt, nut	M 8×1.25	2.5±0.5	18.1±3.6
6	Power train system	Drive unit mounting bolt, nut	M12×1.75	13.4±0.6	96.9±4.3
7		Drive wheel mounting nut	M14×1.5	14±1.5	101.2±10.8
8		Load wheel mounting nut	M50×1.5	5±0.5	36.2±3.6
9		Caster wheel mounting bolt	M12×2.75	10±2.0	72.3±14.4
10	Others	Head guard mounting bolt	M12×1.75	19±3.0	137.4±21.7

5. TORQUE CHART

Use following table for unspecified torque.

1) BOLT AND NUT - Coarse thread

Bolt size	8T		10T	
	kgf · m	lbf · ft	kgf · m	lbf · ft
M 6 × 1.0	0.85 ~ 1.25	6.15 ~ 9.04	1.14 ~ 1.74	8.2 ~ 12.6
M 8 × 1.25	2.0 ~ 3.0	14.5 ~ 21.7	2.7 ~ 4.1	19.5 ~ 29.7
M10 × 1.5	4.0 ~ 6.0	28.9 ~ 43.4	5.5 ~ 8.3	39.8 ~ 60.0
M12 × 1.75	7.4 ~ 11.2	53.5 ~ 81.0	9.8 ~ 15.8	70.9 ~ 114
M14 × 2.0	12.2 ~ 16.6	88.2 ~ 120	16.7 ~ 22.5	121 ~ 163
M16 × 2.0	18.6 ~ 25.2	135 ~ 182	25.2 ~ 34.2	182 ~ 247
M18 × 2.0	25.8 ~ 35.0	187 ~ 253	35.1 ~ 47.5	254 ~ 344
M20 × 2.5	36.2 ~ 49.0	262 ~ 354	49.2 ~ 66.6	356 ~ 482
M22 × 2.5	48.3 ~ 63.3	349 ~ 458	65.8 ~ 98.0	476 ~ 709
M24 × 3.0	62.5 ~ 84.5	452 ~ 611	85.0 ~ 115	615 ~ 832
M30 × 3.0	124 ~ 168	898 ~ 1214	169 ~ 229	1223 ~ 1656
M36 × 4.0	174 ~ 236	1261 ~ 1704	250 ~ 310	1808 ~ 2242

(1) Fine thread

Bolt size	8T		10T	
	kgf · m	lbf · ft	kgf · m	lbf · ft
M 8 × 1.0	2.2 ~ 3.4	15.9 ~ 24.6	3.0 ~ 4.4	21.7 ~ 31.8
M10 × 1.2	4.5 ~ 6.7	32.5 ~ 48.5	5.9 ~ 8.9	42.7 ~ 64.4
M12 × 1.25	7.8 ~ 11.6	56.4 ~ 83.9	10.6 ~ 16.0	76.7 ~ 116
M14 × 1.5	13.3 ~ 18.1	96.2 ~ 131	17.9 ~ 24.1	130 ~ 174
M16 × 1.5	19.9 ~ 26.9	144 ~ 195	26.6 ~ 36.0	192 ~ 260
M18 × 1.5	28.6 ~ 43.6	207 ~ 315	38.4 ~ 52.0	278 ~ 376
M20 × 1.5	40.0 ~ 54.0	289 ~ 391	53.4 ~ 72.2	386 ~ 522
M22 × 1.5	52.7 ~ 71.3	381 ~ 516	70.7 ~ 95.7	511 ~ 692
M24 × 2.0	67.9 ~ 91.9	491 ~ 665	90.9 ~ 123	658 ~ 890
M30 × 2.0	137 ~ 185	990 ~ 1339	182 ~ 248	1314 ~ 1796
M36 × 3.0	192 ~ 260	1390 ~ 1880	262 ~ 354	1894 ~ 2562

2) PIPE AND HOSE(FLARE TYPE)

Thread size(PF)	Width across flat(mm)	kgf · m	lbf · ft
1/4"	19	4	28.9
3/8"	22	5	36.2
1/2"	27	9.5	68.7
3/4"	36	18	130.2
1"	41	21	151.9
1-1/4"	50	35	253.2

3) PIPE AND HOSE(ORFS TYPE)

Thread size(UNF)	Width across flat(mm)	kgf · m	lbf · ft
9/16-18	19	4	28.9
11/16-16	22	5	36.2
13/16-16	27	9.5	68.7
1-3/16-12	36	18	130.2
1-7/16-12	41	21	151.9
1-11/16-12	50	35	253.2

4) FITTING

Thread size(PF)	Width across flat(mm)	kgf · m	lbf · ft
1/4"	19	4	28.9
3/8"	22	5	36.2
1/2"	27	9.5	68.7
3/4"	36	18	130.2
1"	41	21	151.9
1-1/4"	50	35	253.2

6. RECOMMENDED LUBRICANTS

Use only oils listed below or equivalent.

Do not mix different brand oil.

Service point	Kind of fluid	Capacity ℓ (U.S. gal)		Ambient temperature ℃(°F)
		HBR 14/15/18-7	HBR 20/25-7	-35 (-31) / -20 (-4) / -10 (14) / 0 (32) / 10 (50) / 20 (68) / 30 (86) / 40 (104)
Drive unit	Gear oil	1.6 (0.42)	4.4 (1.16)	SAE 80W/90; SAE 75W/90
Hydraulic oil tank	Hydraulic oil	18.1 (4.0)	24 (5.3)	ISO VG 32; ISO VG 46; ISO VG 68
Fitting (Grease nipple)	Grease	0.1 (0.03)	0.1 (0.03)	NLGI No.1; NLGI No.2

GROUP 3 PERIODIC REPLACEMENT

For operation safety, never fail to perform periodic maintenance or make periodic replacement of the consumable parts listed in the following.

These parts may deteriorate in time and are susceptible to wear. It is difficult to estimate the degree of wear at time of periodic maintenance; therefore, even if no apparent wear is found, always replace with new parts within the prescribed period of replacement(Or earlier if trouble is found).
Note that periodic replacement has nothing to do with guarantee service.

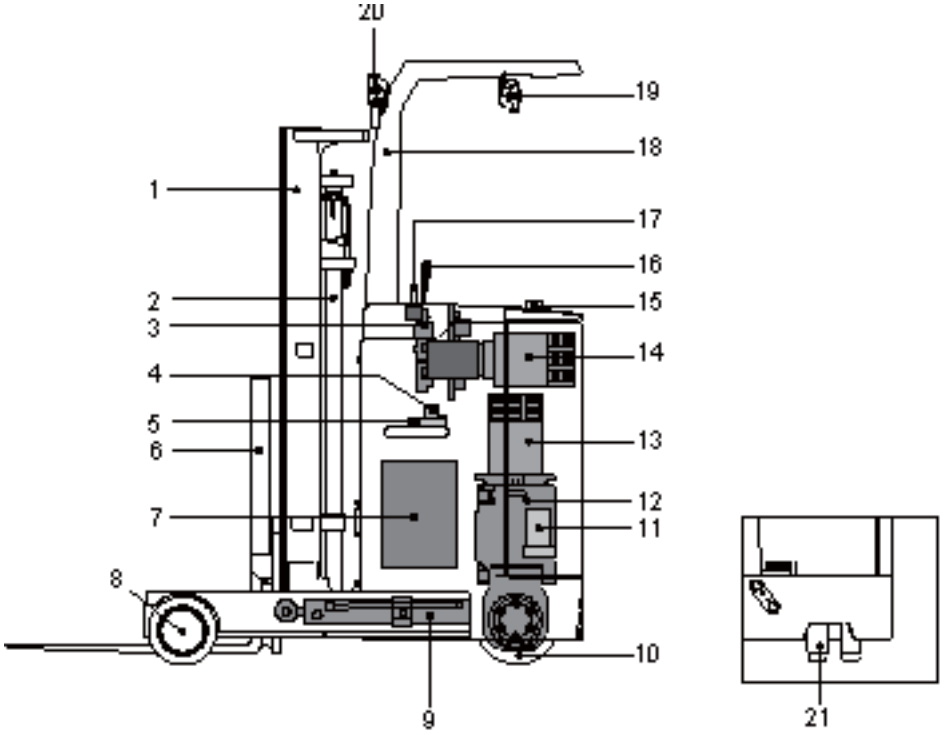
※ **Replacement of consumable service parts is not covered under warranty.**

No.	Description	Period of replacement
1	Hydraulic oil	Every 1 year
2	Brake fluid	Every 1 year
3	Differential oil	Every 1 year
4	Gear oil	Every 1 year
5	Wheel bearing grease	Every 1 year
6	Power steering hose	Every 1 year
7	Rubber parts of the power steering inside	Every 2 year
8	Cups and dust seals etc. of cylinder	Every 2 year
9	Reservoir tank tube	Every 1 year
10	Lift chain	Every 2 year
11	Hydraulic equiprnent hose	Every 2 year
12	Brake switch(hydraulic)	Every 2 year

SECTION 2 REMOVAL & INSTALLATION OF UNIT

SECTION 2 REMOVAL & INSTALLATION OF UNIT

GROUP 1 STRUCTURE



B147RE01

1	Mast	8	Load wheel	15	Steering wheel
2	Lift cylinder	9	Reach cylinder	16	Control levers
3	Main control valve	10	Drive wheel	17	Accelerator
4	EPS filter	11	EPS motor	18	Over head guard
5	EPS controller	12	Drive unit	19	Rear work lamp(opt)
6	Carriage & backrest	13	Drive motor	20	Head lamp
7	Battery	14	Pump motor	21	Caster wheel

GROUP 2 REMOVAL AND INSTALLATION OF UNIT

Remove and install following units as explained in the flow chart.

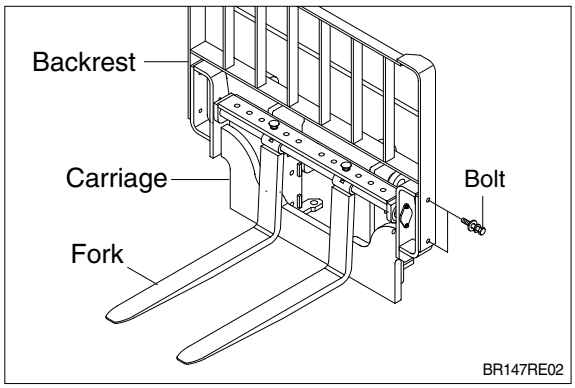
1. MAST

1) REMOVAL

Backrest & fork → Carriage → Piping → Mast

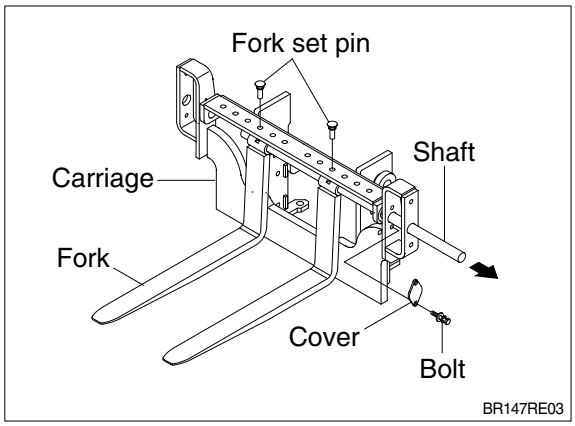
(1) Backrest

① Remove bolts securing backrest to fork carriage. Lift backrest straight up and remove it from carriage.



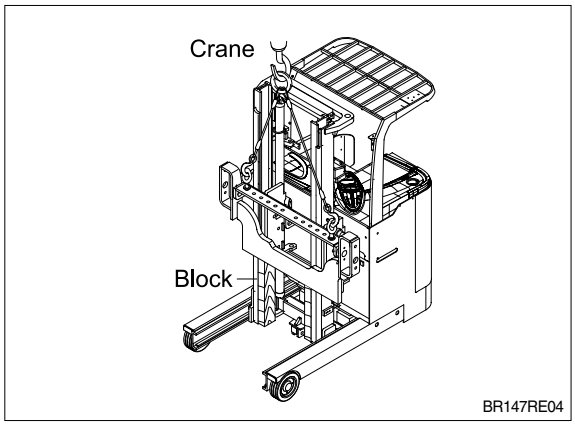
(2) Forks

① Remove shaft cover and bolt.
② Remove fork set pin and then draw out the shaft.
③ Carefully remove forks one by one.

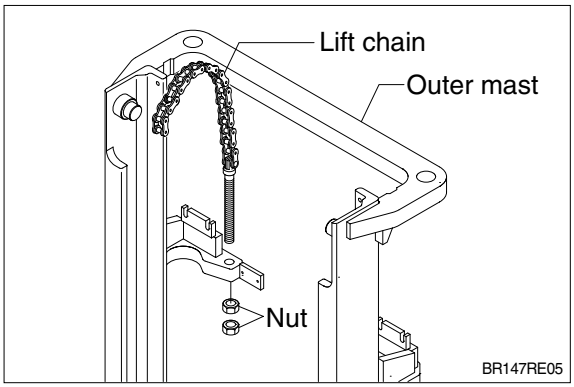


(3) Carriage

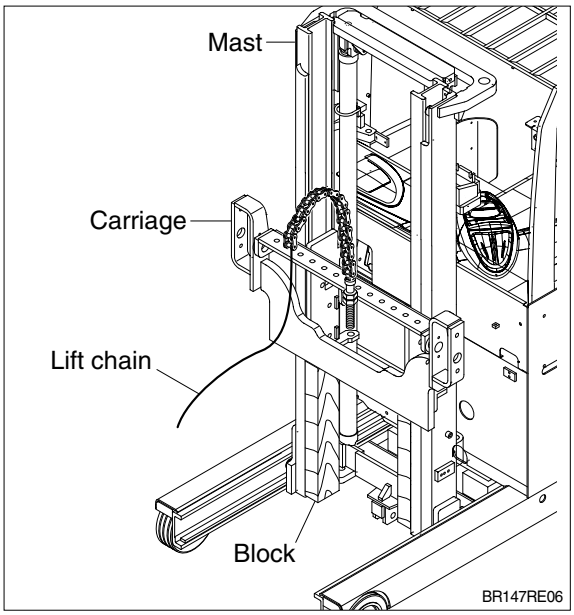
① With the mast vertical, raise the carriage high enough to place blocks under the load forks. This is done to create slack in the load chains when the carriage is lowered. Lower the carriage all the way down to the floor. Make sure the carriage is level, this will prevent any binding when the mast is raised.



② While supporting lift chains, remove the split pins and slide out chain anchor pins from the chain anchors of stationary upright.



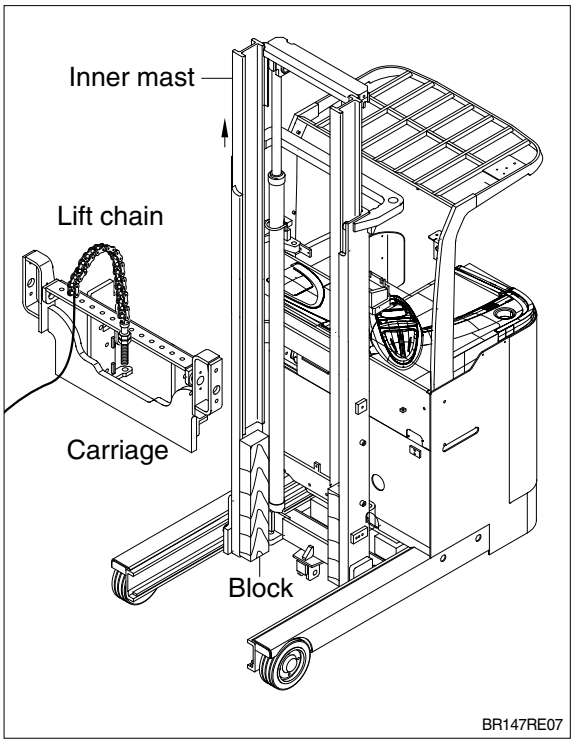
③ Pull the chains out of the sheaves and drape them over the front of the carriage.



④ Slowly raise inner mast upright until mast clears top of fork carriage. Move carriage to work area and lower the mast.

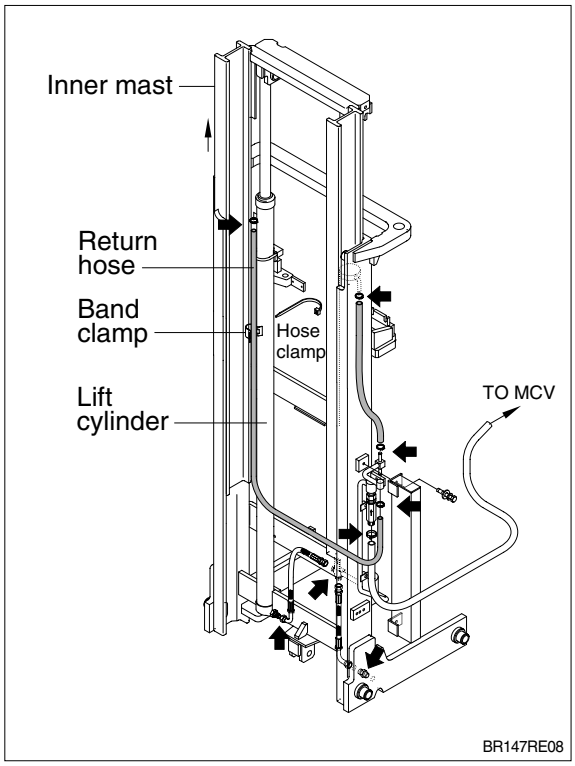
⚠ Make sure that carriage remains on floor and does not bind while mast is being raised.

⑤ Inspect all parts for wear or damage. Replace all worn or damaged parts.



(4) PIPING

① Remove the return hoses and clamps attached to the cylinder.
② Remove the return hoses from the connector.
③ Remove hose assembly, connector, down safety valve from the lift cylinder.
④ Disconnect hose assembly from the flow regulator.

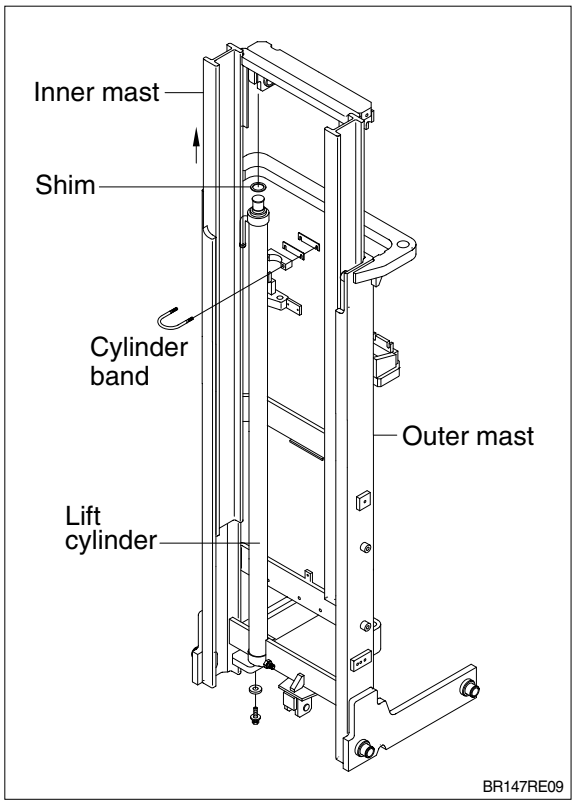


(5) LIFT CYLINDER

① Loosen hexagonal bolts and remove washers securing the lift cylinders to inner mast.
② Bind the lift cylinder with overhead hoist rope and pull up so that the rope has no slack or binding.

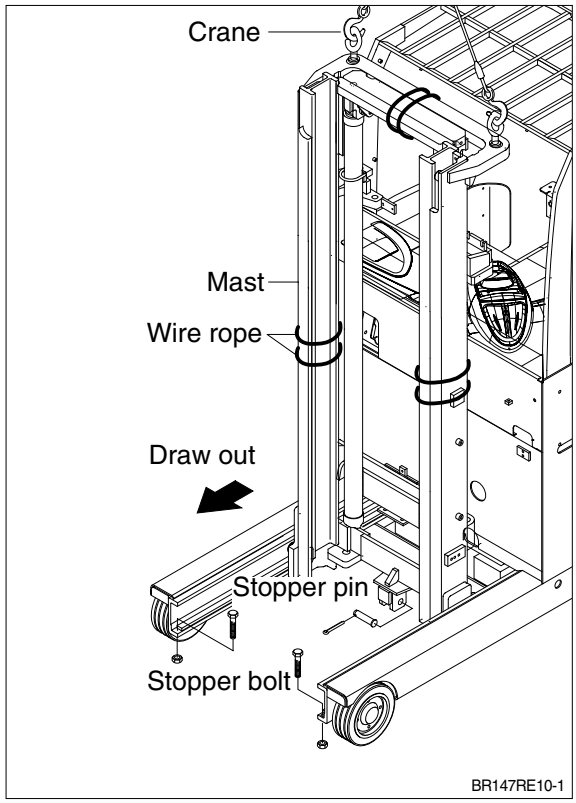
⚠ Make sure that the lift cylinder be tightened firmly for safety.

③ Loosen and remove hexagon nuts and cylinder band securing cylinder to outer mast.
④ Using an overhead hoist, slowly raise the inner mast high enough to clear lift cylinder.
⑤ Using an overhead hoist, draw out lift cylinder carefully and put down on the work floor.



(6) MAST REMOVAL

① Pass wire rope around the inner and outer masts to allow lifting them out with a hoist.
② Remove the stopper pin at the end of reach cylinder and then remove the stopper bolt at the end of guide rail.
③ Draw out the mast from the guide rail with lifting up.
④ Lower the mast and place it on stand.

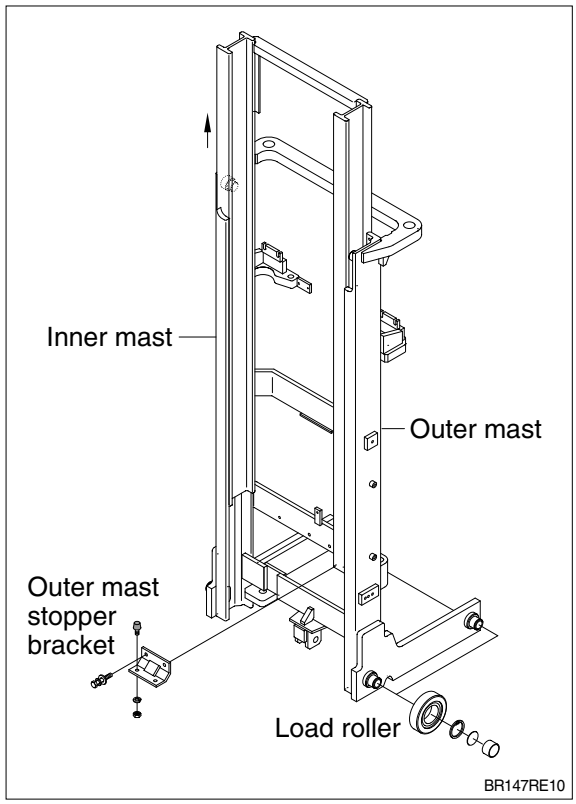


(7) INNER MAST

① Using an overhead hoist raise the inner mast straight and carefully draw out of outer mast section.

⚠ **Be careful the mast not to swing or fall.**

② Using an universal puller, remove the load rollers.



2) INSTALLATION

After assembling mast components totally without piping connections, install mast assembly to the equipment.

※ **Installation procedure for each of mast component is the reverse of the removal procedure.**

(1) LIFT CYLINDER INSTALLATION AND ADJUSTMENT

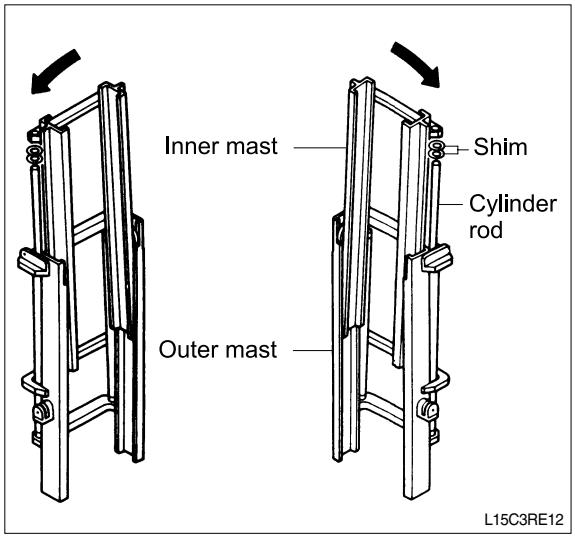
① Assemble the lift cylinder inside the outer mast, then tighten the stopper bolt. If the cylinder assembly has been replaced, adjust as follows so that the left and right cylinders are synchronized at the maximum lifting height.

② Assemble the cylinder rod to the inner mast, and check the left-to-right play of the mast at the maximum lifting height.

※ **If play is to LEFT, install adjustment shim to LEFT cylinder.**

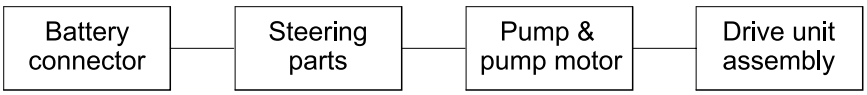
※ **If play is to RIGHT, install adjustment shim to RIGHT cylinder.**

· Shim thickness : 1.0mm(0.04in)



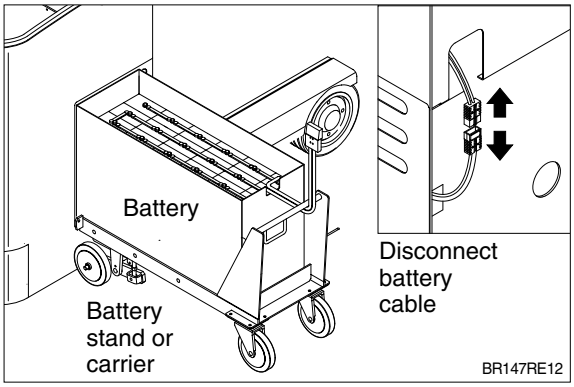
2. POWER TRAIN ASSEMBLY

1) REMOVAL

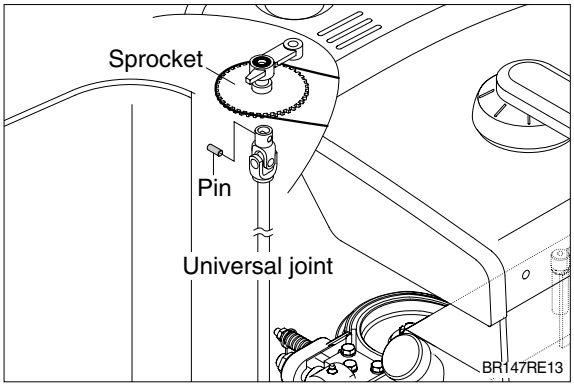


BR147RE001

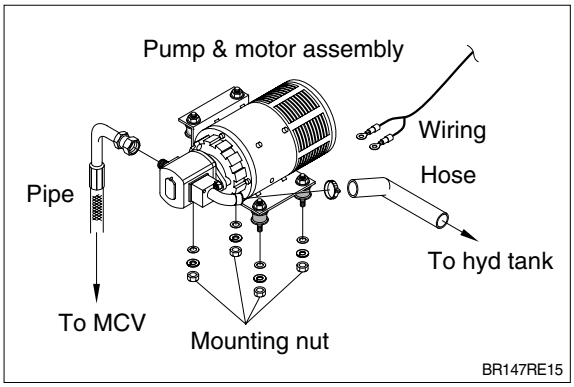
(1) Disconnect the battery cable and then pull out the battery to battery stand or carrier.



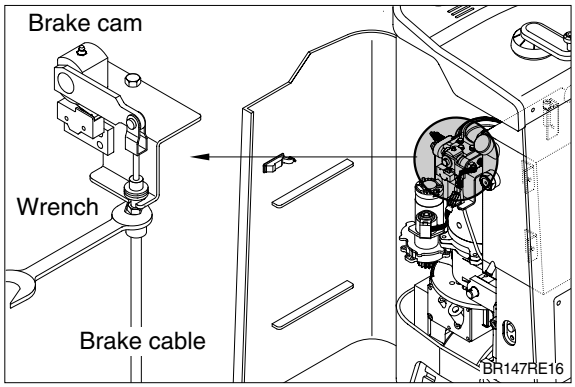
(2) Remove steering joint parts.



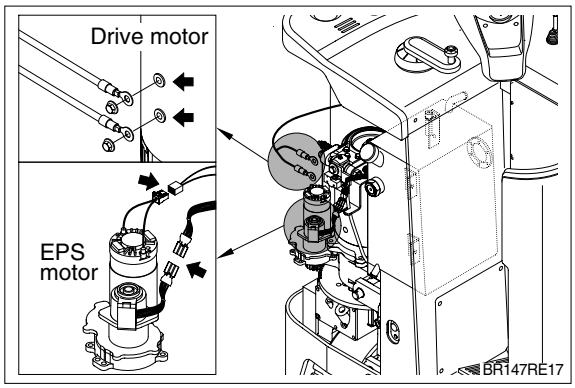
(3) Disconnect the hose, pipe and wiring from pump & motor assembly.
Loosen mounting nuts from the bracket and then take out the assembly.



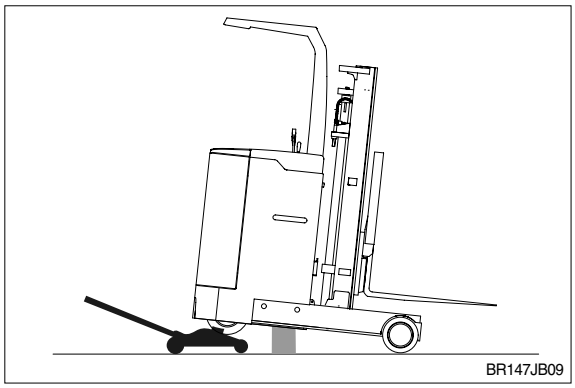
(4) Remove brake cable.



(5) Disconnect the wiring.
① Drive motor wiring
② EPS motor wiring.

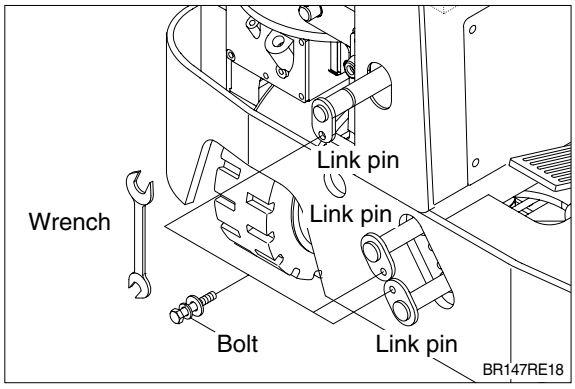


(6) Jack up the frame and support both side of frame on wood block.

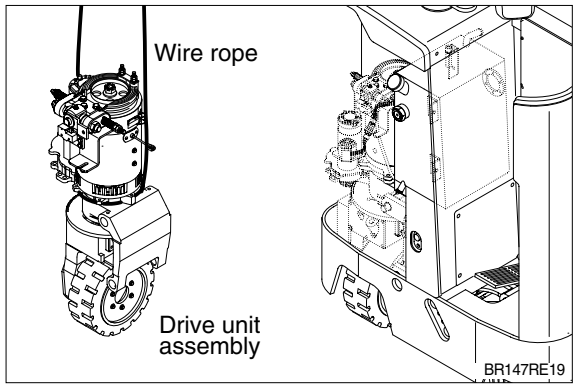


(7) Remove the support bolts and pull out the link pins.

※ **When removing link pins, use care not to damage link pin.**



(8) Remove drive unit assembly from frame by lifting.

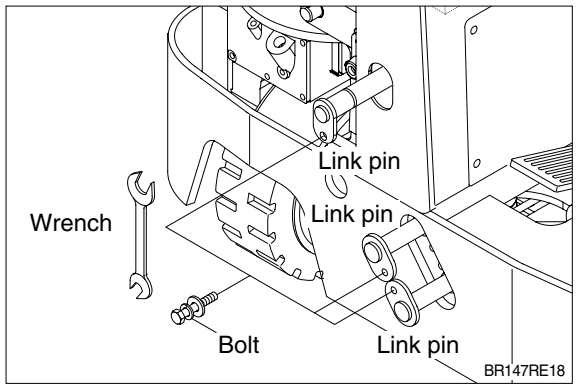


2) INSTALLATION

Installatron is in the reverse order to removal, but be careful of following points.

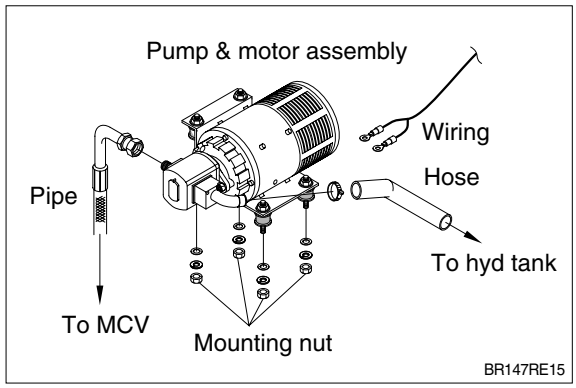
(1) Link pin support bolts.

· Tightening torque : 4.0~6.0kgf · m
(28.9~43.4lbf · ft)



(2) Hyd pump & pump motor mounting.

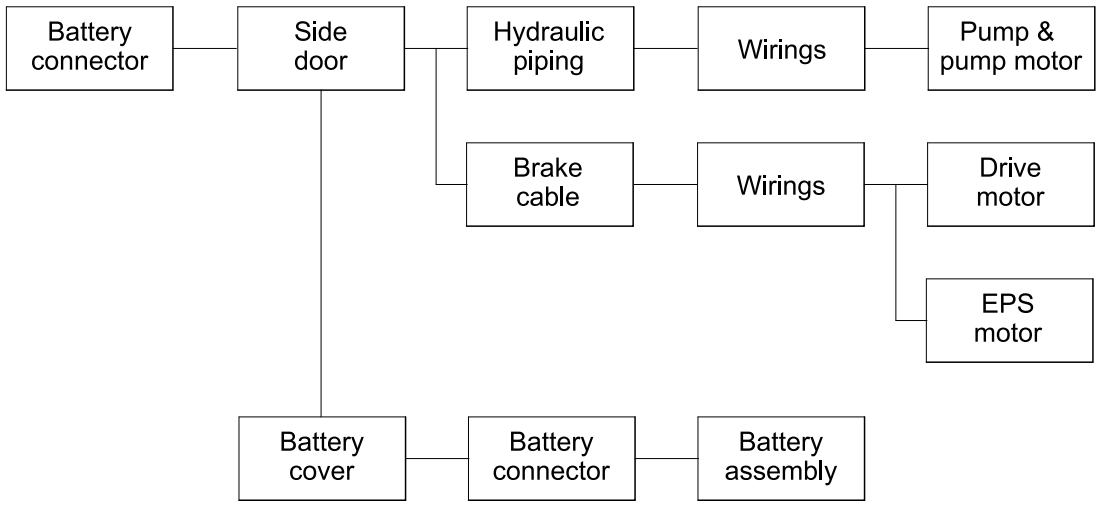
· Tightening torque : 4.0~6.0kgf · m
(28.9~43.4lbf · ft)



3. ELECTRICAL COMPONENTS

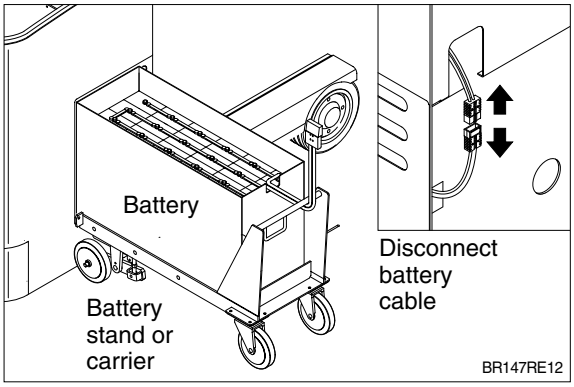
Before removing each component, disconnect cables and earth lines attached to the component.

1) REMOVAL

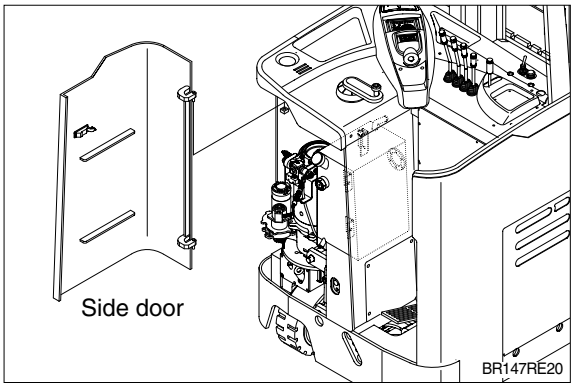


(1) PUMP MOTOR

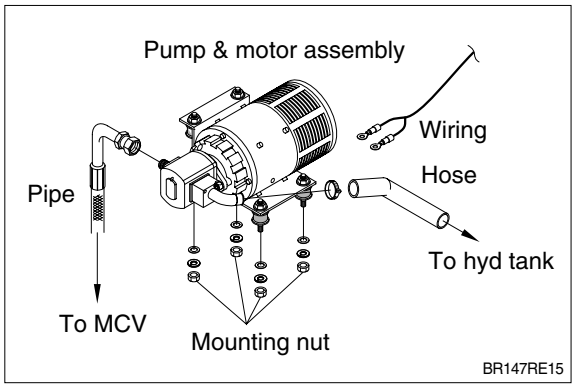
① Disconnect the battery cable and then pull out the battery to battery stand or carrier.



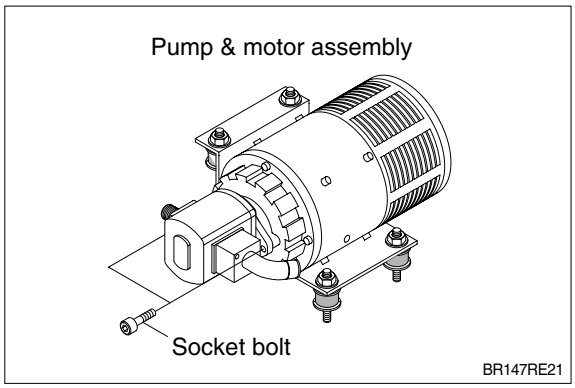
② Remove side door.



③ Disconnect the hose, pipe and wiring from pump & motor assembly.
Loosen mounting nuts from the bracket and then take out the assembly.

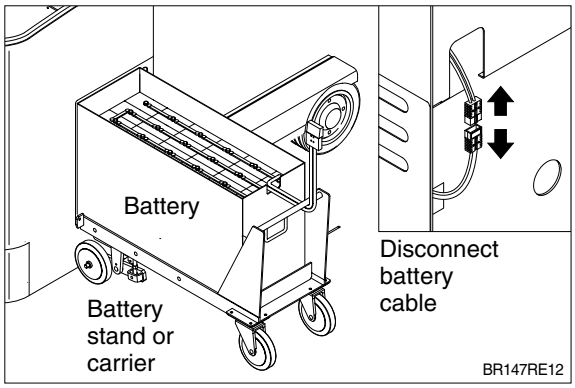


④ Remove 2 socket bolts fastening the pump & motor and then disengage the pump from motor.

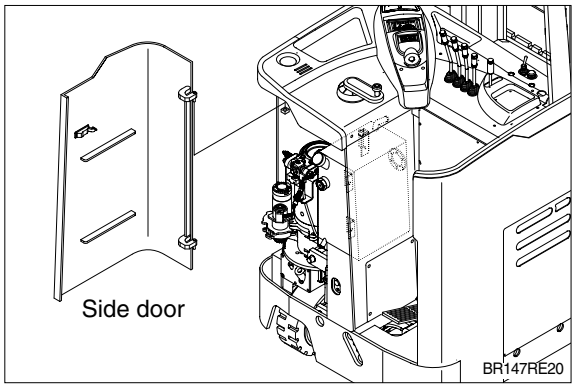


(2) DRIVE MOTOR

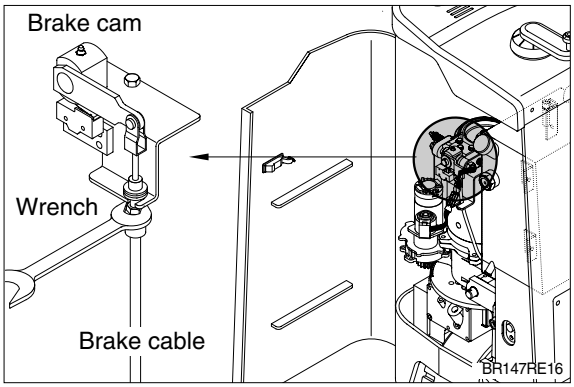
① Disconnect the battery cable and then pull out the battery to battery stand or carrier.



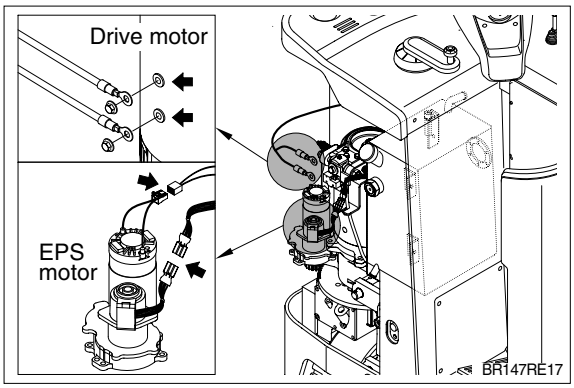
② Remove side door.



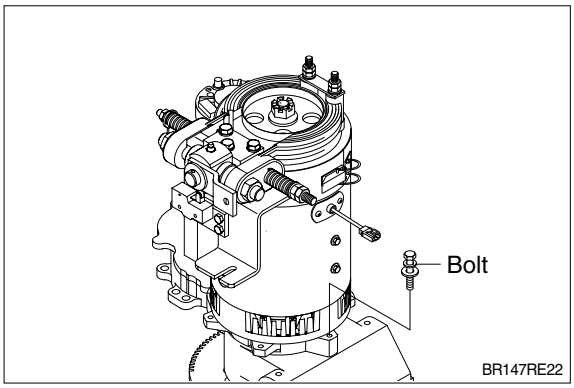
③ Remove brake cable.



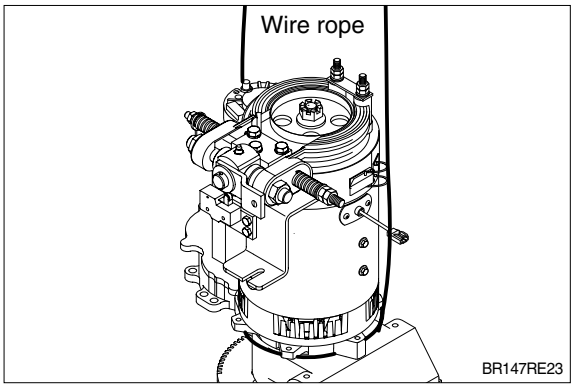
④ Disconnect wirings.
a. Drive motor wiring
b. EPS motor wiring



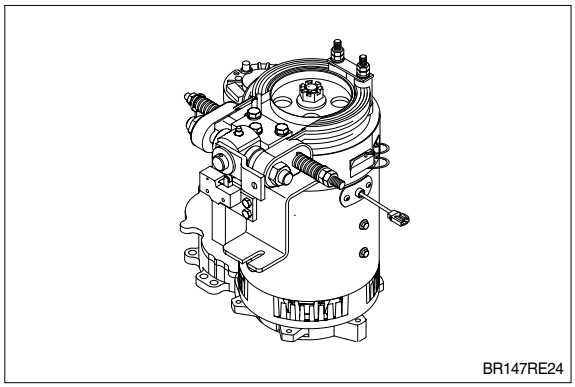
⑤ Remove bolts connecting the motor and drive unit.



⑥ Tie wire rope around the drive motor and lift up slowly.

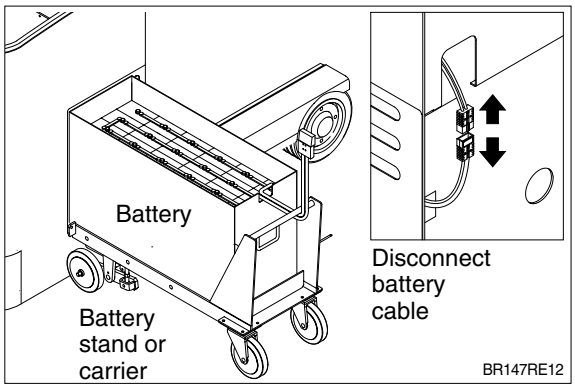


⑦ Put the motor on the clean work bench.

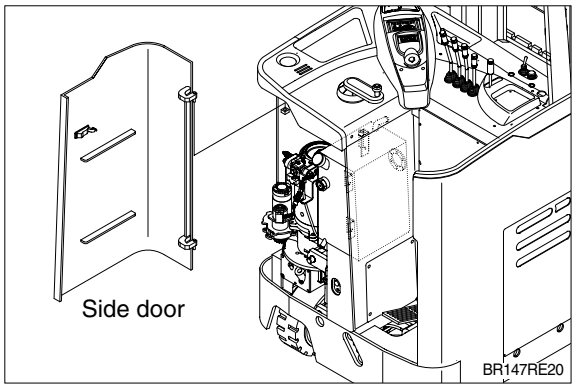


(3) EPS MOTOR

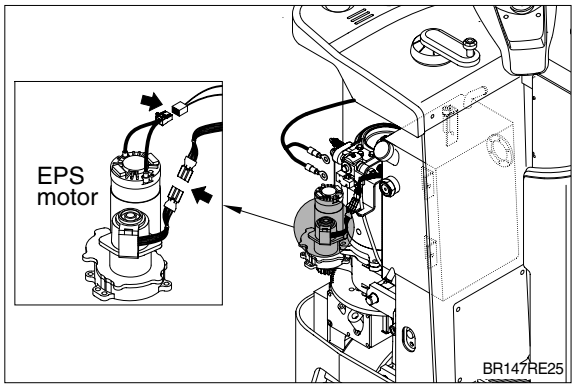
① Disconnect the battery cable and then pull out the battery to battery stand or carrier.



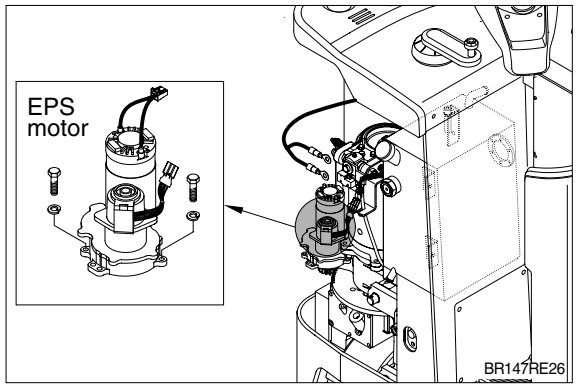
② Remove side door.



③ Disconnect wirings.



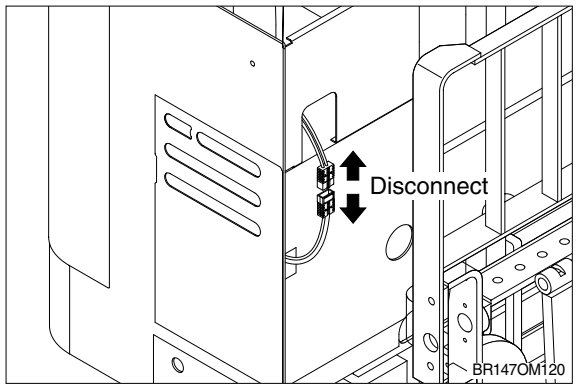
④ Loosen bolts and remove EPS motor assembly.



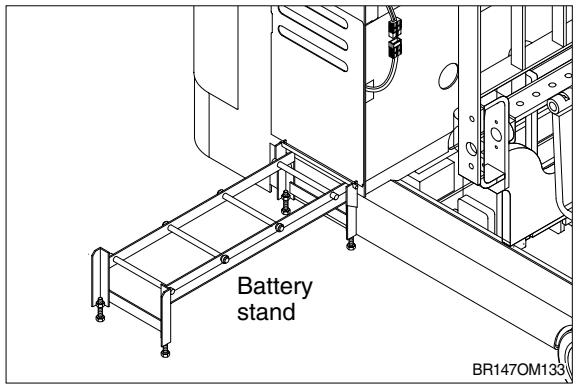
(4) BATTERY ASSEMBLY

When the spare battery is used for continuous operation or it is required to check the battery, motor, etc., remove the battery through the following procedure:

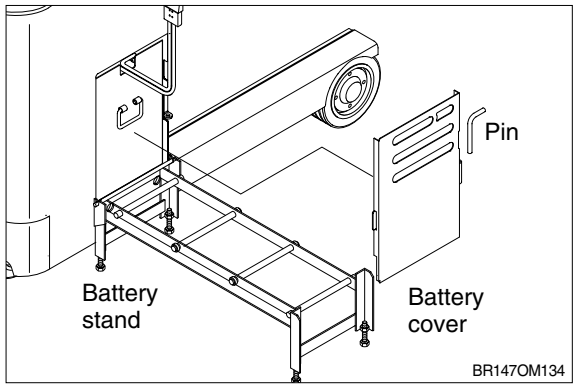
① Disconnect the battery connector.



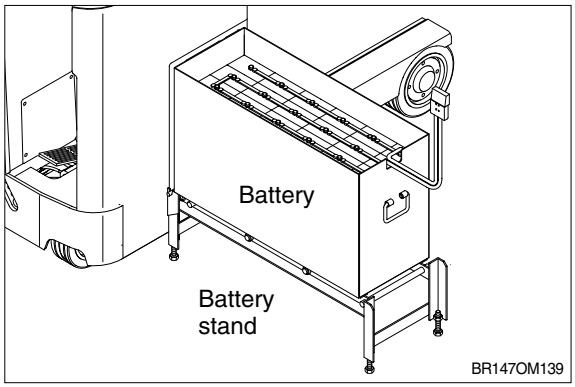
② Put the battery stand to the battery stopper side.



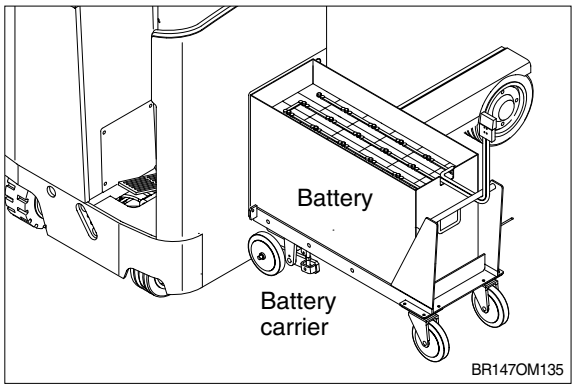
③ Disengage the battery stopper pin and remove battery cover from side frame.



④ Adjust the height of the roller of the stand to that of the roller of the vehicle.
Slide the battery to the stand.



⑤ The same procedure is applied when the optional battery carrier is used.



2) INSTALLATION

Installation is in the reverse order to removal, but be careful of following points.

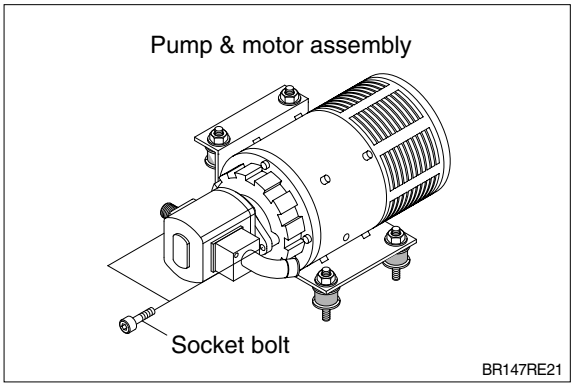
(1) PUMP MOTOR

① Pump motor mounting nut.

· Tightening torque : 4.0~6.0kgf · m
(28.9~43.4lbf · ft)

② Hydraulic pump mounting bolt

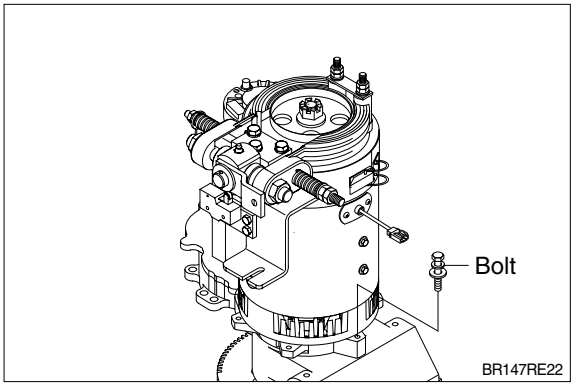
· Tightening torque : 4.0~6.0kgf · m
(28.9~43.4lbf · ft)



(2) DRIVE MOTOR

① Connetion bolts between drive motor and drive unit.

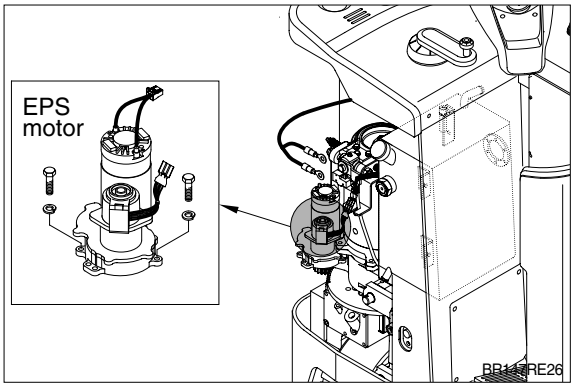
· Tightening torque : 1.8~2.2kgf · m
(13~16lbf · ft)



(3) EPS MOTOR

① EPS motor mounting bolts.

· Tightening torque : 1.8~2.2kgf · m
(13~16lbf · ft)

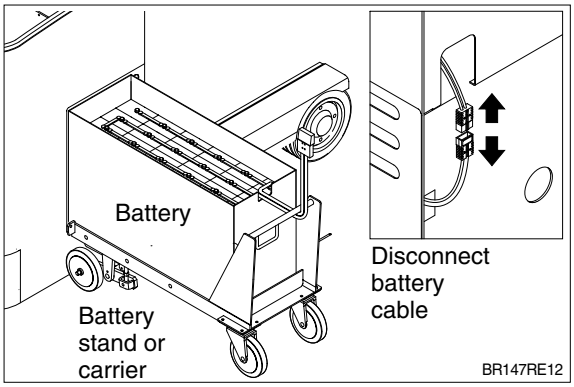


4. CASTER LINK ASSEMBLY

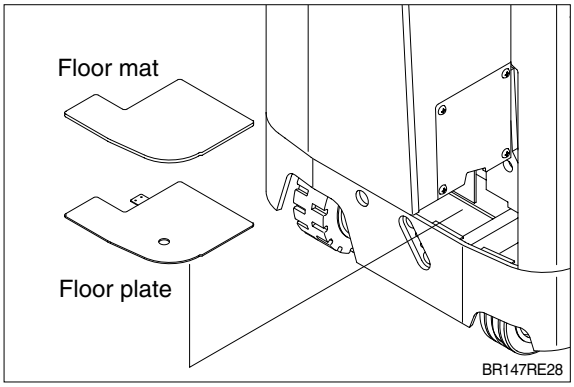
BR147RE003

1) REMOVAL

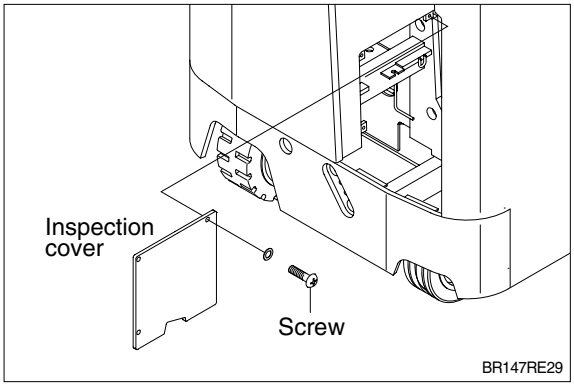
(1) Disconnect the battery cable and then pull out the battery to battery stand or carrier.



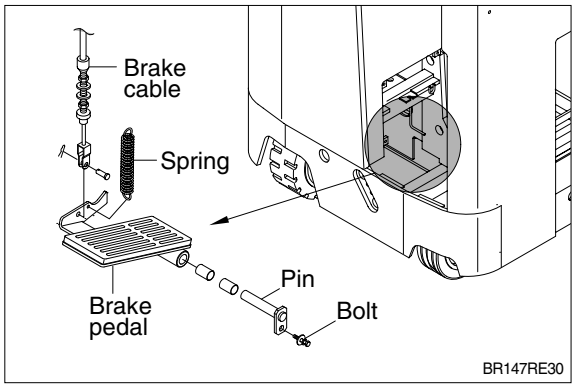
(2) Remove floor mat and floor plate.



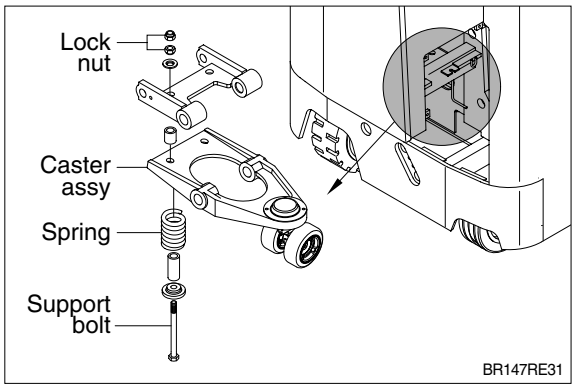
(3) Remove inspection cover by loosening the screw.



(4) Remove bolt, pin, spring and brake cable to remove the brake pedal assembly.

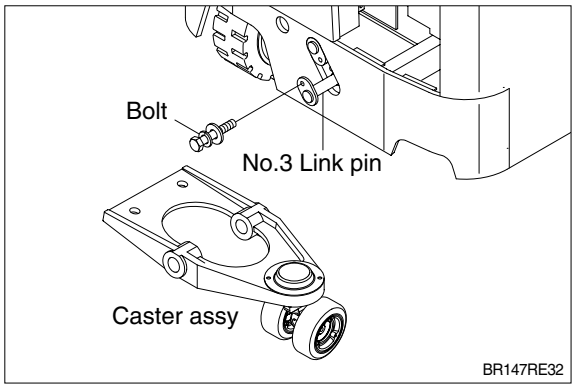


(5) Remove lock nut from the top end of support bolt for spring at caster side(lower side).
Spring and support bolts are dropped down.



(6) Remove lock bolt for No.3 link pin(lowest one) and pull out the link pin by punching from the battery store place.

(7) Jack up the rear side of frame and remove the caster assembly.

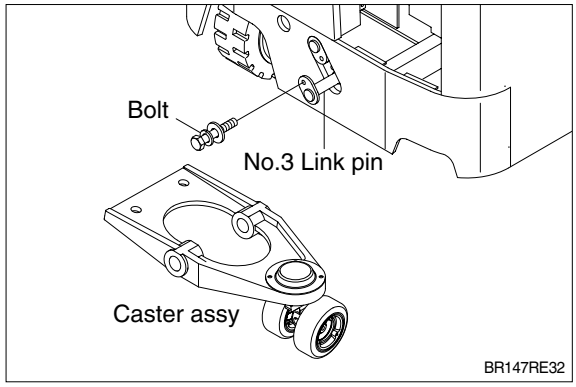


2) INSTALLATION

Installation is in the reverse order to removal, but be careful of the following points.

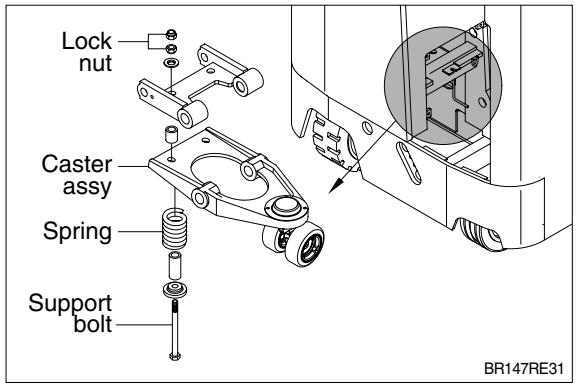
(1) No.3 link pin(lowest one) fixing bolt.

· Tightening torque : 2.0~3.0kgf · m
(14.5~21.7lbf · ft)



(2) Lock nut fixing the support bolt.

· Tightening torque : 12~15kgf · m
(87~109lbf · ft)



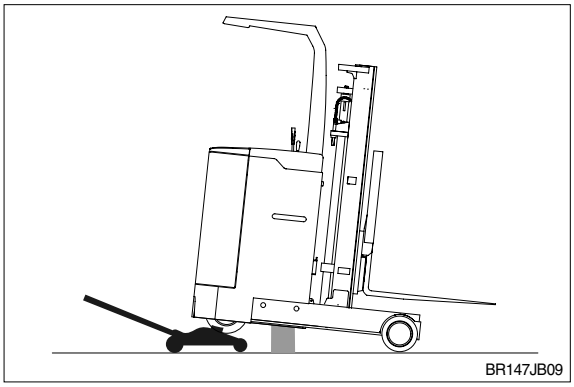
5. TIRE & WHEEL ASSEMBLY

1) REMOVAL

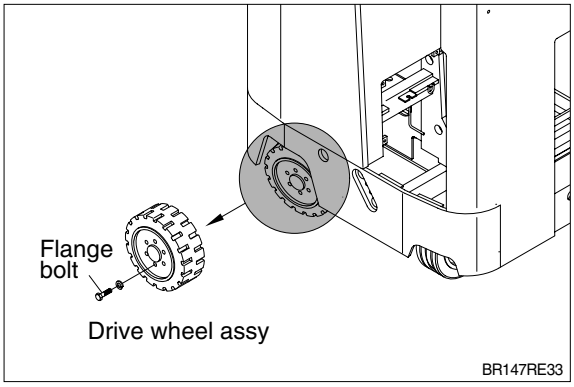
(1) DRIVE TIRE & WHEEL ASSEMBLY

① Jack up the frame

※ **Jack up until the tire clear off the ground.**

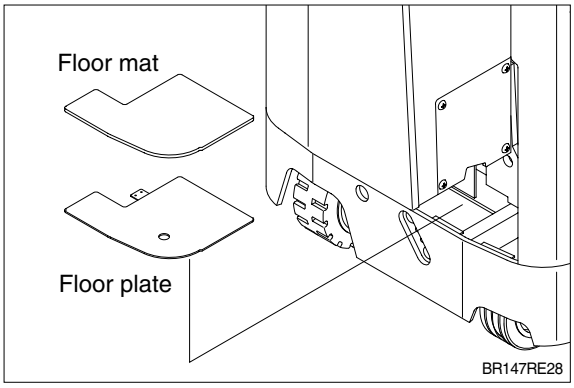


② Remove 6 flange bolts attaching the drive wheel and take off the drive wheel assembly.

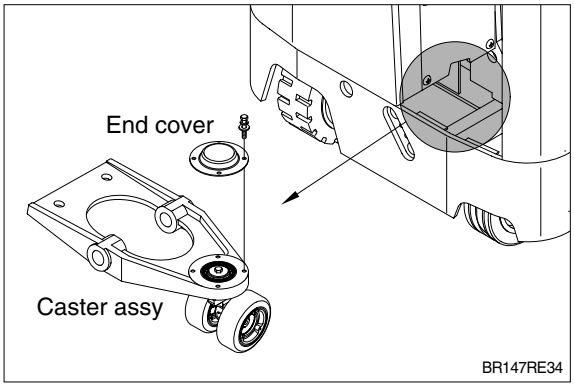


(2) CASTER WHEEL ASSEMBLY

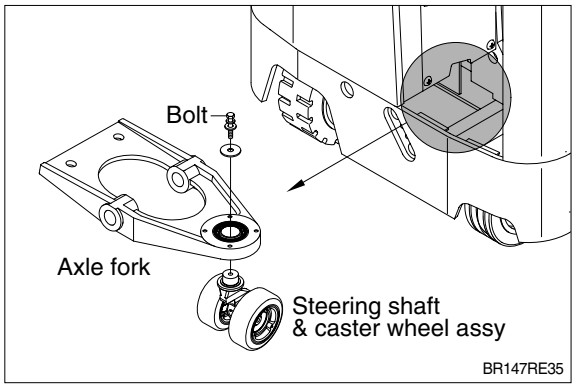
① Remove floor mat and floor plate.



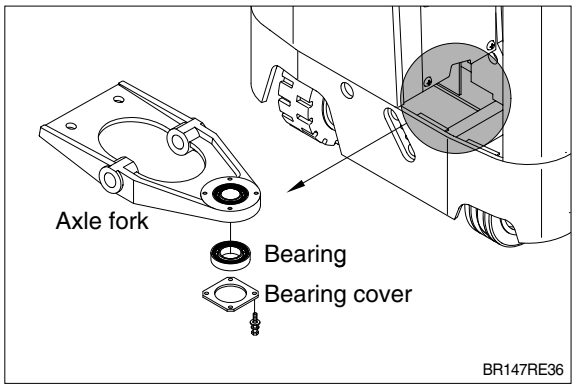
② Remove the end cover at upper end of steering shaft.



③ Remove bolt and take out the steering shaft & caster wheel assembly from axle fork.

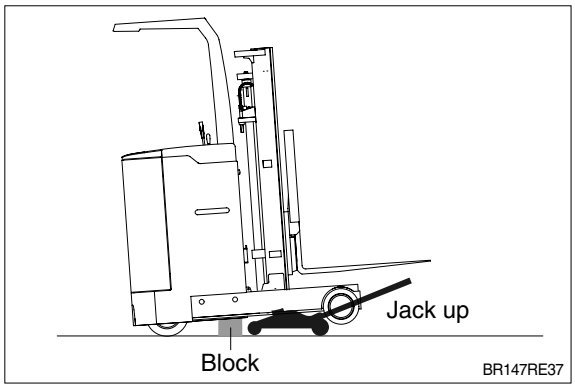


④ Remove remained bearing from the axle fork.

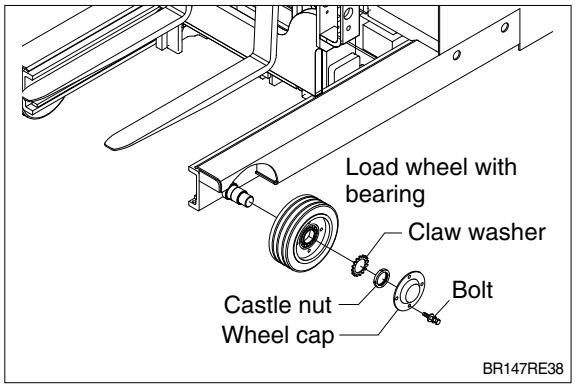


(3) LOAD WHEEL ASSEMBLY

① Jack up the reach legs and fix the machine with blocks.



② Take off the load wheel cap, and remove castle nut, and claw washer in succession.
Remove the load wheel together with bearing.

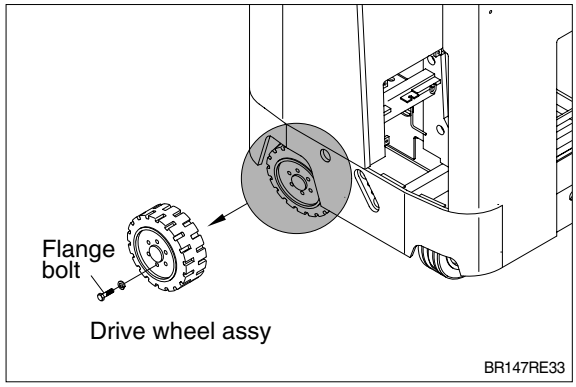


2) INSTALLATION

Installation is in the reverse order to removal, but be careful of the following points.

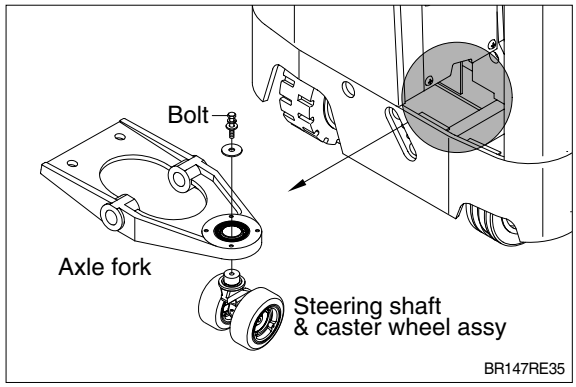
(1) Drive wheel flange bolts

· Tightening torque :
HBR14/15/18-7 : 19~22kgf · m
(137~159lbf · ft)
HBR20/25-7 : 13.5~15.5kgf · m
(98~112lbf · ft)



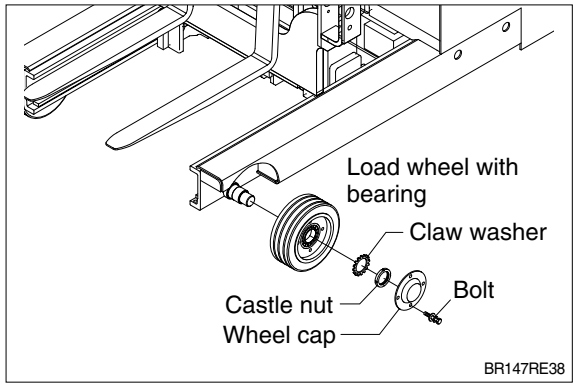
(2) Caster wheel bolts.

· Tightening torque : 8~12kgf · m
(58~87lbf · ft)



(3) Load wheel bolts.

· Tightening torque : 4.5~5.5kgf · m
(33~40lbf · ft)



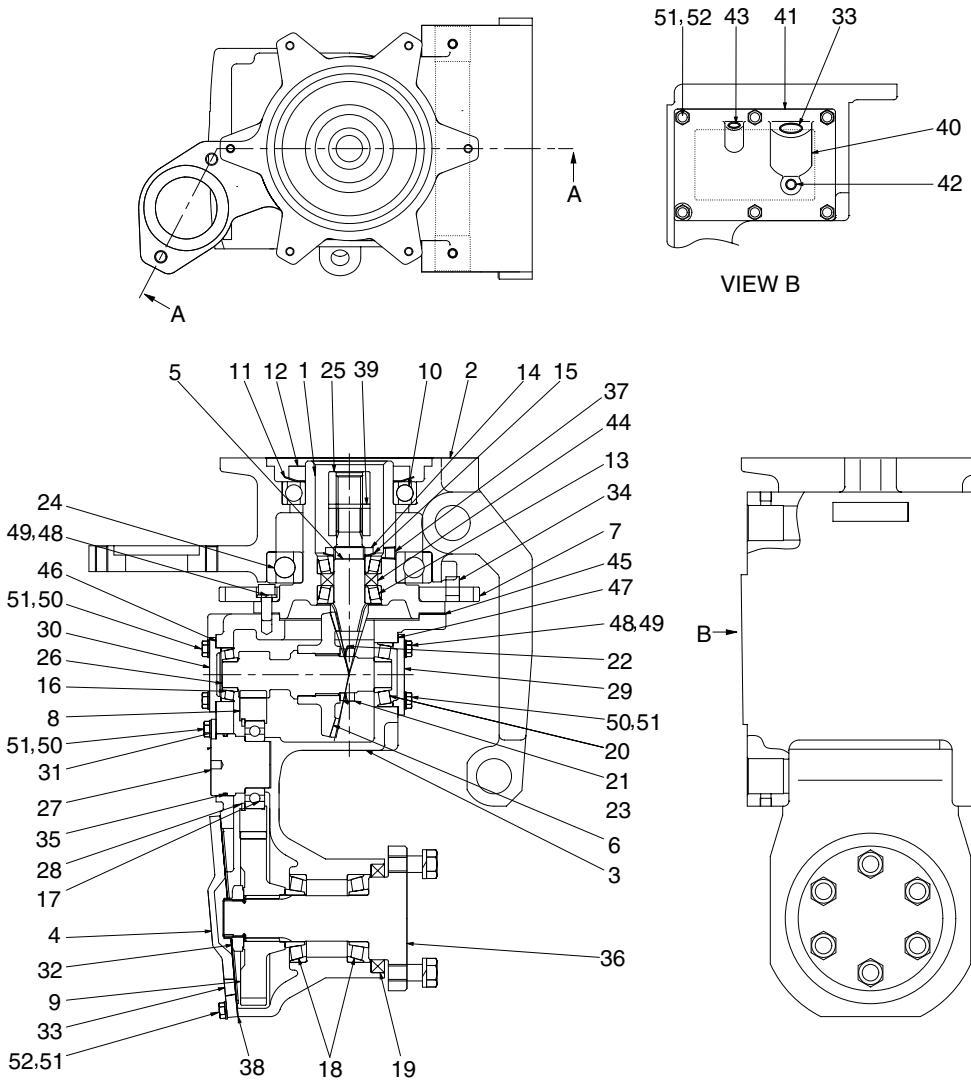
SECTION 3 POWER TRAIN SYSTEM

GROUP 1 STRUCTURE AND OPERATION

1. DRIVE AXLE UNIT

1) STRUCTURE

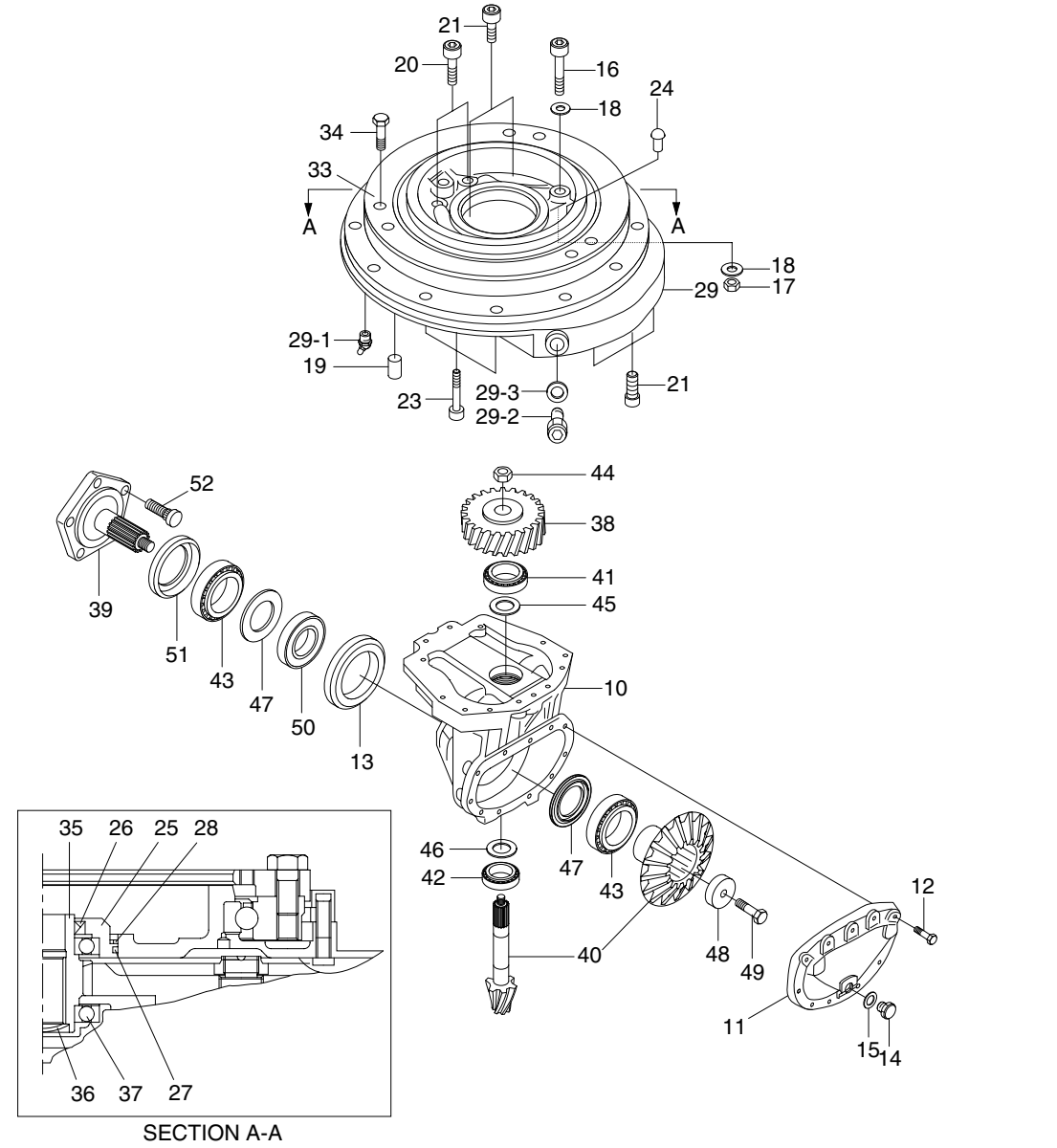
(1) HBR14/15/18-7



BR147DU100

1	Gear case cover	14	Bearing lock nut	27	Idler gear shaft	40	Case
2	Drive bracket	15	Bearing lock washer	28	Snap ring	41	Gasket
3	Gear box case	16	Bearing	29	Cover	42	Taper plug
4	Cover	17	Bearing	30	Cover	43	Air breather
5	Spiral pinion	18	Bearing	31	Lock plate	44	Oil seal
6	Spiral bevel gear	19	Seal	32	Drive shaft nut	45	Shim
7	Steering gear	20	Taper roller bearing	33	Taper plug	46	Shim
8	Idle gear	21	Bearing lock nut	34	Spring pin	47	Shim
9	Gear	22	Bearing lock washer	35	O-ring	48	Socket bolt
10	Bearing	23	Gear spacer	36	Drive wheel shaft	49	Spring washer
11	Washer	24	Bearing	37	Taper plug	50	Hexagon bolt
12	Bearing lock nut	25	Sleeve	38	Gasket	51	Spring washer
13	Taper roller bearing	26	Pinion shaft	39	Spring pin	52	Hexagon bolt

(2) HBR20/25-7



BR147DU103

10	Housing	25	Cover	39	Wheel shaft
11	Cover	26	Seal ring	40	Bevel gear set
12	Hexagon screw	27	O-ring	41	Taper roller bearing
13	Ring gamma	28	Circlip	42	Taper roller bearing
14	Magnet plug	29	Upper part	43	Taper roller bearing
15	Seal ring	29-1	Lub nipple	44	Hexagon nut
16	Socket head screw	29-2	Plug	45	Shim
17	Hexagon nut	29-3	Seal ring	46	Shim
18	Washer	33	Centering ring	47	Shim
19	Parallel pin	34	Hexagon screw	48	Washer
20	Socket head screw	35	Pinion	49	Hexagon screw
21	Socket head screw	36	Plug	50	Seal ring
23	Socket head screw	37	Ball bearing	51	Seal ring
24	Breather valve	38	Super gear	52	Wheel bolt

2. SPECIFICATION

1) HBR14/15/18-7

Item		Unit	Specification
Max input torque		Kgf · m	-
Max input rpm		rpm	-
Gear ratio	G2 : G1	-	35 : 8(4.375 : 1)
	G3 : G2	-	46 : 10(4.6 : 1)
	Total	-	20.125
Quantity of oil		ℓ	1.6

2) HBR20/25-7

Item		Unit	Specification
Max input torque		Kgf · m	2200
Max input rpm		rpm	3500
Gear ratio	G2 : G1	-	42 : 7(6.000 : 1)
	G3 : G2	-	80 : 23(3.478 : 1)
	Total	-	20.870
Quantity of oil		ℓ	4.4

GROUP 2 TROUBLESHOOTING

Problem	Probable cause	Remedy
Continuous metallic groan		
1) During acceleration	· Worn out gears.	- Adjust back-lash or replace gears.
	· Pinion and bevel gear meshed too deeply.	
2) During travelling at uniform speed	· Lack of gear oil.	- Refill
	· Worn out gears.	- Replace
	· Loose or worn out bearing.	- Adjust preload or replace.
	· Loose bevel gear wheel	- Replace bolts and washers. Tighten new bolts and washer.
3) When turning corners.	· Worn out differential gear or thrust washer.	- Replace
Continuous knocking sound		
1) During travelling at uniform speed	· Chipped gear teeth.	- Replace
	· Foreign matter in axle case.	- Clean
	· Worn out spline of drive shaft.	- Replace
Oil leakage		
1) Differential housing housing leaks.	· Oil level too high	- Lower oil level
	· Broken oil seal	- Replace
2) Axle case leaks	· Mounting bolts for housing loose.	- Retighten
	· Damaged packing case cracked.	- Replace
	· Worn out hub grease seal.	- Replace
3) Hub, leaks	· Worn out oil seal.	- Replace
	· Worn out bearing or eccentric rotation due to damage.	- Replace
Power is not transmitted		
1) Drive shaft, gear	· Broken or slipped out drive shaft.	- Repair or replace
	· Gear teeth stripped or worn out.	- Replace
	· broken differential case parts.	- Replace
Oil leakage on wheel shaft	· Radial shaft seal wrongly installed or damaged.	· Remove wheel shaft and install a new radial shaft seal.
	· Race on wheel shaft damaged.	· Remove wheel shaft. Check wheel shaft race for reusability; if possible, rework.
Oil leakage on housing cover	· Housing cover not sealed.	· Seal housing cover with LOCTITE No. 574.
	· Housing cover or housing plane face uneven.	· Touch up plane faces with oil rubber.
	· Bolts not tightened according to the specified tightening torque.	Tighten bolts with the specified tightening torque.

Fault	Probable cause	Remedy
Oil leakage on oil filler or oil drain plug	· Dirt between sealing ring and housing. · Old sealing ring was used. · Bolts not tightened according to the specified tightening torque.	· Cleaning required. · Use new sealing ring · Tighten bolts with the specified tightening torque.
Oil leakage between housing and top section	· Seal faces not sealed or uneven. · Burrs on cylinder pin. · Bolts not tightened according to the specified tightening torque.	· Apply LOCTITE 574 onto seal faces. · Touch up seal faces with oil rubber. · Use a new cylinder pin. · Tighten bolts with the specified tightening torque.
Oil leakage on top section within helical gear stage / input	· Too much oil in transmission. · O-ring on cover defective. · Breather valve defective.	· Check oil level. · Install new O-ring. · Replace breather valve.
Beating noise at helical gear stage	· Teeth on input pinion and/or helical gear damaged by false installation.	· Check tooth flanks for damage and touch up damaged spots with oil rubber.
Ringing noise	· Helical gear stage running without oil.	· Check oil level. Refill oil.
Grinding noise	· Bearing preload or backlash not correctly adjusted.	· Checking and new adjustment.
Bearing damage on input pinion	· No axial play.	· Install new bearing and adjust axial play.
Pivoting bearing is difficult to rotate or backlash recognizable	· Cover disc loosened and dirt entered into the bearing. · Cage segments are damaged. · Plastic deformation of balls or ball race. · Bearing not relubricated. · Grease not distributed.	· Replace pivoting bearing. · Replace pivoting bearing. · Replace pivoting bearing. · Relubricate pivoting bearing. · Rotate pivoting bearing several times by hand.

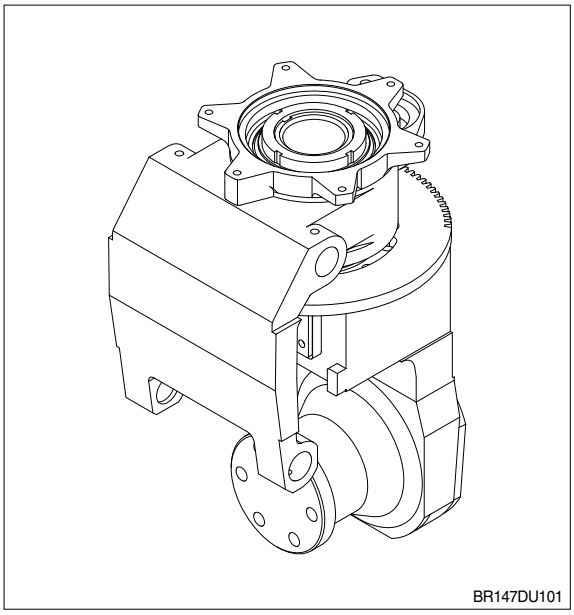
GROUP 3 DISASSEMBLY AND ASSEMBLY

1. HBR14/15/18-7

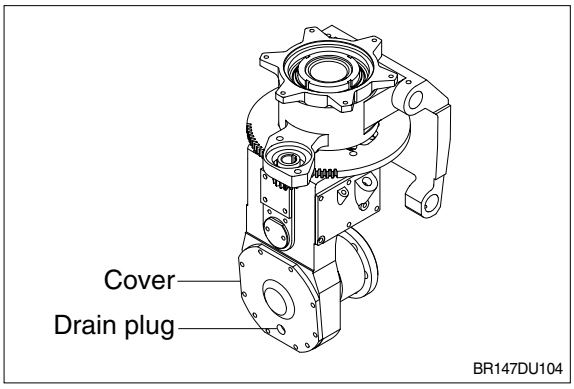
1) DISASSEMBLY

※ Before starting disassembly check the backlash and tooth contact for use as reference during assembly.

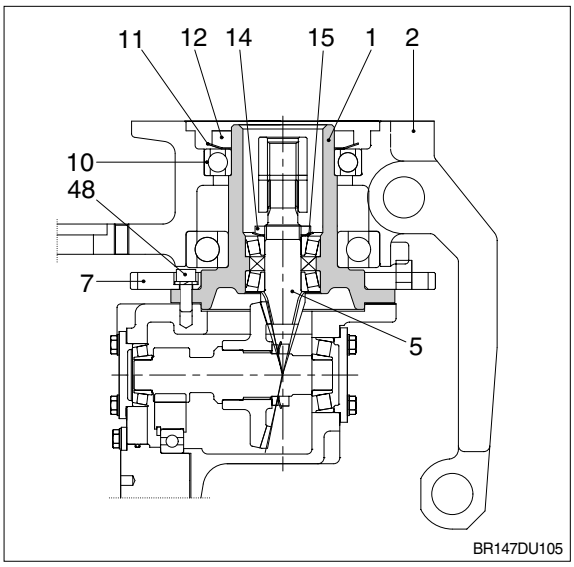
(1) Stabilize the drive unit assembly by using wooden block.



(2) Remove the plug and drain out the oil.
Remove the gear case cover and drain out the oil.



(3) Loosen the lock nut and remove the lock nut(12) and washer(11).
(4) Remove drive unit bracket(2). Remove the outer race of bearing(10) and oil seal from bracket.
(5) Remove bolts(48) and remove the steering gear(7).
(6) Remove bolts(11EA).
(7) Remove the cover(1) of gear case with spiral bevel pinion(5).
(8) Remove bearing nut(14) by straightening the locking part of the bearing washer(15), and remove the spiral bevel pinion(5) from the cover of gear case(1).



(9) Remove the end cover(29, 30).

(10) Remove the bearing(16, 20) installed on the side of spiral bevel gear(6) for pinion shaft(26).

Loose the nut for spiral bevel gear(6) by straightening the locking of the washer and remove the nut(21) and the washer(22).

When loosening the nut, lock the pinion shaft by puting capper for between the idle gear(8) and the pinion shaft(26).

※ After removing the idle gear(8) remove the pinion shaft(26) and spiral bevel gear(6).

(11) Support drive shaft(36) at drive wheel side not to rotate.

Remove the lock nut(32) of drive gear and pull out the drive shaft(36) to drive wheel side.

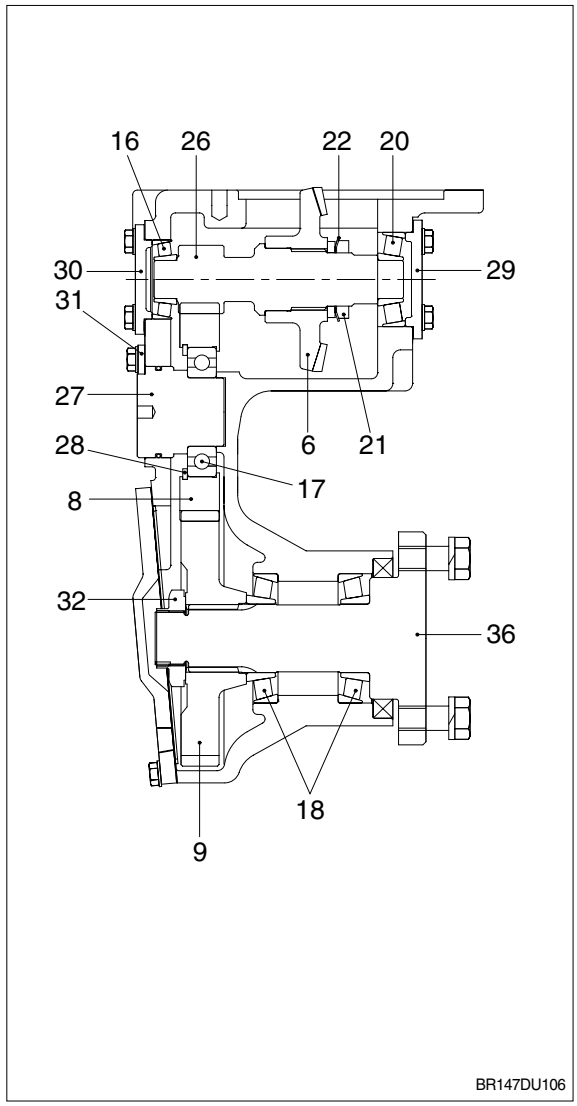
Remove the bearing(18) from drive shaft.

(12) Remove the locking plate(31) for idle gear shaft and remove idle gear shaft(27).

Pull out the idle gear from the side of drive gear(9).

(13) After removing the snap ring(28), remove the bearing(17) for idle gear.

(14) Pull out the pinion shaft(26) and the spiral bevel gear(6).



2) INSPECTION

(1) Inspect the gear case for cracks, bearing insertion parts for injuries, oil seals for damage and for other defects. Replace if found defective.
Inspect for gear case cracks visually and by use of flaw penetrants.

(2) Inspect the drive unit bracket for cracks, bearing insertion parts for injuries, bushings for damage, and other defects. Replace if found defective.

(3) Inspect the gear case cover for cracks, bearing insertion parts for injuries and for other defects. Replace if found defective.

(4) Inspect the spring adjuster and spring bracket for damage and spring for deterioration.
Replace parts found defective.

(5) Inspect the tooth part and spline part of steering pinion for damage and the bearing for damage, and replace the parts found defective.

(6) Inspect the bearing and oil seal of steering part for damage, and replace the parts found defective.

(7) Inspect the steering gear for damage, and replace parts found defective.

(8) Inspect the spiral pinion shaft, counter gear shaft and idle gear shaft for tooth damage and shaft bend, and the bearings for damage. Replace the parts if found defective.

(9) Inspect the spiral bevel pinion shaft for tooth damage and shaft bend, and the bearing holder and bearing for damage. Also inspect spiral bevel gear for damage.
Replace the parts if found defective.

(10) Inspect the drive wheel shaft for cracks, splines for wear and damage, and the bearings for damage. Replace the parts found defective.

3) ASSEMBLY

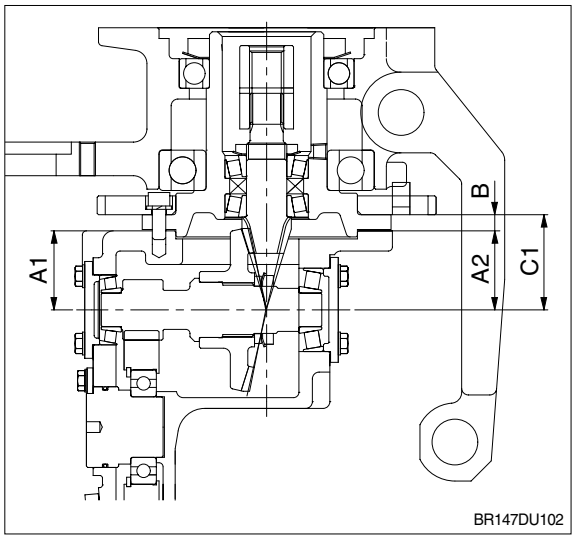
(1) Assemble the oil seal to the cover of gear case, assemble the bearing to spiral bevel pinion shaft. Assemble the spiral bevel pinion shaft bearing, washer and nut to the cover of gear case, and screw on the locking nut.
Tighten the locking nut while measuring starting torque required to start the bevel pinion turning.
Bevel pinion starting torque. 2.7~3.0kgf · cm(0.2~0.22lbf · ft)

(2) Assemble the drive wheel shaft to the gear case, assemble the spur gear from opposite side and screw on the locking nut. Tighten the locking nut while measuring starting torque reguired to start the spur gear turning. Spur gear starting torque. 23.6~26.3kgf · cm(1.7~1.9lbf · ft)

(3) Measure A1, A2 of the gear case and B of the gear case cover, and adjust C to be 69.00~69.10 by shim.

Shim thickness

3329022000 ····· 0.10mm
3329022100 ····· 0.20mm
3329022200 ····· 0.30mm
3329022300 ····· 0.50mm



(4) On the adjusting the tooth contact of spiral bevel gear, if changing the shim, idle of decrease the shim inserting between the cover of shaft both side and the gear case shim thickness.

Idle gear side		Drive tire side	
No.	Shim thickness	No.	Shim thickness
3329024400	0.10mm	3329024000	0.10mm
3329024500	0.20mm	3329024100	0.20mm
3329024600	0.30mm	3329024200	0.30mm
3329024700	0.50mm	3329024300	0.50mm

(5) Adjust the backlash between spiral bevel pinion and bevel gear.
Mount the dial gauge on gear case and read the backlash while rotating the drive wheel shaft.
Backlash 0.15~0.20mm
If the backlash is not within the specified range, readjust the bevel gear shims. Increase the shim thickness if the backlash is too large, and decrease if too small.

(6) Check the contact between the drive pinion and bevel gear tooth.
Clean the gear tooth and apply red lead of the surfaces of 8 or 9 bevel gear tooth.
Turn the bevel gear in both forward and reverse directions and determine by the patterns made on the tooth face whether the tooth is contacting properly.

4) INSTALLATION

Perform the removal in reverse order.

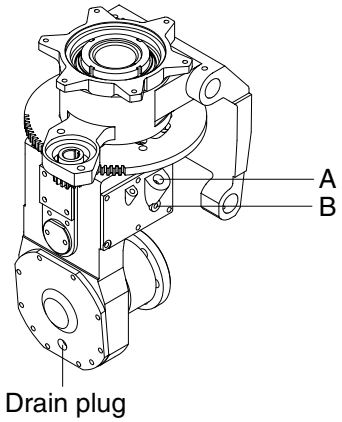
5) LBRICATION PROCEDURES

Lubrication of drive unit gear case is performed as follows :

※ **Cover the brakes and drive motor with waste to prevent the gear oil from splashing on these parts.**

(1) Fill in oil through the filler hole A.

(2) After operating the vehicle for several hours, remove plug B and check the oil level. Replenish it now.

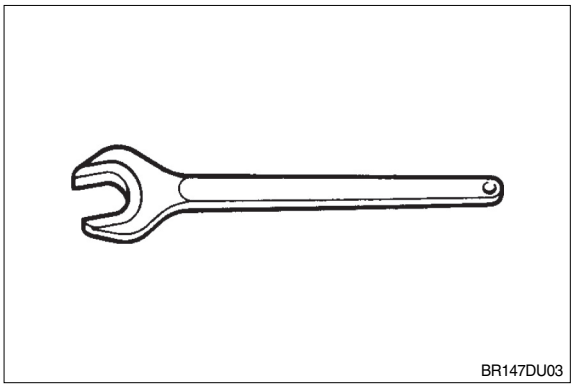


BR147DU107

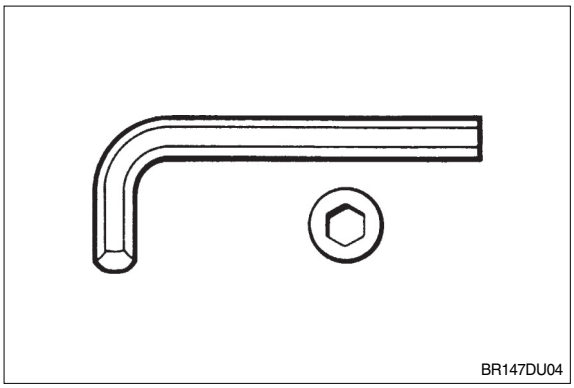
2. HBR20/25-7

1) STANDARD TOOLS

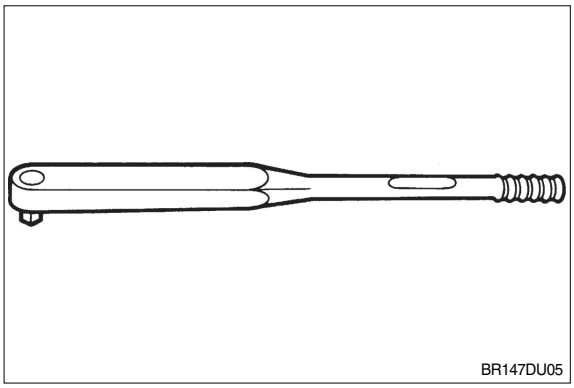
(1) Open jaw spanner 10, 13, 30㎜.



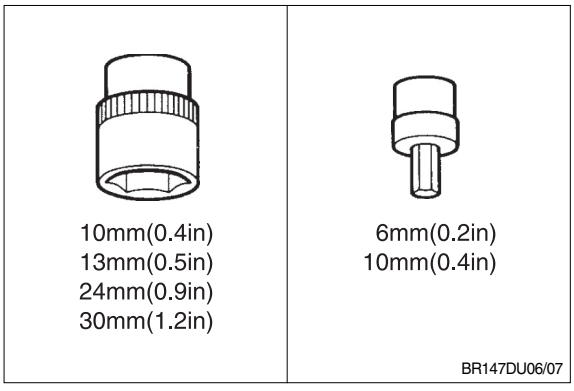
(2) Allen wrench 6, 10㎜.



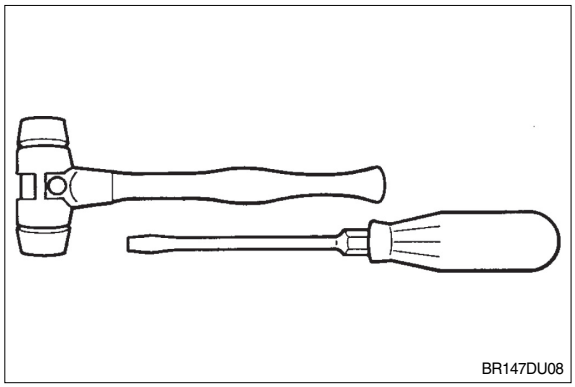
(3) Torque spanner
Adjustable from 9.5 to 300Nm.



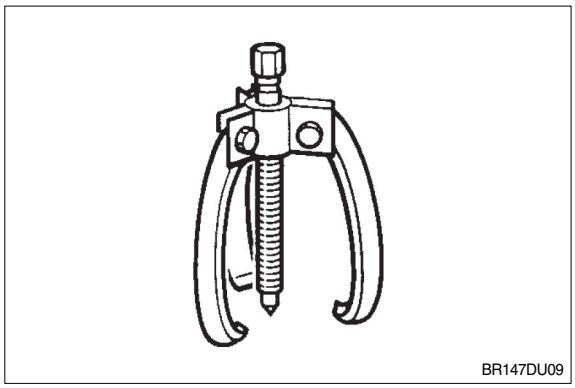
Hexagonal socket spanner.



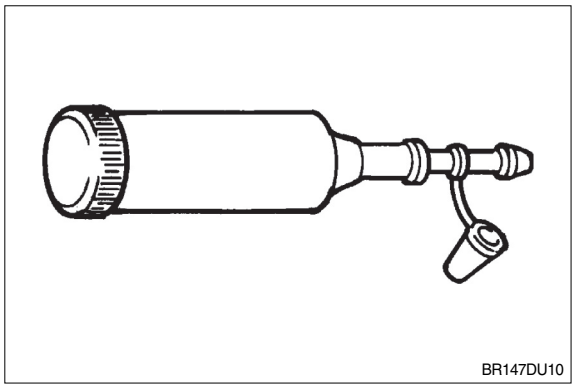
(4) Plastic hammer(1000g).
Steel hammer(250g).
Stable screwdrivers or levers.


BR147DU08

(5) Two-armed or three-armed puller.

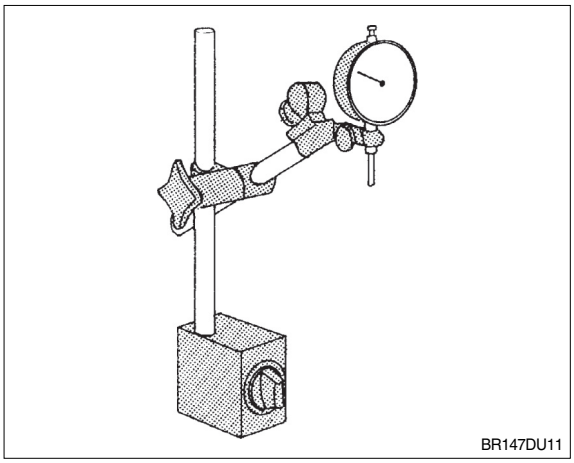

BR147DU09

(6) Grease gun
With adapter for hydraulic-type lubricating nipple acc. to DIN 71412-M8×1.

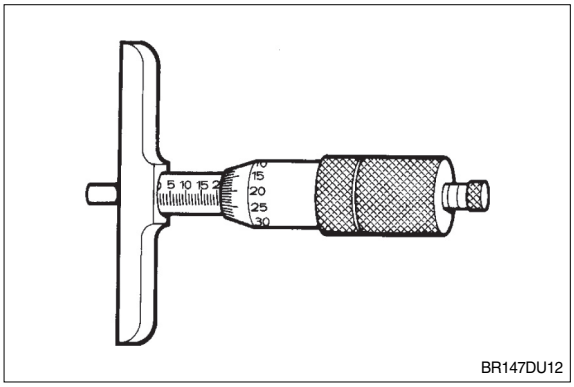

BR147DU10

2) MEASURING TOOLS

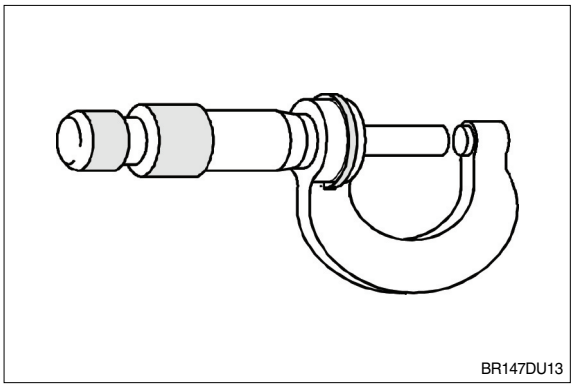
(1) Dial gauge with magnetic stand.



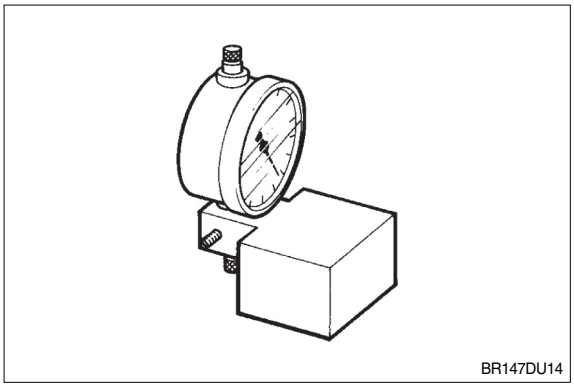
(2) Micrometer depth gauge
Measuring depth up to 70㎜.



(3) Micrometer
Measuring range up to 25㎜.



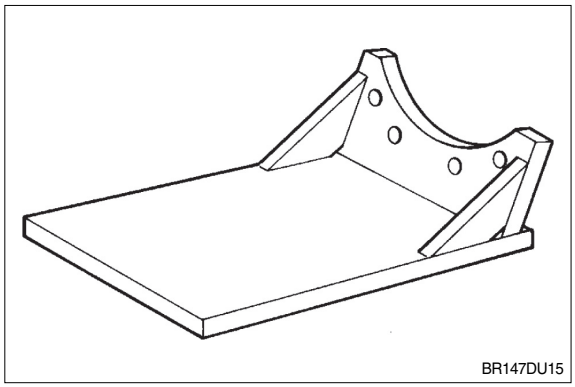
(4) Measuring device
For determination of installation dimension for bevel pinion shaft.



3) SPECIAL TOOLS

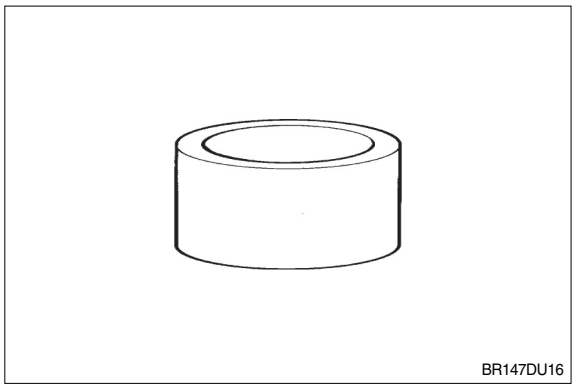
(1) Assembly plate(A)

If no assembly fixture is available.



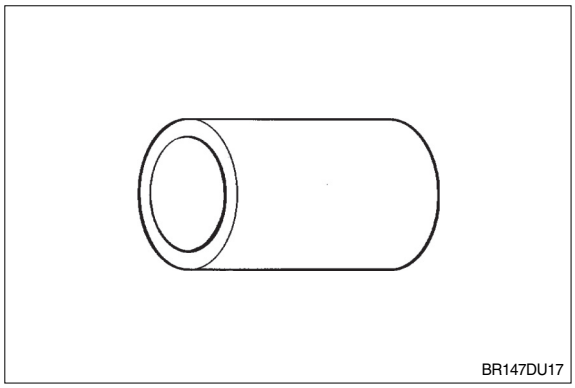
(2) Bush(B)

To press off bearing inner ring from bevel pinion shaft.



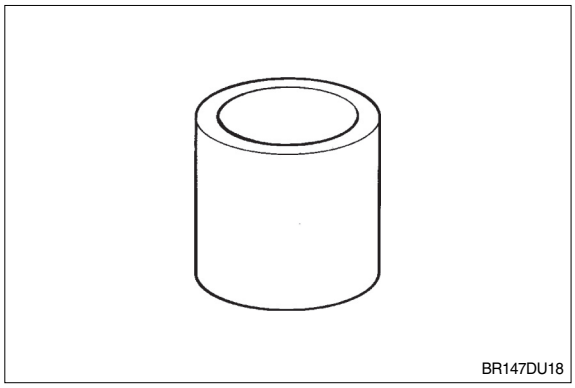
(3) Bush(C)

To press bearing inner ring onto bevel pinion shaft.



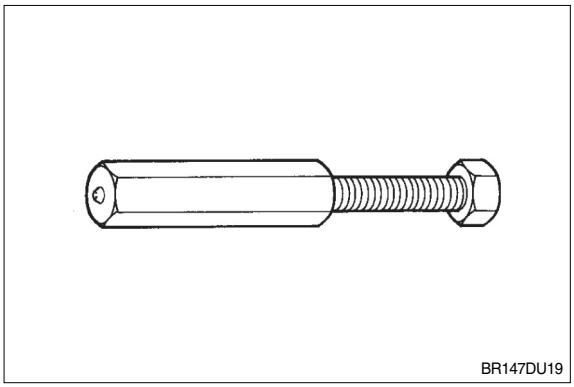
(4) Measuring bush(D)

For determination of installation dimension for bevel pinion shaft.



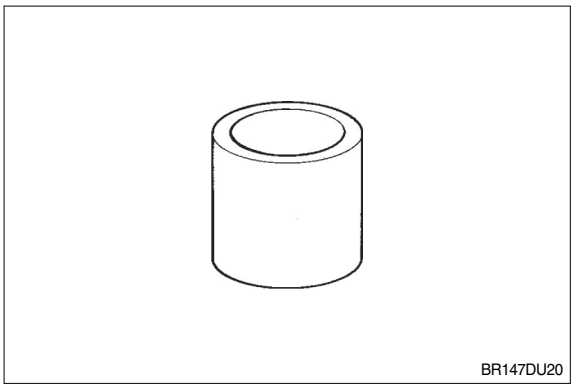
(5) Clamping fixture(F)

To clamp bevel pinion shaft into the housing.



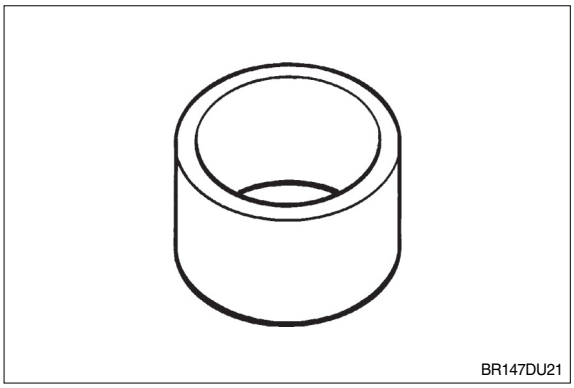
(6) Bush(G)

To press bearing inner ring onto bevel pinion shaft.



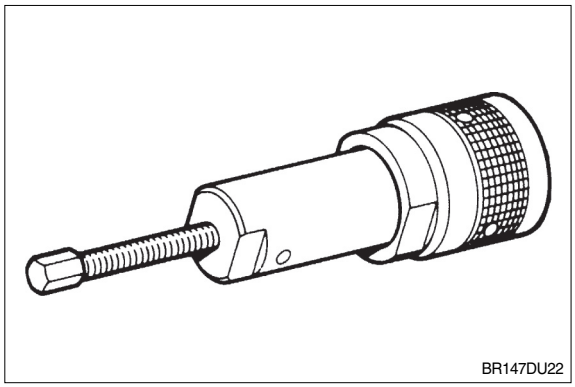
(7) Sleeve(H)

To press bearing inner ring onto wheel shaft and onto crown gear.



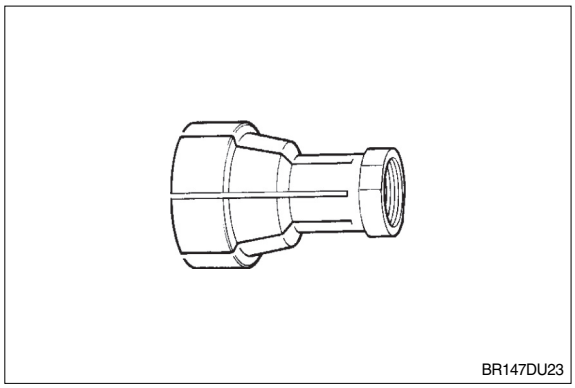
(8) Puller(M)

To pull off bearing inner rings from the wheel shaft and the crown gear.



BR147DU22

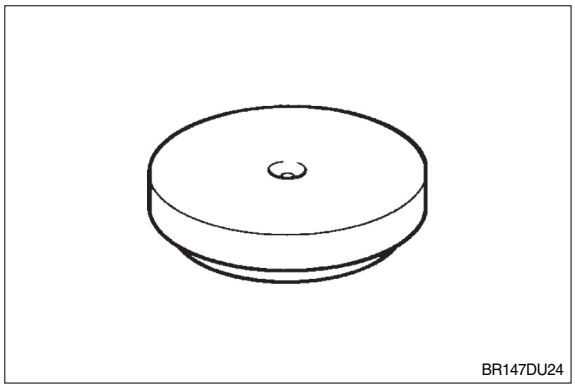
Clamping pliers



BR147DU23

(9) Pressure piece(N)

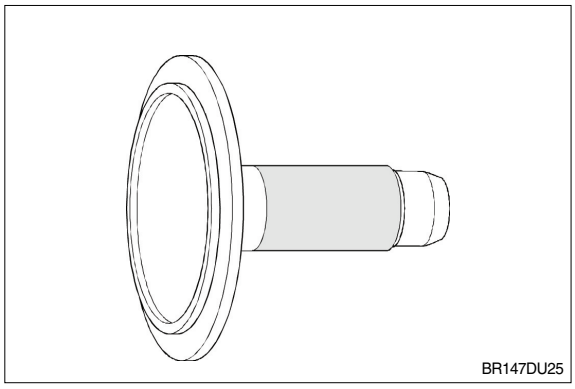
To pull off bearing inner ring from the crown gear.



BR147DU24

(10) Assembly drift(S)

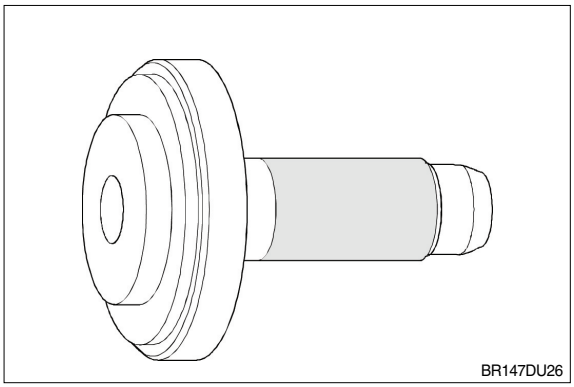
Install protective shield.



BR147DU25

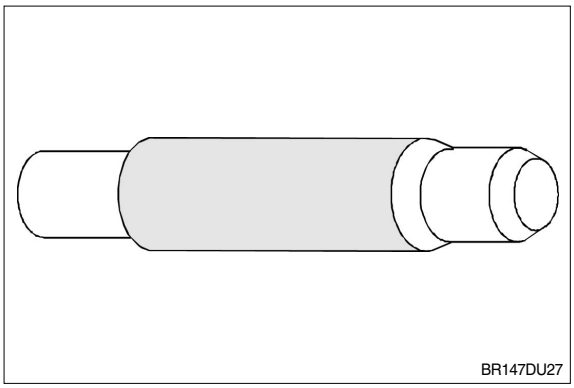
(11) Assembly drift(T)

Install radial shaft seal.



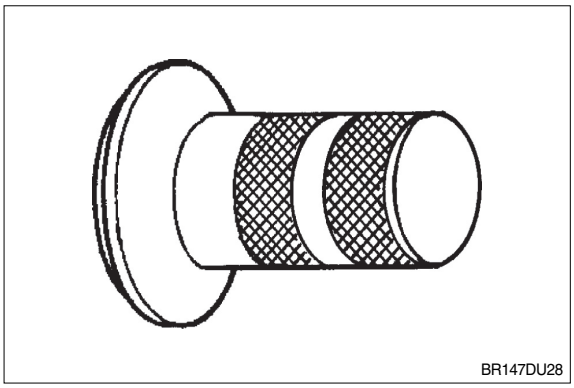
(12) Assembly drift(U)

To install breather filter.



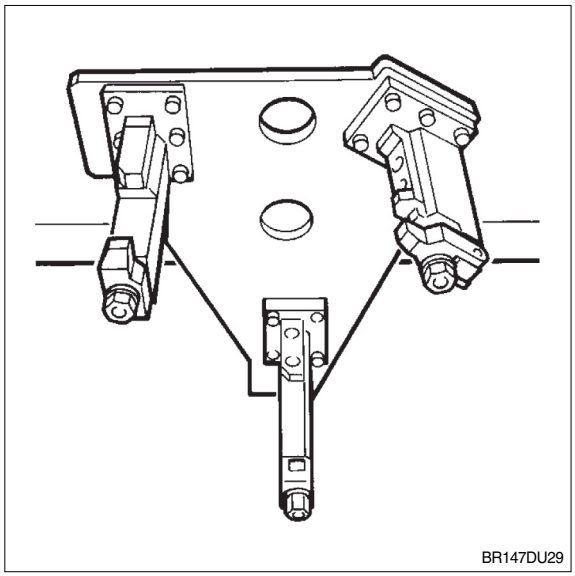
(13) Assembly drift(V)

To install grooved ball bearings into the housing seat.



4) DISASSEMBLY

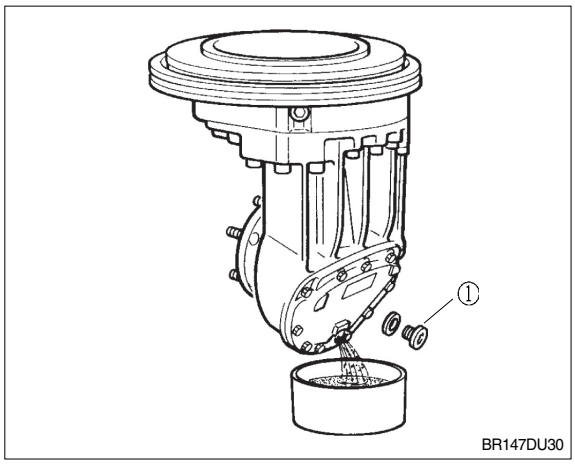
※ Prior to disassembly clean drive unit carefully. A great help is a bright, spacious working place, free of dirt and chips.
The necessary working steps are described and illustrated in the correct sequence.
Parts only available as assembly groups will not be stripped any further.
Please observe strictly the instructions of the vehicle manufacturer for removing the drive unit from the vehicle.
For dis-and reassembly we recommend to use a fixture as shown in below figure.


BR147DU29

(1) DRAIN OFF DRIVE UNIT

① Place a suitable receptacle under the oil drain plug(①) and unscrew it with a 6mm allen wrench.
Drain oil completely into the receptacle.

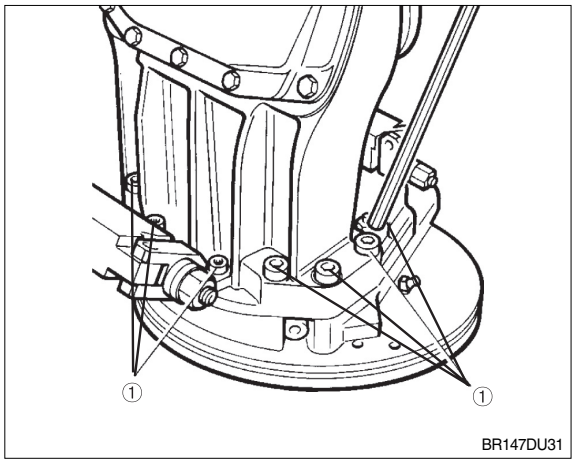
※ Do not drain oil into the sewerage system or into the soil.
Observe oil drain time.



BR147DU30

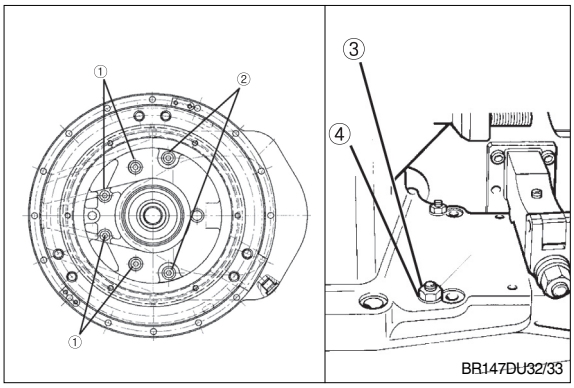
(2) REMOVE HOUSING TOP SECTION

① Loosen and remove the socket head bolts(①) on the bottom side of the drive unit housing as well as inside the housing top section.



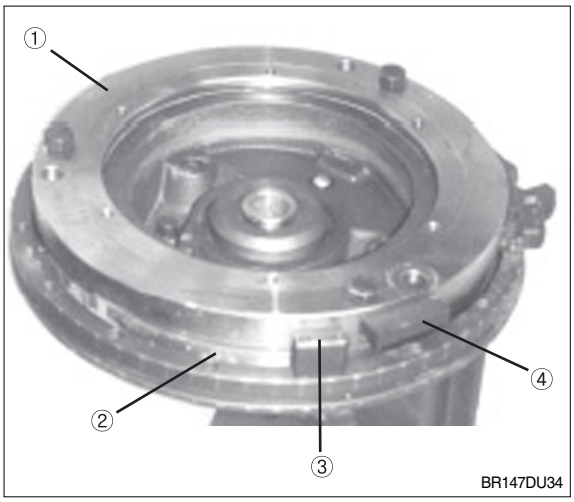
BR147DU31

② This drive unit has the housing top section additionally fastened to the housing by means of 2 socket head bolts(②), hexagon nuts(③) and washers (④).



③ For motor fixing the centering ring(②) is bolted onto the pivoting bearing(①).
Two final stops(③) on the chain tread and the lock plate(④) connected with the centering ring are required for the steering lock.

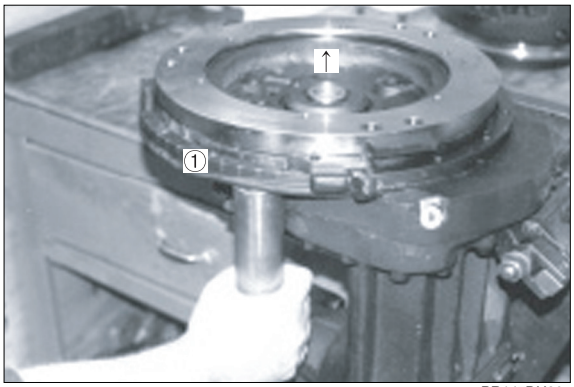
※ Only in case of damage the lock plate and the 2 final stops have to be removed and replaced.



④ Slightly beat with a plastic hammer or a copper mandrel from the bottom against the top section(①), so that it loosens from the transmission housing.
Cautiously lift off and remove the housing top section.

※ Housing top section can only be replaced completely. Centering ring can be reused.

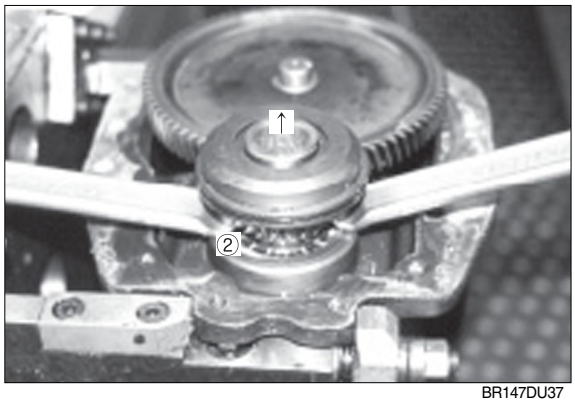
※ Remove cylinder pins, breather valve and grease nipples only in case of damage. Check housing top section acc. to chapter "Reassembly", refer to page 3-40 and keep it properly.



Remove input from the housing top section and dismantle it

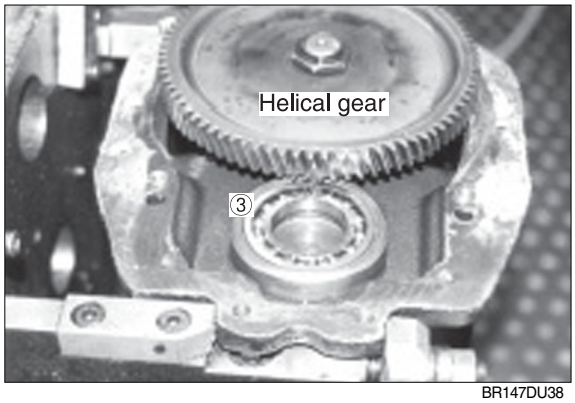
⑤ By means of two assembly levers press cover assy(②) cautiously against the bearing outer ring(With radial shaft seal, grooved ball bearing, O-ring and input pinion) out of the bearing bore.

※ Do not damage the input pinion toothing. Damages might cause loud-er running noises.



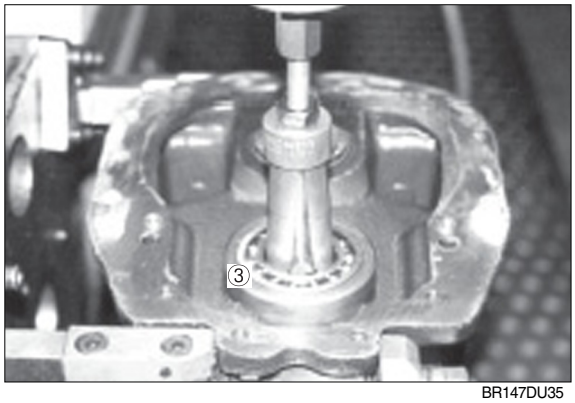
BR147DU37

※ Prior to remove the grooved ball bearing(③) the helical gear has to be taken off first, page 3-24, (7).



BR147DU38

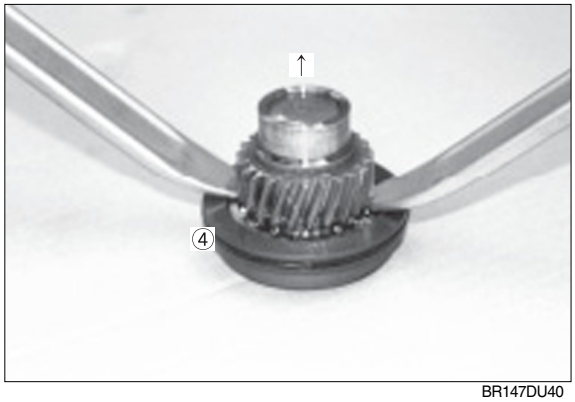
⑥ Pull grooved ball bearing(③) with a bearing extractor out of the bore hole in the housing top section and remove it.



BR147DU35

⑦ By means of two assembly levers press input pinion(④) cautiously out of the cover and remove it.

※ Do not damage the input pinion toothing. Damages might cause louder running noises.

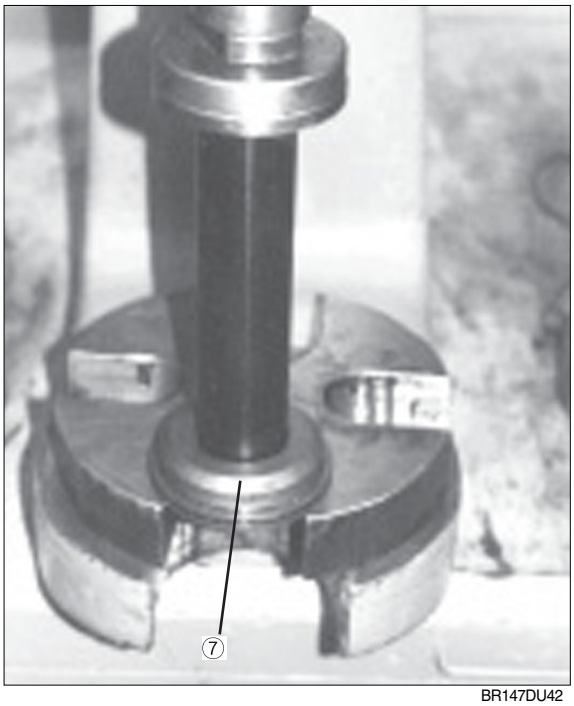


BR147DU40

⑧ Remove radial shaft seal(⑤) from the cover, only if unavoidable.

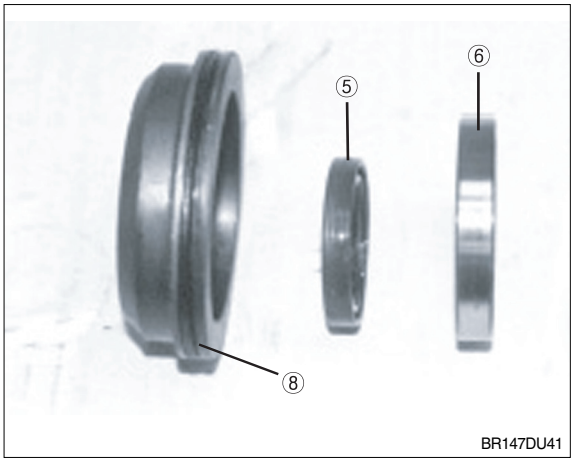
※ Radial shaft seal will be destroyed at removal. Use new radial shaft seal for reassembly.

⑨ By means of bush press radial shaft seal and grooved ball bearing(⑥) out of the cover(⑦) and remove them.
Remove O-ring(⑧) from the slot in the cover.



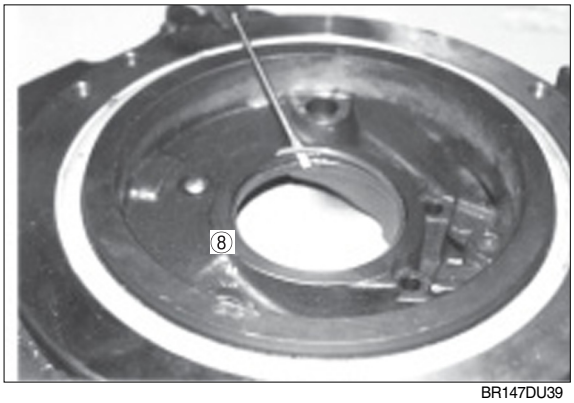
BR147DU42

※ Use O-ring only once.
For reassembly a new O-ring is to be used.



BR147DU41

⑩ Unsnap and remove circlip(⑧) with the aid of a screw driver from the housing top section.

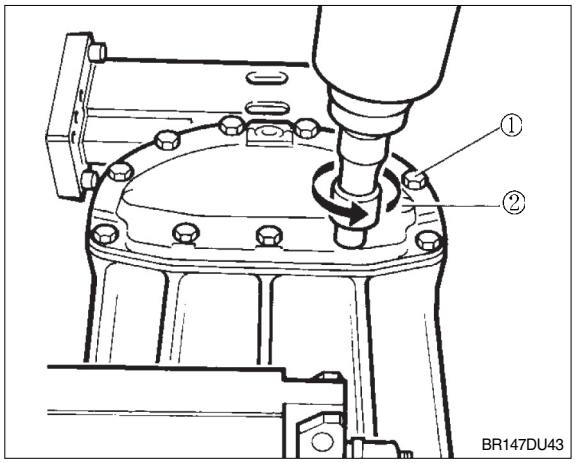


BR147DU39

(3) REMOVE HOUSING COVER

① Remove hexagon bolts(①) in the housing cover.

Loosen and remove housing cover(②) from the housing by slightly beating with a plastic hammer against the outer edge.

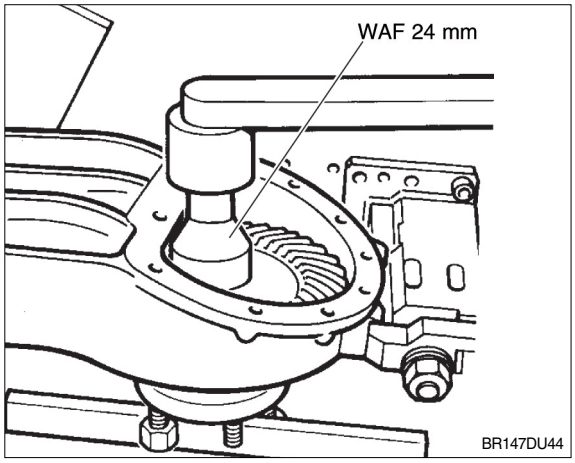


(4) REMOVE WHEEL SHAFT AND CROWN GEAR

① Place drive unit into the fixture and fasten it with screws.

Screw 2 wheel nuts onto the wheel bolts and hold the wheel shaft with a lever.

Screw off the hexagon bolt with a hexagonal spanner WAF= 24mm and remove it with the washer from the wheel shaft.

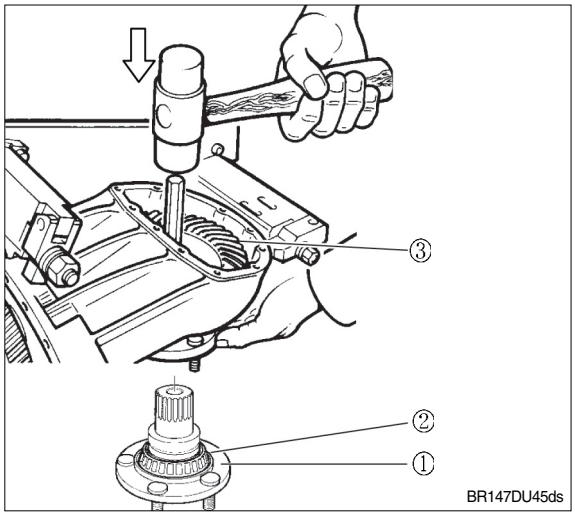


② Drive wheel shaft(①) with the aid of a copper mandrel and a hammer out of the housing and remove it.

※ Take care that the wheel shaft is not damaged during removal.

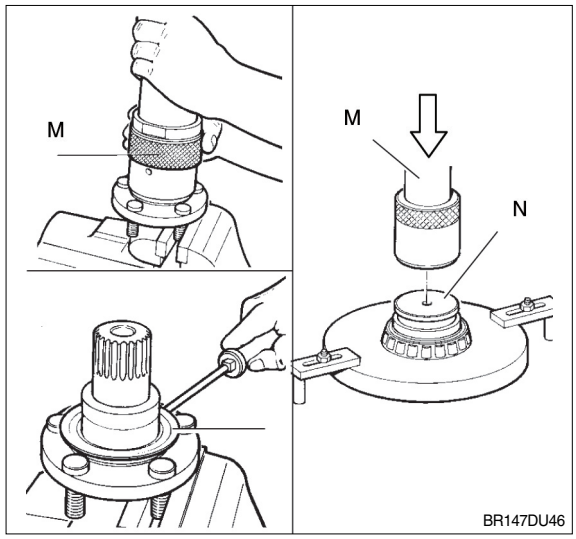
※ During disassembly of the wheel shaft the sealing ring(②) on the wheel shaft and the radial shaft seal in the housing can be damaged and should always be replaced.

③ Then carefully remove the crown gear(③) from the housing.



(5) REMOVE BEARING INNER RINGS FROM WHEEL SHAFT AND CROWN GEAR

① If the taper roller bearings are to be reused, we recommend to use puller **M**.
(See page 3-16 special tools)



Remove bearing inner ring from wheel shaft

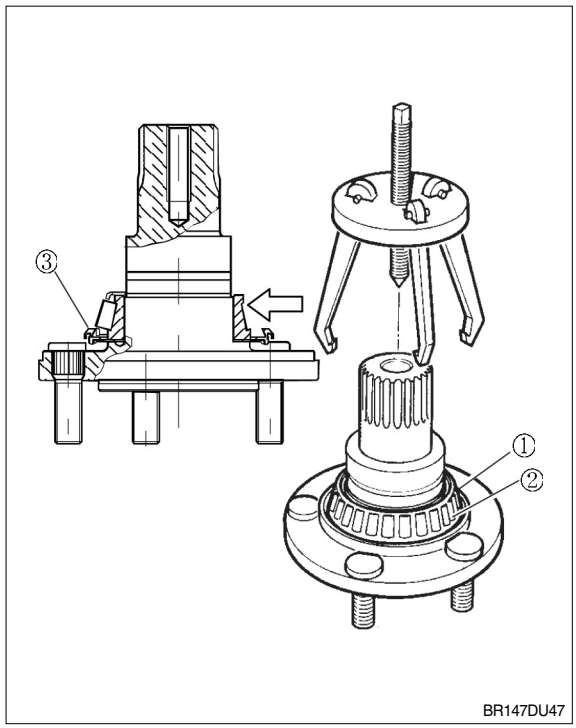
② Place clamping pliers of the puller onto the rollers of the bearing inner ring.
By means of union nut tightly connect clamping pliers with the rollers.
Bolt spindle to the wheel shaft face and remove the bearing inner ring cautiously and evenly at all sides.
Take off the sealing ring(①) from the wheel shaft.

※ Avoid damage at the wheel bolt threads at counter-supporting.
Protect wheel bolt thread against damage with suitable fixtures.

Remove bearing inner ring from crown gear

③ Proceed as described under(5), ② for removal of the bearing inner ring from the crown gear.
Crown gear should be clamped on the work bench and pressure piece **N** be inserted into the crown gear bore hole to support the spindle.
For replacement of the taper roller bearings, the following steps are required

- Open bearing cage(①) by cutting and remove the rollers(②).
- Cautiously remove the bearing inner ring with a puller(e.g. three-armed puller) over the bearing collar(□).
- Remove sealing ring(③) from wheel shaft.

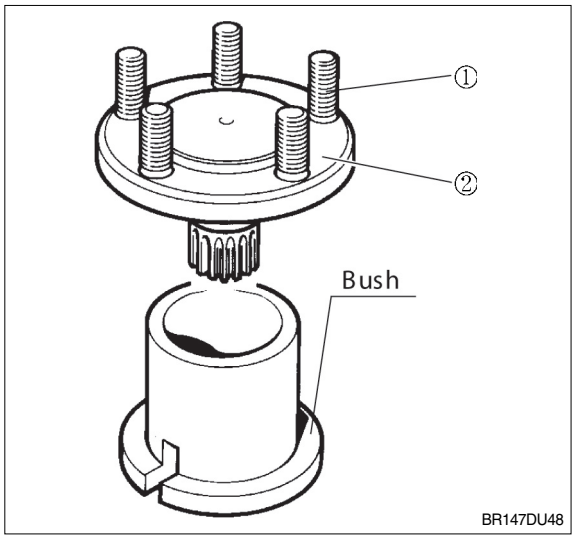


(6) PRESS WHEEL BOLTS OUT OF THE WHEEL SHAFT

① Wheel bolts(①) can only be pressed out at removed wheel shaft.

※ Make these 2 steps only in case of emergency. Do not damage wheel bolt threads at pressing-out.

- Place wheel shaft(②) into a suitable bush and press out wheel bolts with a press.
- By means of a copper mandrel and a hammer drive wheel bolts out of the wheel shaft. Be especially careful at this step, since at replacement or installation of the new wheel bolt with the old wheel shaft, the position of both parts to each other must exactly be obtained again.



BR147DU48

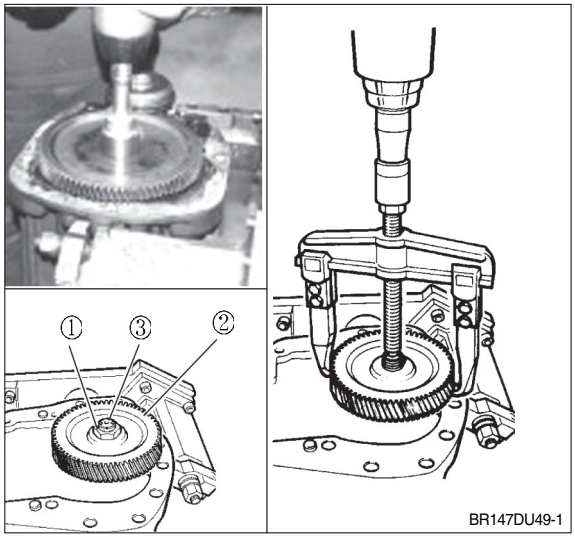
(7) REMOVE BEVEL PINION SHAFT

Remove helical gear

① Bevel pinion shaft can only be removed, when crown gear was taken off before. Unscrew hexagon nut(①).

※ Use hexagon nut only once.

② Pull off and remove helical gear(②) from bevel pinion shaft(③) with the aid of a puller (three-armed puller).

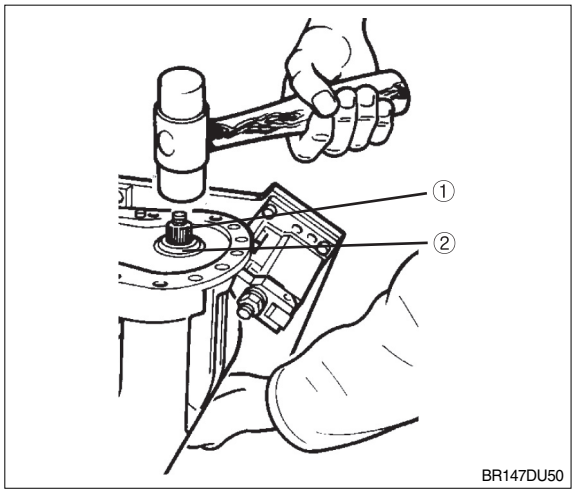


BR147DU49-1

Drive out bevel pinion shaft

③ Drive out bevel pinion shaft(①) with the aid of a plastic hammer from the bearing seat.
Take off and remove the taper roller bearing inner ring(②) from the bearing bore hole.

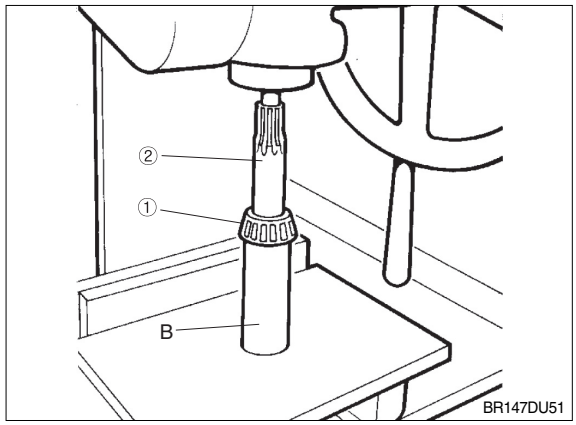
※ Take care that the bevel pinion shaft is not damaged during removal.



BR147DU50

Press off taper roller bearing inner ring from the bevel pinion shaft

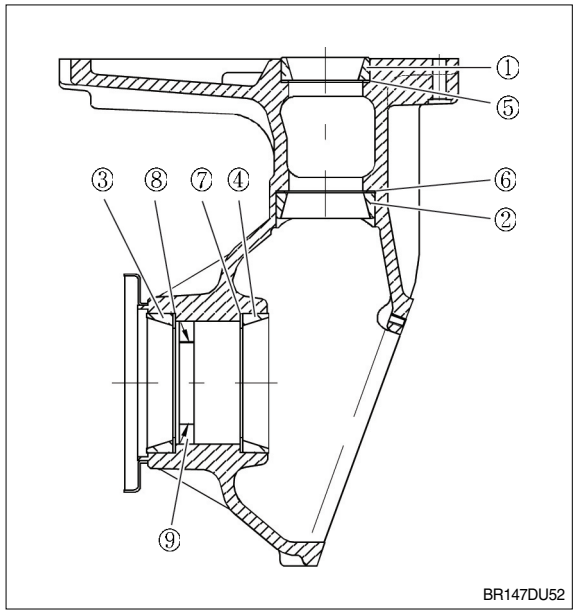
④ By means of bush **B** press off the bearing inner ring(①) from the bevel pinion shaft(②).



(8) REMOVE TAPER ROLLER BEARING OUTER RINGS AND RADIAL SHAFT SEAL

① Cautiously drive the bearing outer rings(①,②,③ and ④) for supporting of the wheel and bevel pinion shaft with the aid of a copper mandrel and a hammer out of the housing.
Take care that shim rings(⑤,⑥,⑦ and ⑧) are not damaged during removal of the bearing outer rings.

※ Put bearing outer ring to the respective bearing inner ring.
Do not reuse deformed or damaged shim rings.



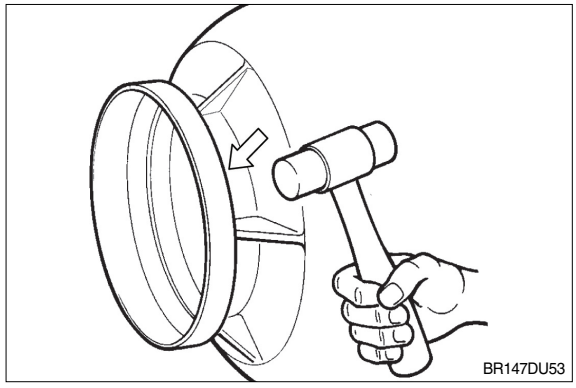
② By means of a copper mandrel or robust screw driver and a hammer drive out and remove radial shaft seal(⑨) from the housing.

※ During disassembly of the wheel shaft the radial shaft seal can be damaged and must always be replaced.

(9) REMOVE THREAD PROTECTIVE SHIELD (GAMMA RING)

① By means of robust screw driver and a plastic hammer cautiously drive out and remove the thread protective shield from the adhesive point on the housing neck

※ Use the thread protective shield only once. For reassembly a new thread protective shield must be used.



5) REASSEMBLY

※ Clean all parts with a suitable cleaning agent and remove residues of LOCTITE.

⚠ **Keep away cleaning agent from your skin, do not drink it or inhale its vapours. Wear safety gloves and goggles. In case of skin contact rinse immediately with a lot of water. If by mistake the cleaning agent was swallowed, call medical aid immediately.**
Observe regulations for prevention of accidents.

※ Check all parts for wear, damages and cracks, if required replace them.
In case of damaged running teeth, the gear set parts have to be replaced per set.
Always replace damaged taper roller bearings(inner and outer ring).
Do not reuse deformed shim rings and worn thrust washers.
Touch up seal faces or smoothen them with a fine file.

※ For reassembly the following new parts should be used :

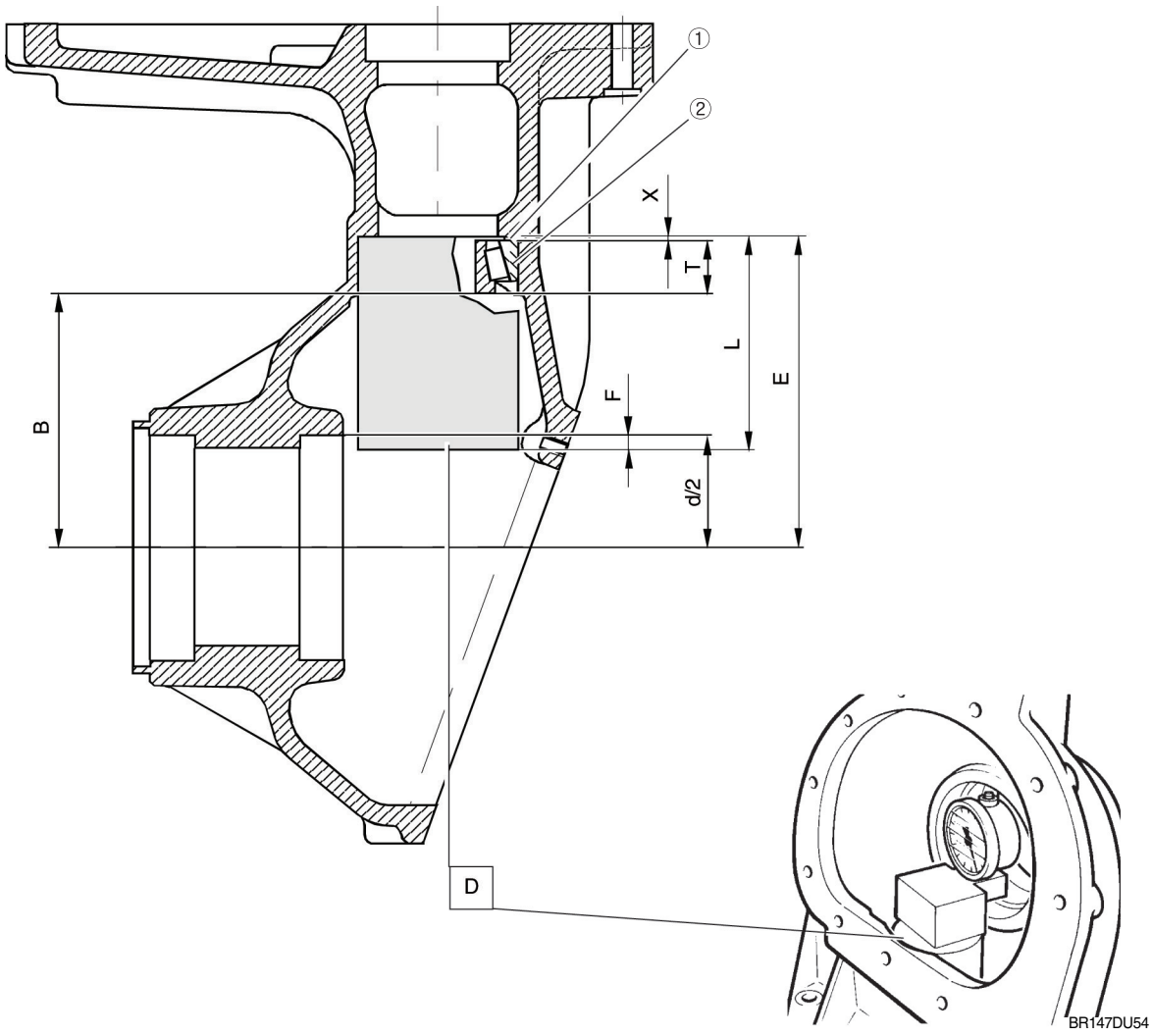
- Hexagon nut for bevel pinion shaft and helical gear fastening
- Hexagon bolt and washer for crown gear fastening
- Radial shaft seal on the wheel shaft
- Spring washers and lock washers
- Deformed or damaged shim rings
- Sealing rings on oil drain and oil filler plug

(1) DETERMINATION OF INSTALLATION DIMENSION FOR BEVEL PINION SHAFT

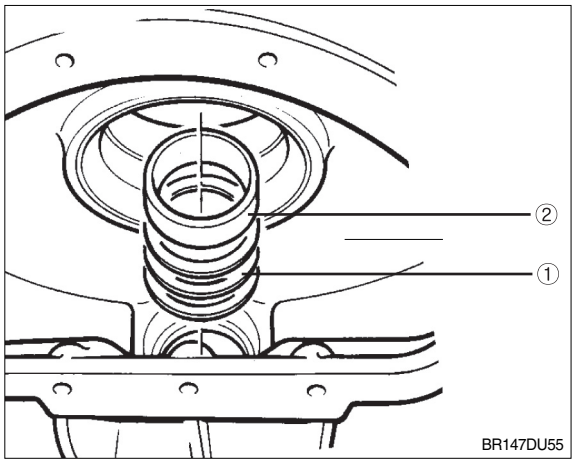
※ The bevel gear set, consisting of bevel gear shaft and bevel gear, is provided with certain installation dimensions. The installation dimension of the bevel pinion shaft is 100.00㎜.
The correct adjustment of the bevel pinion shaft is required for an exact setting of the contact pattern and the torsional backlash of the gearing.
Shim ring thickness and the correct adjustment of the bevel pinion shaft respectively can be determined acc. to the following method :

- Place measuring bush **D** into the housing-bearing bore and measure dimension F.
- Determine housing dimension **E** by thefollowing equation. **E = L - F + d/2** which means :

L = Length of the measuring bush **D**(dimension marked on it 77.50mm)
F = Difference dimension from bearing seat diameter to front face measuring bush **D**
d/2 = Measure housing borehole
By means of the equation : **X = E - B - T** it is possible to calculate the thickness of the shim rings(①).
Which means :
B = Installation dimension of bevel pinion shaft is 100.00mm
(Factory setting of the installation dimension with a tolerance of ±0 is marked on the bevel pinion shaft)
T = Bearing width of the bearing(②)



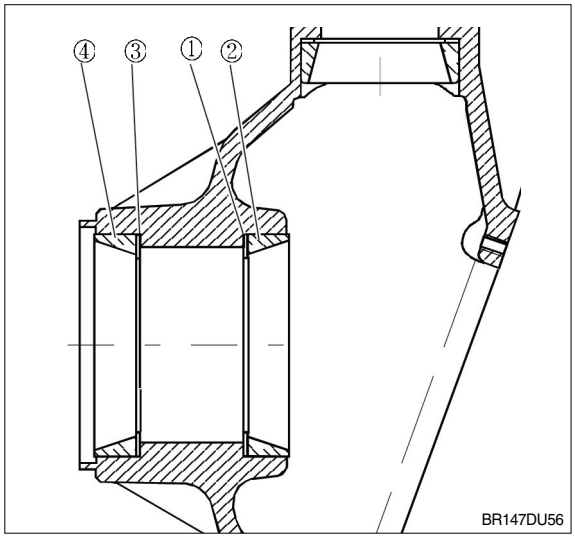
(2) PREASSEMBLE HOUSING



Bearing for bevel pinion shaft

① Shim ring thickness determined in page 3-27 has to be obtained by combining shim rings of variable thicknesses.
Place shim rings(①) into the bearing seat. Install bearing outer ring(②) into bearing seat in the housing.

※ A tolerance of ±0.05 from the determined dimension is permissible.



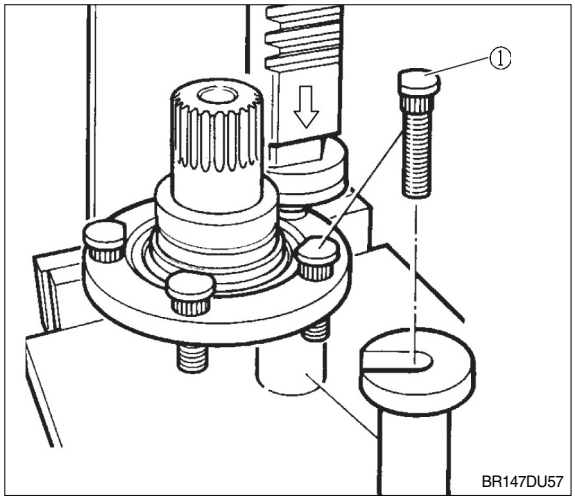
Bearing for wheel shaft

① Place shim ring pack(①and③, remove at disassembly) for presetting into both bearing seats. By means of a copper mandrel and a hammer install the bearing outer rings(②and④) of the wheel shaft bearing into the bearing bore until contact on both sides of the housing.

※ Do not reuse distorted shim rings.

※ Radial shaft seal between taper roller bearings and the thread protective shield are only allowed to be pressed in when the bearing is adjusted.

(3) PREASSEMBLE WHEEL SHAFT



Press in wheel bolts

① Wheel bolts(①) can only be pressed in when the wheel shaft is removed.

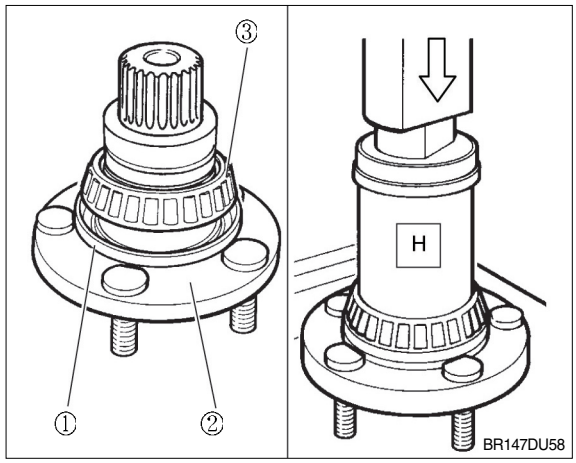
※ Make these steps only in case of emergency. For pressing-in take care that the flattened side on the bolt collar shows to the center of the wheel shaft.

· Place wheel shaft(②) into a suitable bush and press in wheel bolts with a press. Be especially careful at this step, since at pressing in of the new wheel bolt with the old wheel shaft, the position of both parts to each other must exactly be obtained again.

Install sealing ring and bearing inner ring onto the wheel shaft

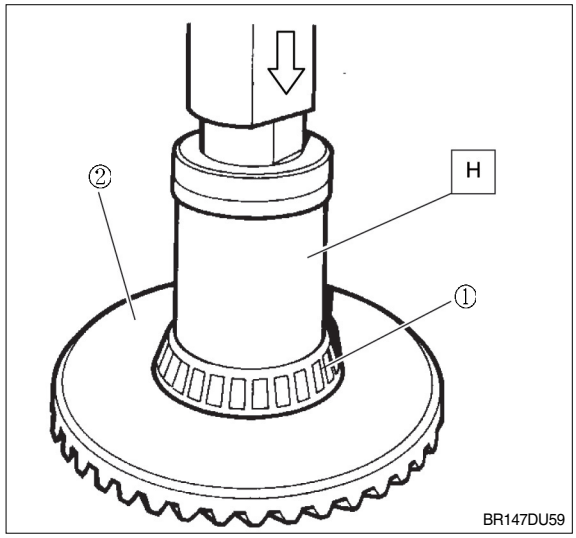
① Push sealing ring(①) on the wheel shaft(②). By means of sleeve **H** press bearing inner ring(③) onto the wheel shaft until contact.

※ **Only when the bearing is adjusted, the sealing and the taper roller bearing can be filled with grease SHELL Alvania R3.**



(4) PRESS BEARING INNER RING ONTO THE CROWN GEAR

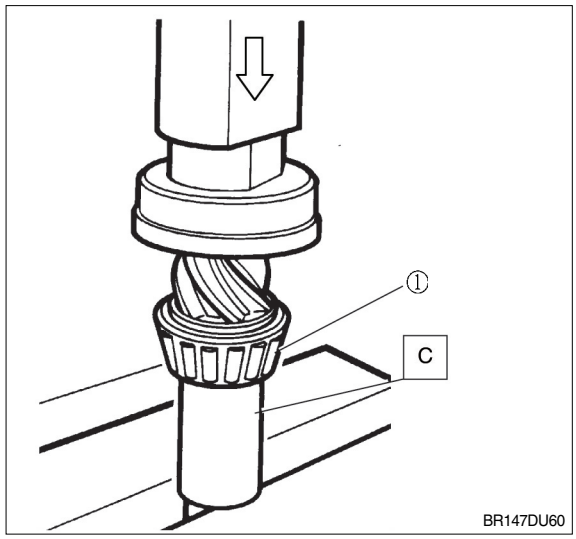
① By means of sleeve **H** press bearing inner ring(①) onto the crown gear(②) until contact.



(5) PREASSEMBLE BEVEL PINION SHAFT

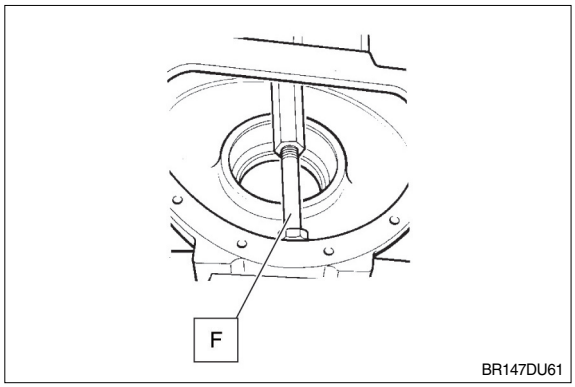
① By means of bush **C** cautiously install bearing inner ring(①) until contact.
If no press is available, the bearing can be installed in accordance with the following note.

※ Heat bearing inner ring up to max. 90°C and install it until contact.
Install subsequently until contact after cooling down.



(6) INSTALL BEVEL PINION SHAFT INTO THE HOUSING

① Wet cage and space between rollers of the bearing inner ring with transmission oil. Insert preassembled bevel pinion shaft from the bottom into the housing and by means of clamping fixture **F** apply a slight preload to the bearing outer ring in the housing.



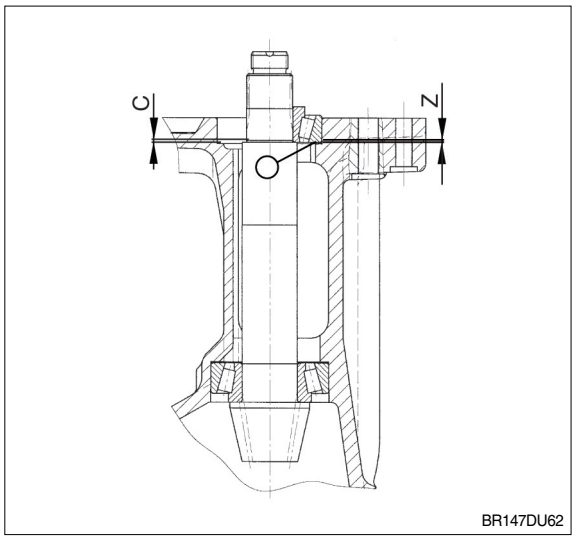
(7) MEASURE BEARING PLAY OF BEVEL PINION SHAFT AND ADJUST BEARING PRELOAD

Measure bearing play

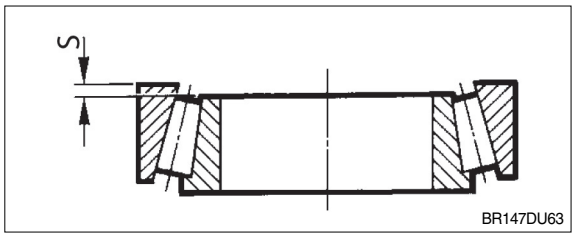
① With the following method the thickness of the shim ring(s)(①) to be added is determined.

Dim. C = Distance from collar of bevel pinion shaft to contact bearing outer ring.

Dim. S = Distance from plane face of bearing outer ring to plane face of bearing inner ring.



② Calculate shim ring thickness(①) by means of equation **Z = C + S**



③ Add shim ring corresponding with thickness Z.

Example :

C = 0.7 measured on housing and shaft

S = 0.08 measured on bearing

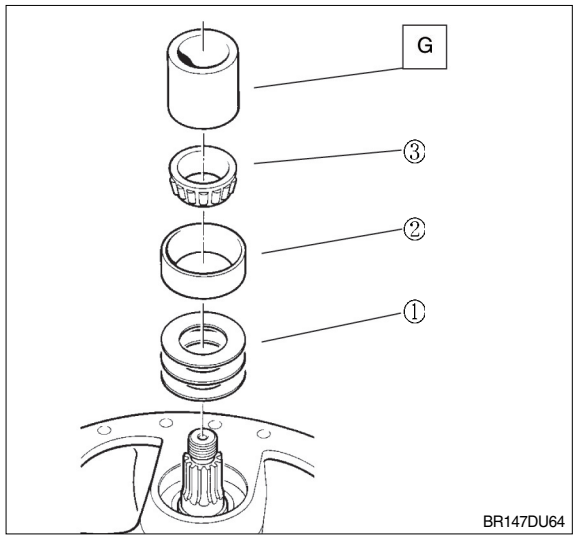
Z = 0.7 + 0.08 = 0.78mm

④ As per experience +0.02mm will be added to dimension **Z**, so that a bearing preload from 0.02 to 0.07mm is set.

Z = 0.78 + 0.02 = 0.8mm

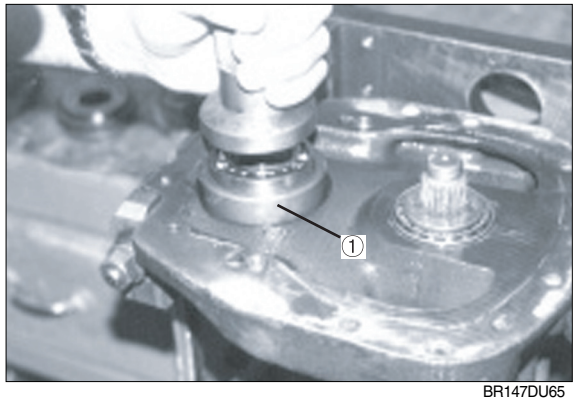
※ A bearing preload of 0.07㎜ shall be achieved.

⑤ Shim ring thickness(thickness Z) determined ①~③ has to be obtained by combining shim rings of variable thicknesses. Place shim ring(s) (①) into the bearing seat. Install bearing outer ring(②) by means of a copper mandrel and a hammer into bearing seat of the housing until contact with the shim ring. Then install by means of bush **G** the bearing inner ring(③) for the bevel pinion shaft bearing onto the bevel pinion shaft until contact.



※ Prior to helical gear installation, the grooved ball bearing must be installed into the housing seat first.

⑥ Drive grooved ball bearing(①) with assembly drift **V** into the bearing bore of the housing until contact.

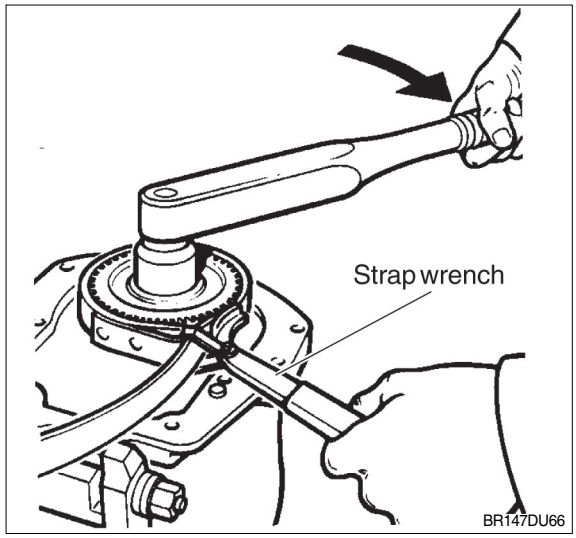


⑦ Carefully push the helical gear(①) onto the spline profile of the bevel pinion shaft and mount it until contact.

⑧ Hold helical gear with a suitable strap wrench, unscrew and tighten the hexagon nut. Do not damage helical gearing at counter-supporting.

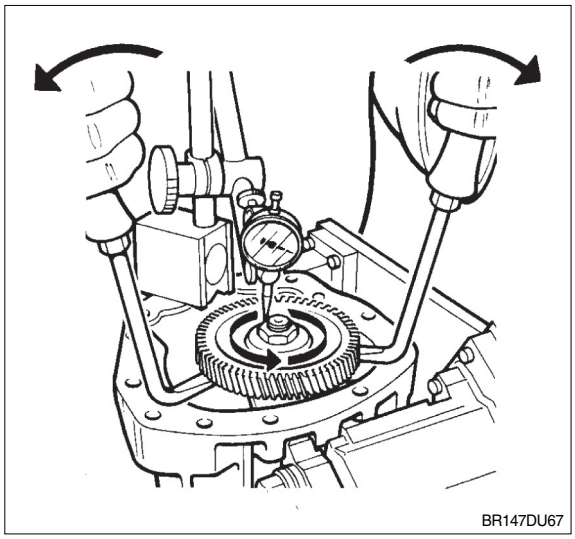
⑨ Tightening torque of the hexagon nut : 150Nm(111ft¡¤lb)

※ Use a new hexagon nut.
Peen hexagon nut after contact pattern check.



⑩ Press bevel pinion shaft down by hand and rotate it several times, so that the taper rollers in the bearing rings are aligned. Position dial gauge as shown in right figure and put the dial gauge indicator to **Zero**.
Mark position of the dial gauge on the helical gear with a colour pencil.
With both hands press bevel pinion shaft upwards and read the bearing play on the dial gauge. (as shown in right figure)
For checking no bearing play is allowed to be **measurable**.

※ This step has to be made with utmost caution and several times, in order to check the adjusted bearing preload.
A direct checking of the now adjusted bearing preload is not possible. However, the bevel pinion shaft must be rotatable by hand.

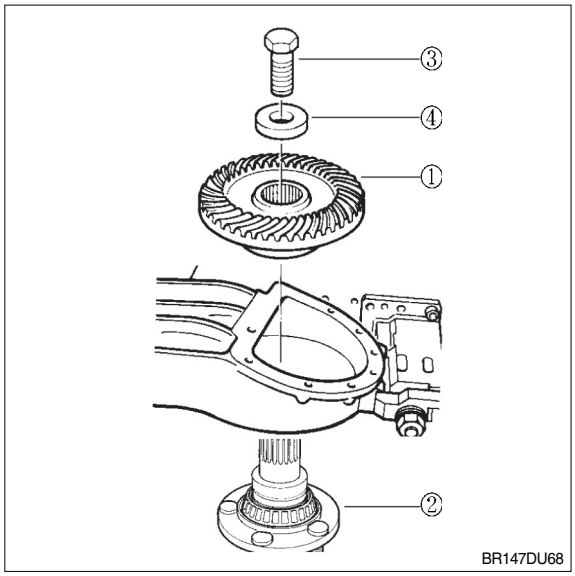

BR147DU67

Adjust bearing preload

Bearing preload : 0.02 to 0.07mm

⑪ Remove helical gear and bevel pinion shaft. Add necessary shim rings to obtain the required bearing preload and install the bevel pinion shaft as indicated in page 3-24. Apply a thin layer of **LOCTITE No.270** onto inner toothing of the helical gear(hub spline).
Install helical gear as in chapter page 3-24.

※ Remove excess LOCTITE with a cloth.



BR147DU68

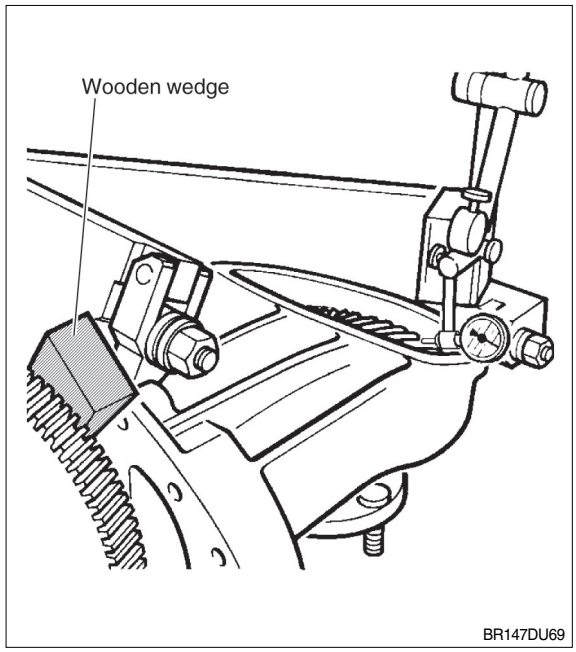
(8) MOUNT WHEEL SHAFT AND CROWN GEAR INTO THE HOUSING

※ **Radial shaft seal between the taper roller bearings has to be installed into the housing, only when bearing preload of the wheel shaft was determined.**

① Insert crown gear(①) into the housing. Cautiously install the wheel shaft(②) into the crown gear toothing. Bolt together the crown gear and the wheel shaft with hexagon bolt(③) and washer(④).

- Tightening torque of hexagon bolt : 245Nm

※ Use hexagon bolt and washer only once.



BR147DU69

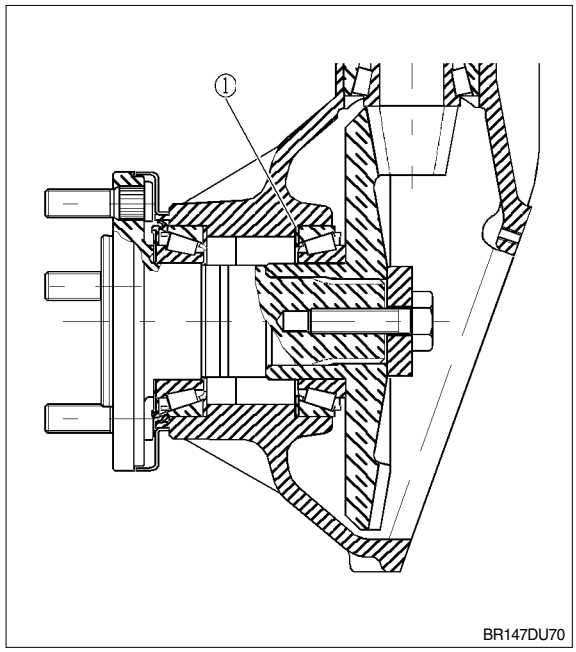
(9) MEASURE AND ADJUST TORSIONAL BACKLASH ON THE CROWN GEAR

① For measurement of the torsional backlash on the crown gear, the bevel pinion shaft has to be blocked against torsion, e.g. with a wooden wedge.
Position dial gauge with magnetic stand right-angled to a tooth flank and measure the torsional backlash rotating the wheel shaft.

- Torsional backlash 0.03~0.11㎜

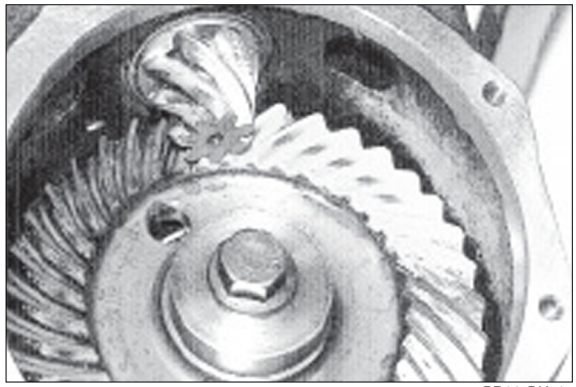
※ A mean value is to be achieved.

② Torsional backlash is corrected by adding or removing of the shim ring(s).



BR147DU70

③ Apply marking ink onto 3~4 tooth flanks of the crown gear and have it to get in mesh with the bevel pinion shaft several times.
Check contact pattern as described under next page.


BR147DU71

(10) CONTACT PATTERN CHECK

For a contact pattern check it is necessary to apply marking ink onto 3~4 tooth flanks of the crown gear. Have the ink-marked tooth flanks get into mesh with the bevel pinion several times. A better recognition of the contact pattern is possible, when the bevel pinion is braked slightly.

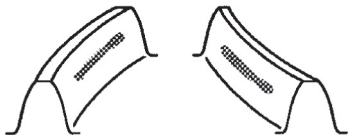
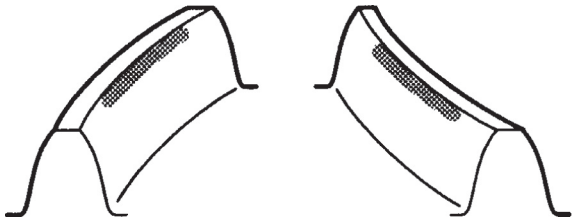
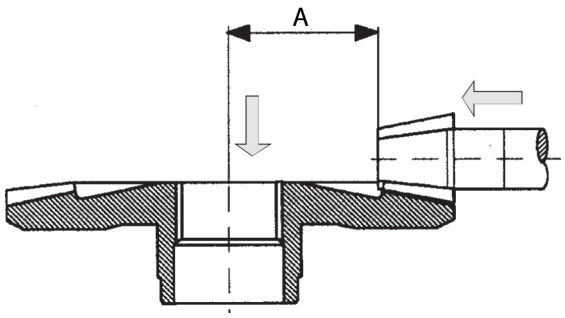
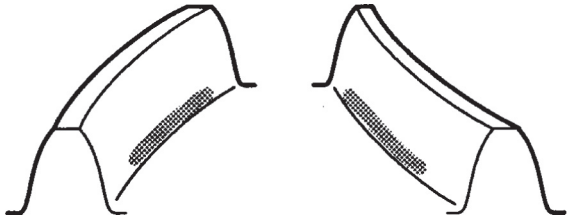
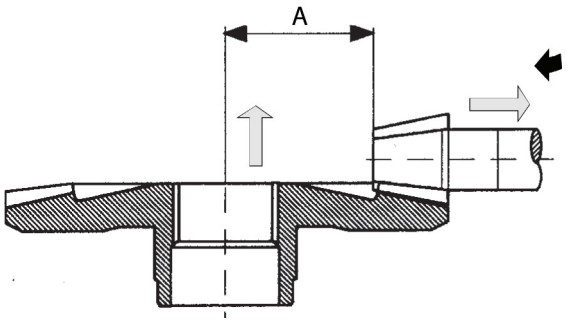
The contact patterns obtained have to be compared with the specified contact pattern as regards size and position. The specified contact patterns are indicated in below diagram.

Insignificant deviations of the ideal shape are possible and permissible. These deviations are firstly due to the varying contact pressures during contact pattern checking.

If there are considerable deviations it has to be checked if the installation dimensions were correctly kept. As a rule wrong installation dimensions are the cause for wrong contact patterns.

Only when at a repeated checking of the installation dimensions no correct contact patterns are obtainable, the position of the contact pattern should be corrected according to the diagram as shown below.

Installation specifications

<table>
<tr><td colspan="2">Correct contact pattery Concave flank  Concave flank</td></tr>
<tr><td>Tooth contact on crown gear false contact patterns</td><td>Correct contact pattern adjustment by changing of the installation dimension in direction of the arrow</td></tr>
<tr><td>① Contact on tip  </td><td>  </td></tr>
<tr><td>② Contact on root  </td><td>  </td></tr>
</table>

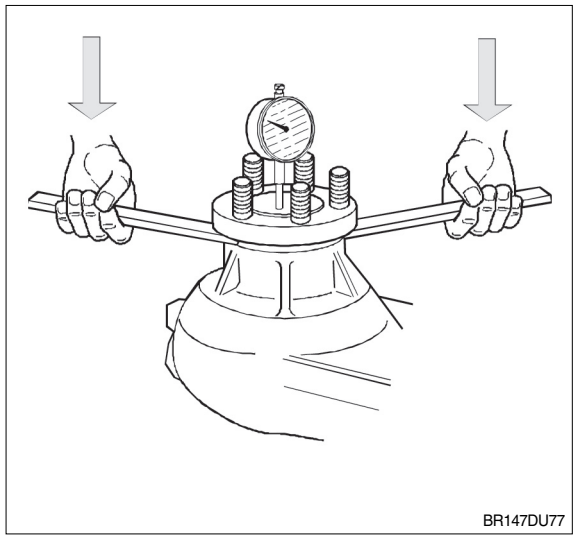
Setting specifications :

On principle all gear sets have to be mounted in accordance with the installation dimension(A).

Only in case of incorrect contact patterns the installation dimension(A) has to be changed.

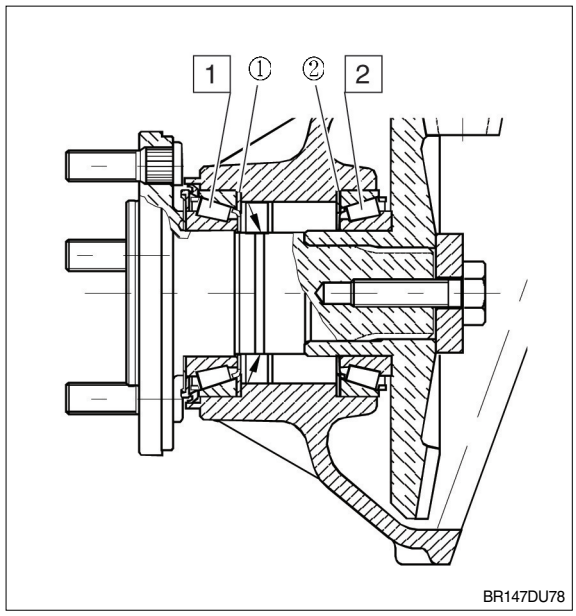
The extent of a change depends on the position of the contact patterns.

(11) MEASURE BEARING PLAY ON WHEEL SHAFT AND ADJUST BEARING PRELOAD


BR147DU77

① Press wheel shaft down by hand and rotate it several times, so that the taper rollers in the bearing rings are aligned.
Position dial gauge as shown in right figure and put the dial gauge indicator to **Zero**. Mark position of the dial gauge on the wheel shaft with a colour pencil.
With two levers(robust assembly levers) press wheel shaft upwards and read the bearing play on the dial gauge.

※ By using shim rings a minimum bearing play of approx. 0.02mm shall be achieved. Only then the final preload is to be adjusted.



BR147DU78

② Remove wheel shaft, by means of a copper mandrel and a hammer drive taper bearing outer ring out of the housing. (also see page 3-25)
Determine shim ring thickness(①) and install with shim ring into bearing seat of housing until contact.

Required bearing preload : 0.05 to 0.10mm

※ It is not possible to check the bearing preload adjusted now. At a check no bearing play is allowed to be measurable. However the wheel shaft must be rotatable by hand.

※ After setting of the bearing preload check the torsional backlash once more.
If the bearing friction torque(see page 3-38) or the torsional backlash are beyond the requested values a new adjustment is required. The final value has to be obtained by adding or removing of shim rings.

※ If for correction of the torsional backlash shim rings(②) are removed or added at bearing point , those have to be added or removed from the shim ring pack(①) at bearing point .

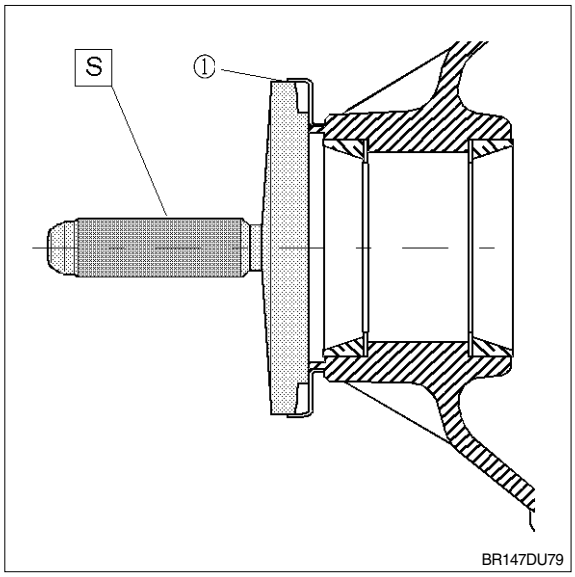
③ After correct adjustment of the bearing preload and the torsional backlash the wheel shaft has to be removed once again in order to install the thread protective shield and the radial shaft seal. Please observe sections (12) and (13).

(12) INSTALL THREAD PROTETIVE SHIELD(GAMMA RING)

① Spray seat for thread protective shield with LOCTITE fast cleaner. Have fast cleaner work and thoroughly remove the dissolved dirt with a clean cloth.
Spray surface again and have it dried.

⚠ Hazardous when breathed or swallowed. Avoid contact with eyes or skin. Do not spray near open flame and glowing parts.

② Apply LOCTITE No.270 onto seat for the thread protective shield on the housing and press on the thread protective shield(①) by means of assembly drift **S** until contact.



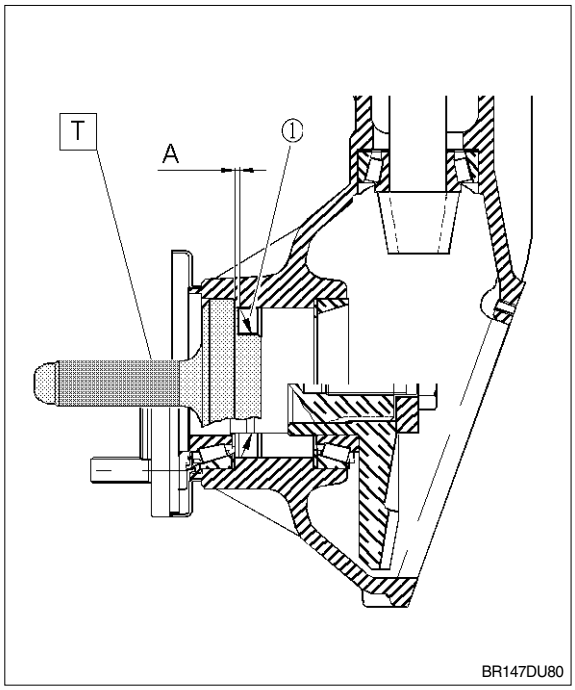
(13) INSTALL RADIAL SHAFT SEAL INTO THE HOUSING

① Remove wheel shaft and crown gear(also see page 3-24). Drive out taper roller bearing outer ring from the housing. Provide outer diameter of radial shaft seal(①) with a thin layer of LOCTITE No. 574 and install it by means of assembly drift **T** into the housing.

¤Ł Observe installation dimension A : GK25 LD $3.0^{+0.5}$mm

③ Apply a thin layer of LOCTITE No. 270 onto surface of inner toothing(hub spline)of the crown gear(①).

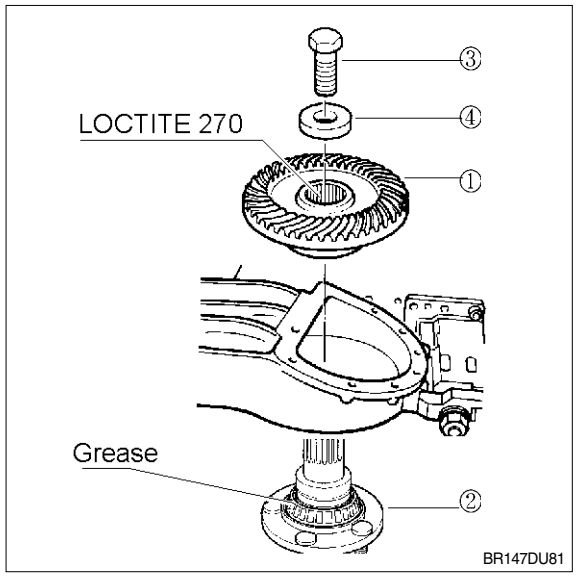
※ Apply LOCTITE only to the inner toothing of the crown gear.



④ Fill sealing ring and taper roller bearings on the wheel shaft(②) with SHELL Alvania R3 grease. Cautiously install wheel shaft(②) into the crown gear toothing.

※ Remove excess LOCTITE with a clean cloth.

⑤ Bolt together the crown gear and the wheel shaft with hexagon bolt(③) and washer(④).
Bolt 2 wheel nuts onto the wheel bolts and lock wheel shaft with a lever.
· Tightening torque : 245Nm

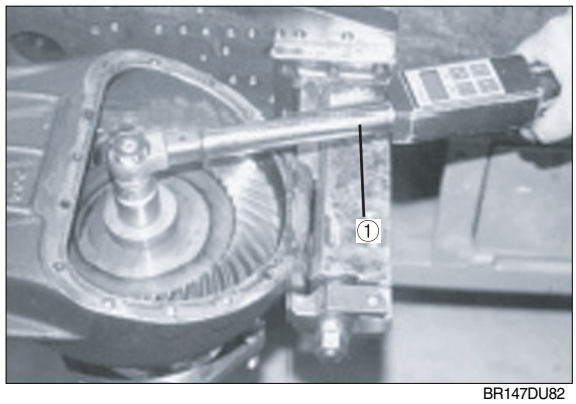


BR147DU81

Check bearing friction torque

⑥ Rotate wheel shaft several times in order to have aligned the taper rollers in the bearing rings. No bearing play must be measurable during the check.
However, the wheel shaft must be rotatable by hand. The bearing preload described in section(11) is correctly adjusted when a bearing friction torque of 9~12Nm is reached.
Use an electronic torque spanner(①) to check the bearing friction torque.

※ If the bearing friction torque is beyond the requested values, a new adjust-ment is required. [see section(11)]



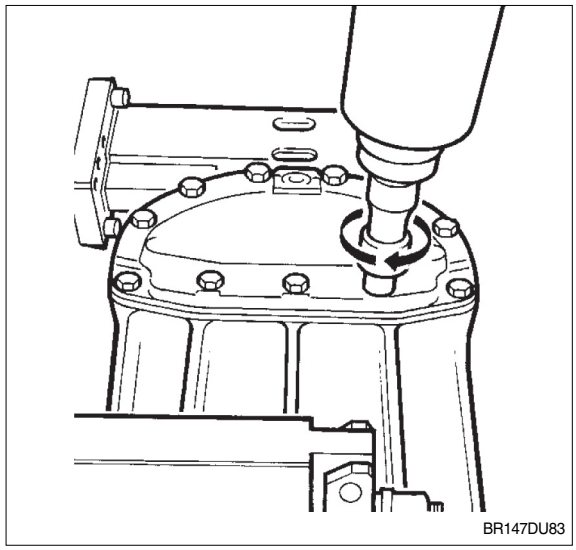
BR147DU82

(14) INSTALL HOUSING COVER

① Apply a thin layer of LOCTITE sealing compound No.574 onto plane face of the housing. Apply one drop each of LOCTITE 243 onto threads of the hexagon bolts(②).

※ If tapped holes are drilled through the housing, the hexagon bolts must be sealed completely with LOCTITE.

② Fasten housing cover(①) with hexagon bolts(②) onto the housing.
· Tightening torque : 9.5Nm


BR147DU83

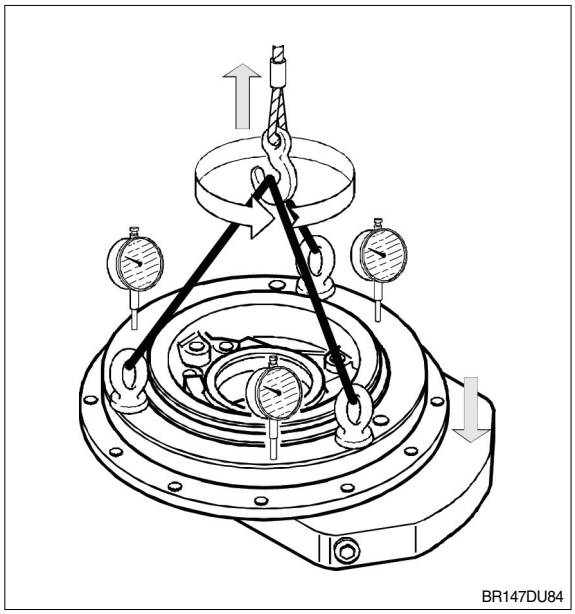
(15) CHECK PIVOTING BEARING(HOUSING TOP SECTION)

① The housing top section has to be replaced, if :

- The peened cover disc on the pivoting bearing has loosened.
- The pivoting bearing is difficult to rotate or sticking.
- The cage segments or balls are damaged.
- The maximum bearing play is exceeded.

※ The housing top section can only replaced completely.

※ Checking of housing top section :
Clamp the housing top section onto the assembly table. Screw 3 eye bolts into the outer ring of the pivoting bearing. Have the pivoting bearing rotated several times.



② Position three dial gauges onto the pivoting bearing and put the dial gauge indicator to **Zero**.
Mark position of the dial gauge on the pivoting bearing with a colour pencil.
Pull with approx. 50kg at the pivoting bearing by means of a medium pillar swivel crane and a spring balance.
Have the pivoting bearing rotated several times and put it back to the marking.

- Max. bearing play of pivoting bearing : 0.03㎜

Install breather valve

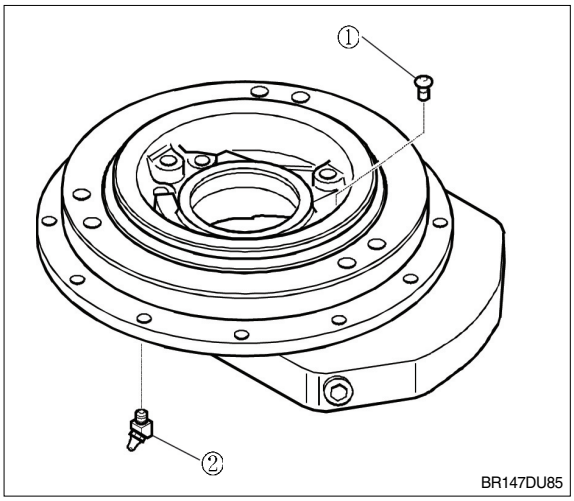
③ Drive breather valve(①) by means of press-in mandrel **U** carefully into the housing top section.

※ Take care for mounting that the cap of the breather valve can still move freely.

Install hydraulic-type lubricating nipple

④ Screw in hydraulic-type lubricating nipple(②) with an open-jaw spanner into the housing top section until contact.

· Tightening torque : 10Nm



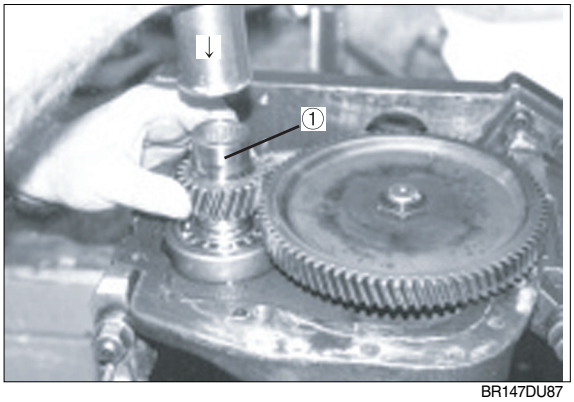
BR147DU85

(16) INSTALL INPUT INTO THE HOUSING TOP SECTION

① Cautiously install the input pinion(①) through the helical gearing.

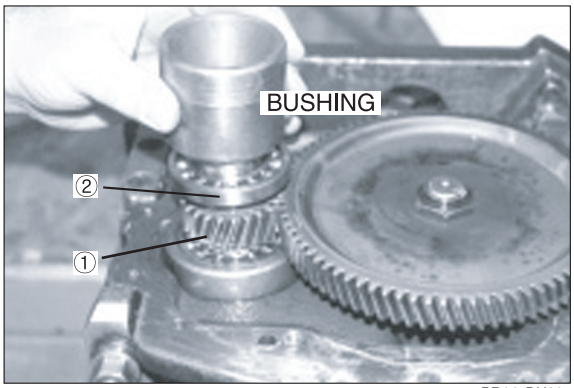
※ **Do not damage toothing of input pinion and helical gear. Damage might cause louder running noises.**

② By means of a copper mandrel cautiously install the input pinion(①) into the bearing bore or onto the bearing seat until contact.



BR147DU87

③ Install the grooved ball bearing(②) with a suitable bush onto the bearing seat of the input pinion until contact.

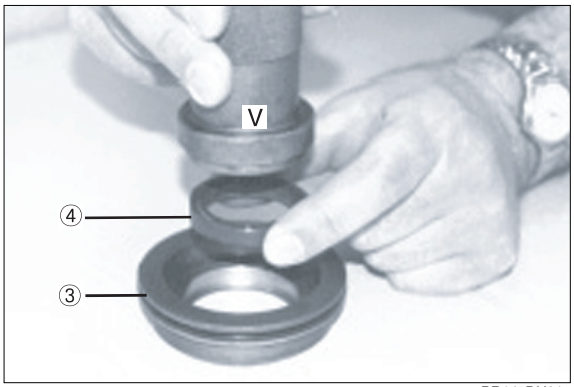


BR147DU86

④ Preassemble cover(③) as follows :

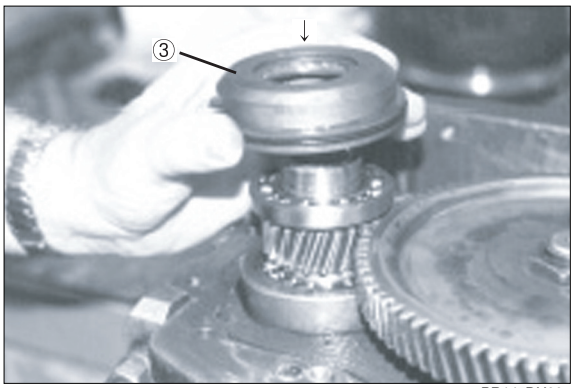
· Install radial shaft seal(④) by means of an assembly drift **V** with the correct side until contact.

※ Do not damage sealing lip of the shaft seal. Apply a thin layer of grease onto the sealing lip.



BR147DU91

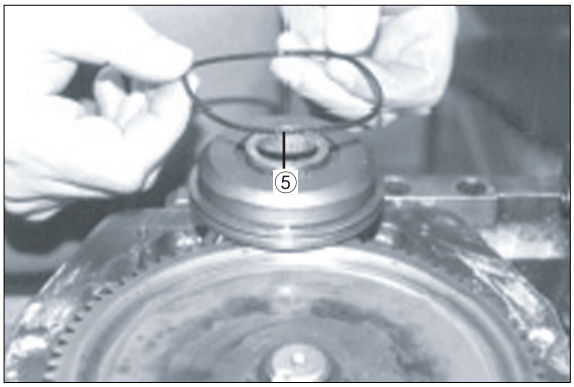
⑤ Cautiously put cover(③, with radial shaft seal preassembled) onto the pinion shaft and install it. By means of a plastic hammer mount cover until contact.



BR147DU90

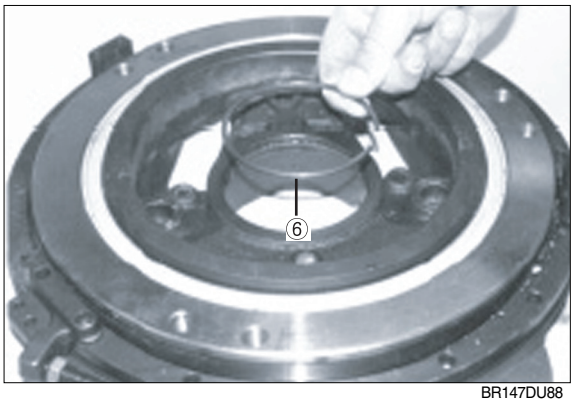
⑥ Insert O-ring(⑤) into slot of the cover.

※ Use new O-ring for installation.
Slightly wet O-ring with gear oil.



BR147DU89

⑦ Insert and snap in circlip(⑥) into bore hole of the housing top section.



BR147DU88

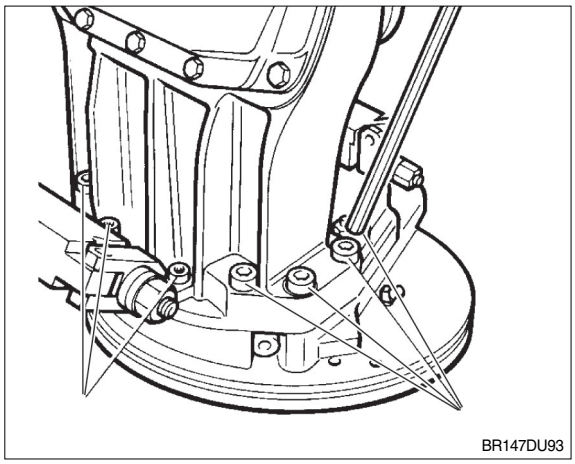
Install housing top section

⑧ Provide sealing surface of the housing with a thin layer of LOCTITE 574.

※ Plane faces of the housing and the housing top section have to be cleaned carefully before with LOCTITE fast cleaner and must be free of grease.

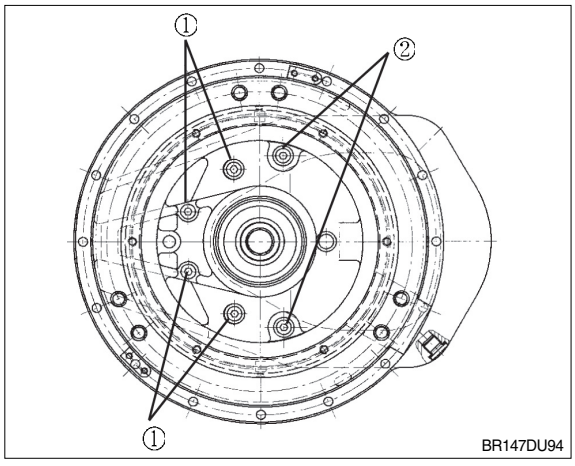
BR147DU92

⑨ Place housing top section onto the housing, so that the cylinderical pins in the transmission housing are positioned in the fitting bores of the top section.

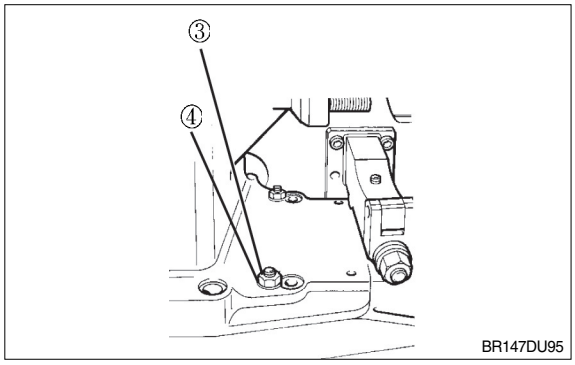


BR147DU93

⑩ Screw in the socket head bolts(①) at the bottom side of the housing as well as inside the housing top section and tighten them uniformly.
In addition also the 2 socket head bolts(②), hexagon nuts(③) and washers (④).



BR147DU94

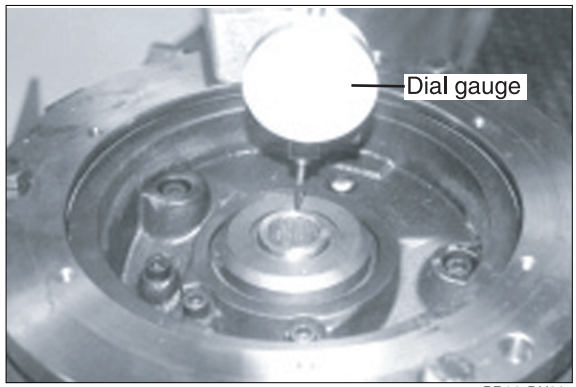


BR147DU95

Check axial play of the input in housing top section

⑪ Have wheel shaft rotated several times.
For measurement of the axial play of the input, a dial gauge with a magnetic stand is to be positioned right-angled onto the plane face of the input pinion and the dial indicator must be put to **Zero**.
Mark position of the dial gauge on the plane face with a colour pencil.
With both hands press input pinion upwards and downwards. Read the axial bearing play on the dial gauge.

※ Axial play of grooved ball bearing 0.1~0.4㎜. When checking a bearing play has to be measurable.



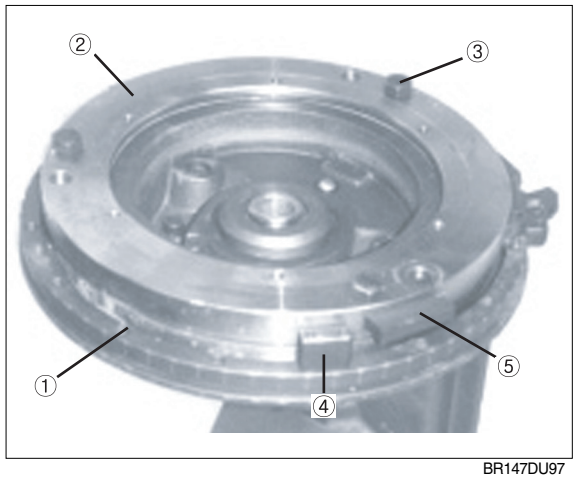
BR147DU96

⑫ Place centering ring(②) for motor fixing onto the pivoting bearing(①) and bolt it with the pivoting bearing. (Also observe instructions in the manual "Operating instructions for helical bevel gear GK 25LD".)

※ **Ovserve min. screw-in depth of the 6 fixing bolts(③).**

⑬ Steering lock is installed as follows :
- Screw two final stops(④) onto the chain tread.
- Place lock plate(⑤) into the groove in the centering ring and connect it with the pivoting bearing by means of screws.

※ For assembly please observe the specified mounting position of the steering lock in the relating installation drawing.



BR147DU97

(17) RELUBRICATION OF PIVOTING BEARING

① Under normal operating conditions the pivoting bearing has to be relubricated once a year. After cleaning with a steam jet device or similar, the pivoting bearing has to be relubricated.

② For the operation in a heavily dust-loaded or humid environment(e.g. cold store application) the pivoting bearing has to be relubricated 2x per month at least.

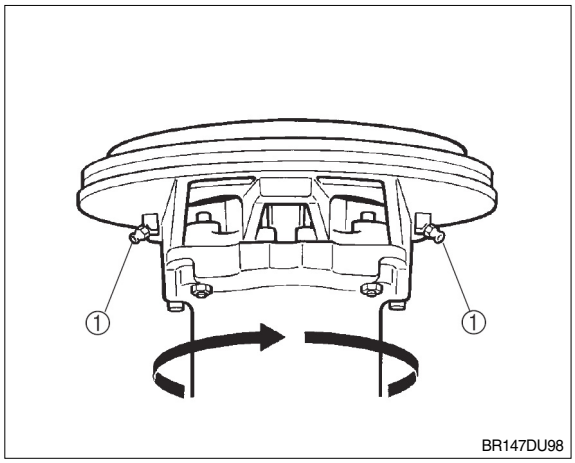
③ We recommend a grease of the quality SHELL Alvania R3 or grease of an equal composition and an equal specification.

Procedure :

- The pivoting bearing has two grease nipples(①).
- Over the two grease nipples press in the grease with a grease gun into the pivoting bearing.
  Drive unit has to be turned slowly.

※ Required grease volume for dry pivoting bearing approx. 55g.

- Rotate drive unit several times, so that the grease distributes completely.
- Remove the grease pressed out of the pivoting bearing with a cloth.

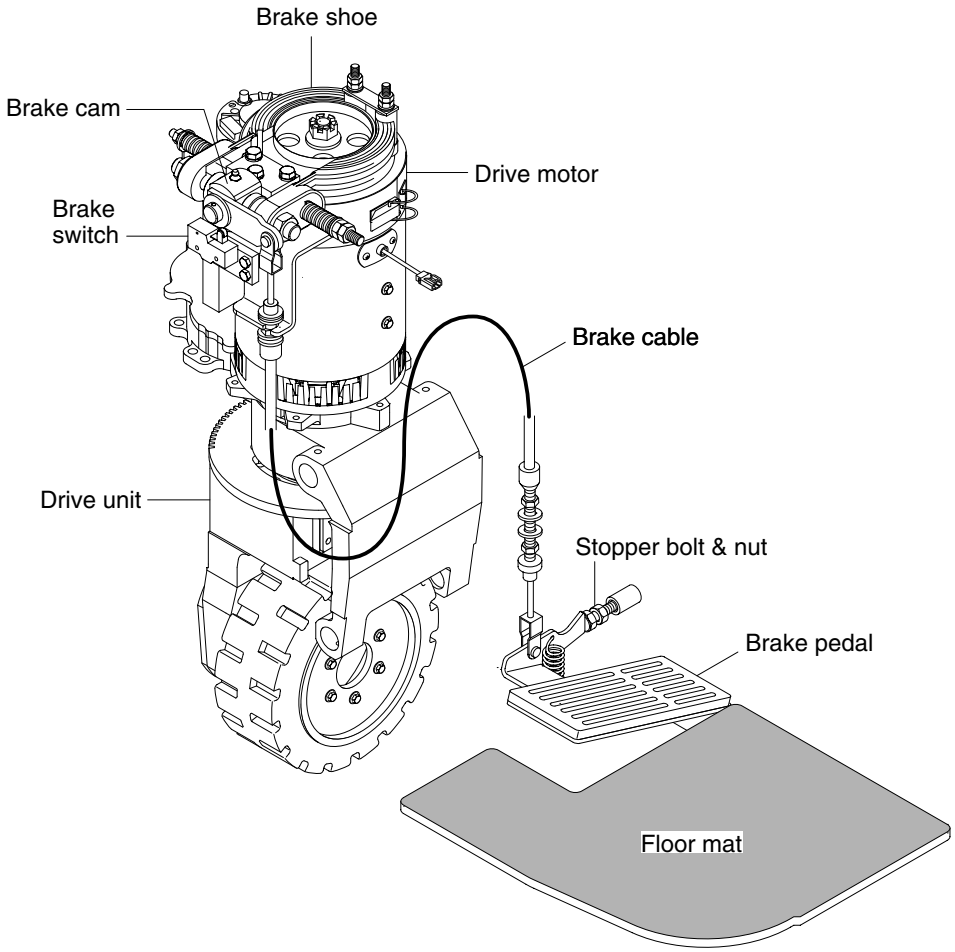


SECTION 4 BRAKE SYSTEM

SECTION 4 BRAKE SYSTEM

GROUP 1 STRUCTURE AND FUNCTION

1. OUTLINE



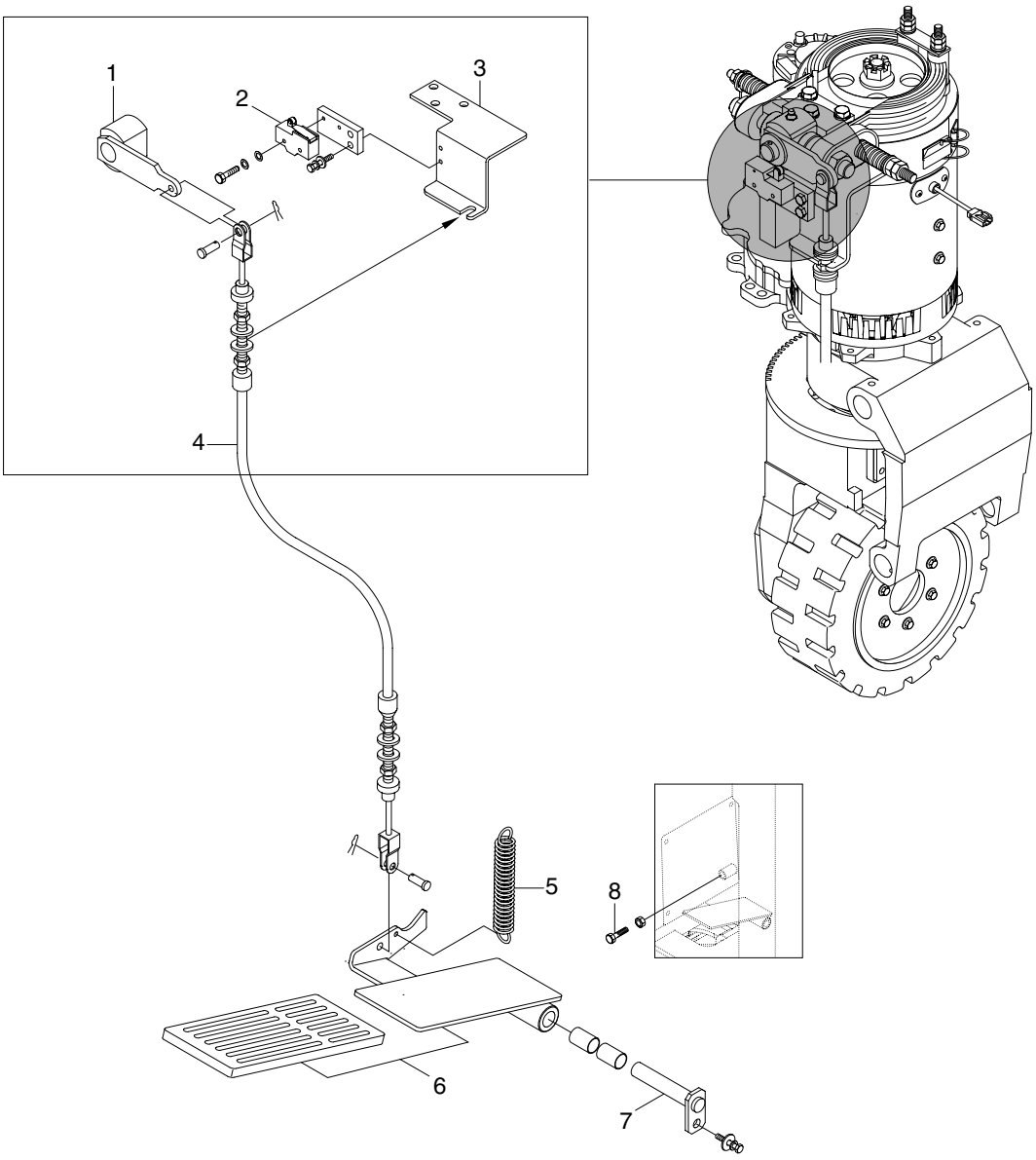
BR147BS01

2. SPECIFICATION

Item		HBR14/15/18-7	HBR20/25-7
Type		Center brake	←
Brake shoe	Material	Rubber mould	←
	W×L×T	40×110×5mm(1.6×4.3×0.2in)	40×140×5mm(1.8×5.5×0.2in)
	Area	44cm²(6.8in²)	63cm²(9.8in²)
Brake drum diameter	New	120mm(4.7in)	140mm(5.5in)
	Repair limit	117mm(4.6in)	133mm(5.2in)
Brake pedal play		10~15mm(0.4~0.6in)	←
Braking distance	Unloaded	Less than 5.0m(197in)	←
	Loaded	Less than 2.0m(79in)	←

3. BRAKE PEDAL AND PIPING

1) STRUCTURE



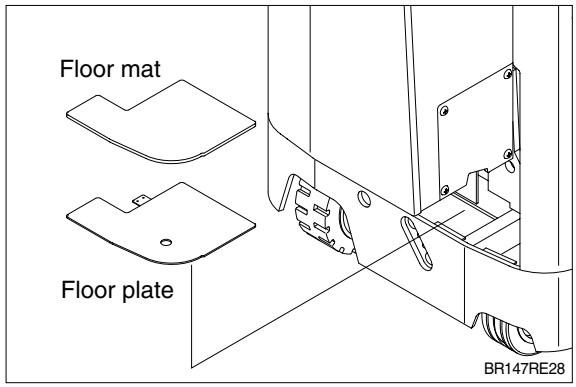
BR147BS02

1	Brake cam	5	Spring
2	Brake switch	6	Brake pedal
3	Bracket	7	Pin
4	Brake cable	8	Stopper bolt

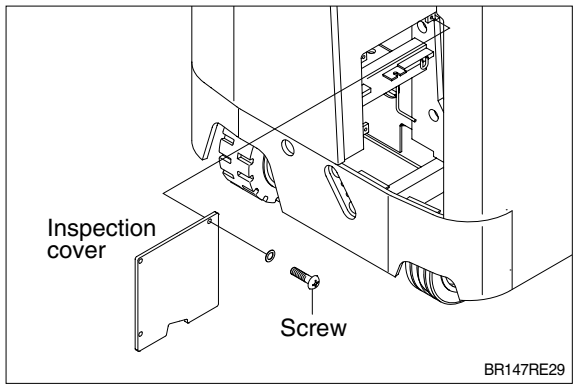
2) DISASSEMBLY AND ASSEMBLY

(1) Disassembly

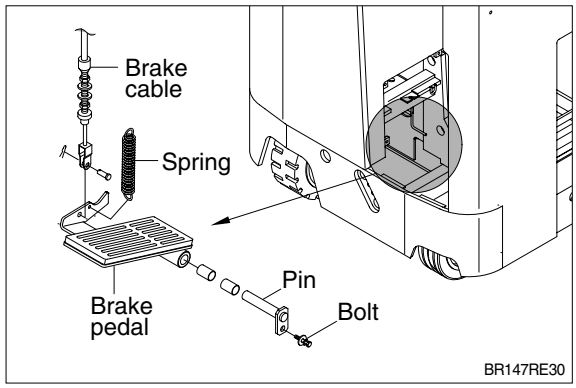
① Remove floor mat and floor plate.



② Remove inspection cover



③ Remove bolt, pin, spring and brake cable to remove brake pedal assembly.

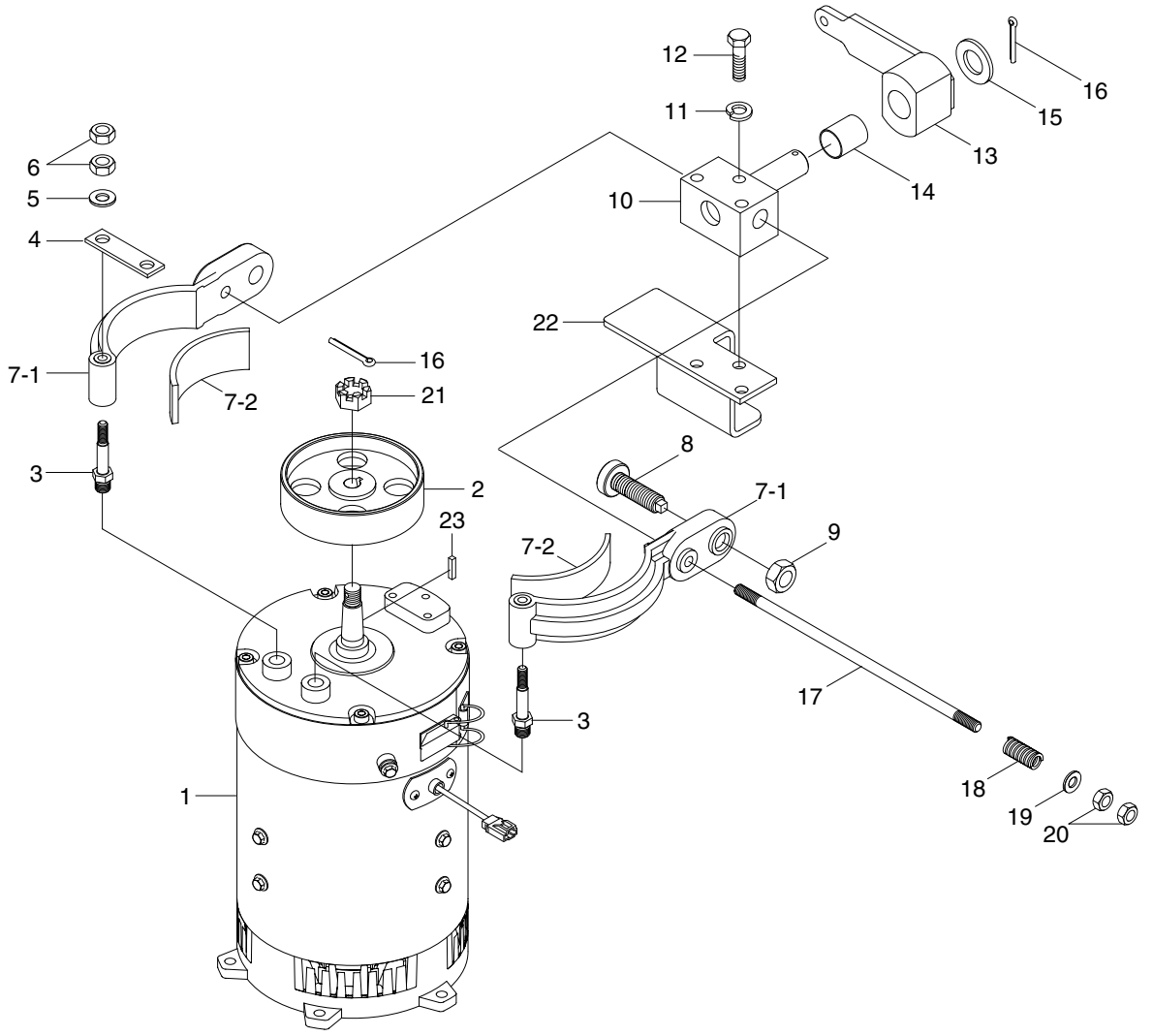


(2) Assembly

Perform disassembly in reverse order.

4. BRAKE SYSTEM

1) STRUCTURE



DRIVE MOTOR

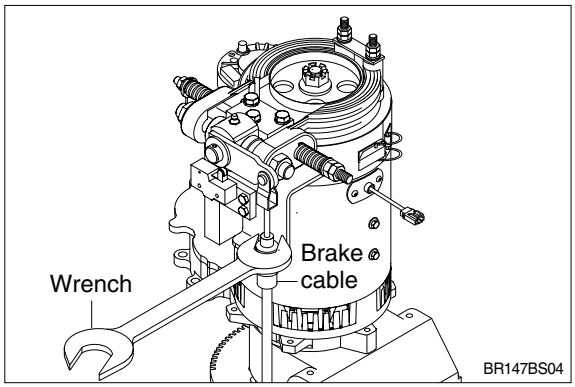
BR147BS03

1	Drive motor	8	Cam bolt	17	Brake rod
2	Brake drum	9	Hexagon nut	18	Spring
3	Brake shoe pin	10	Bracket	19	Plain washer
4	Lock plate	11	Spring washer	20	Hexagon nut
5	Plain washer	12	Hexagon bolt	21	Low castle nut
6	Hexagon nut	13	Brake cam	22	Cable bracket
7	Brake shoe & lining	14	DU bushing	23	Key
7-1	Brake shoe	15	Plain washer		
7-2	Brake lining	16	Split pin		

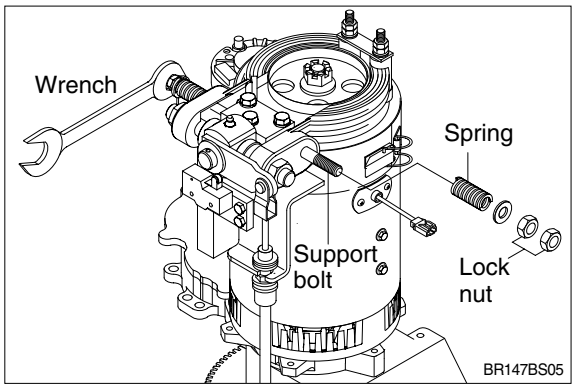
2) DISASSEMBLY AND ASSEMBLY

(1) Disassembly

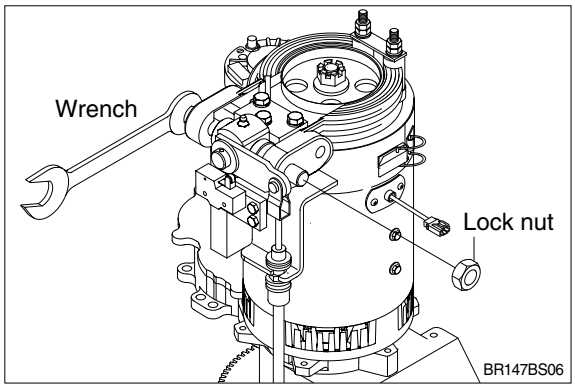
① Remove the brake cable from brake cam.



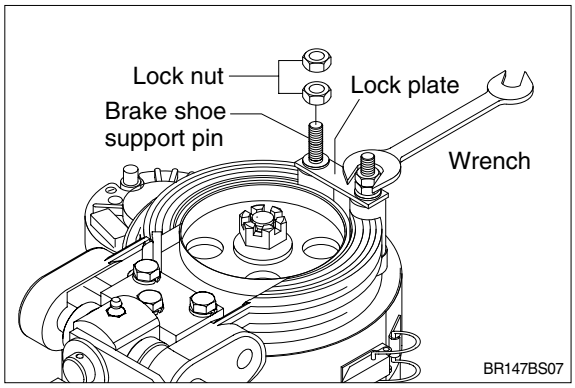
② Remove spring and support bolts after removing lock nut of brake spring.



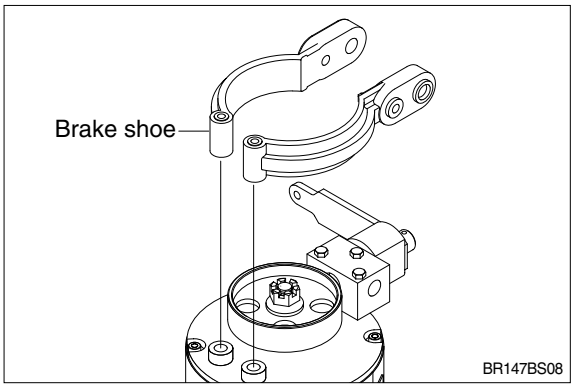
③ Remove lock nut for adjusting bolt.



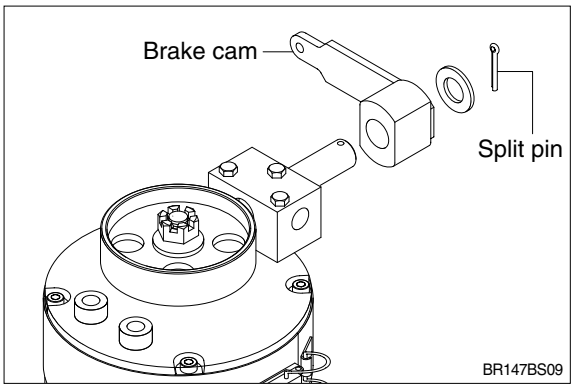
④ Remove lock nut of brake shoe support pin and take lock plate of shaft.



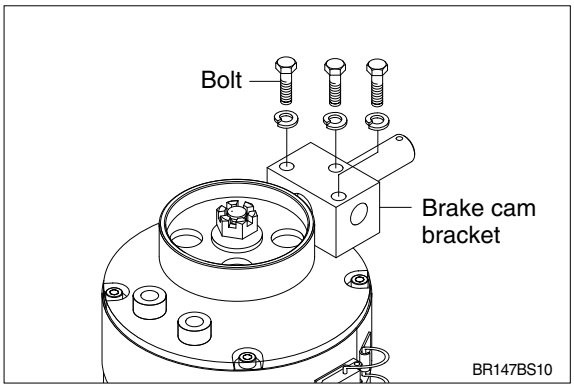
⑤ Take off brake shoe lifting up straightly.



⑥ Remove the split pin from the bracket of cam and remove the cam.

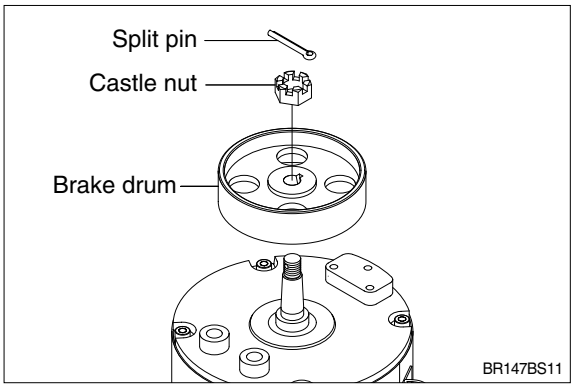


⑦ Remove 3 bolts attached on bracket and take off brake cam bracket.



⑧ Remove the split pin from brake drum mounting bolt and remove the nut.

⑨ Remove brake drum from motor shaft.



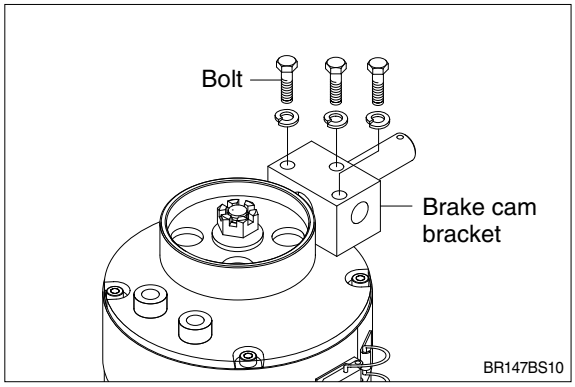
(2) Assembly

Assembly is in the reverse order to disassembly but be careful of following points.

① Brake cam bracket mounting bolts.

· Tightening torque : 1.6~1.9kgf · m
(12~14lbf · ft)

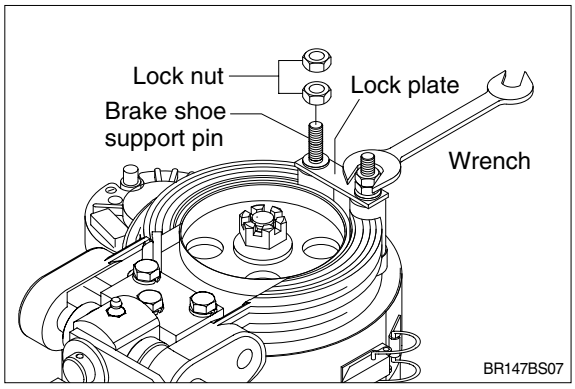
※ Apply loctite #277



② Brake shoe support pin mounting.

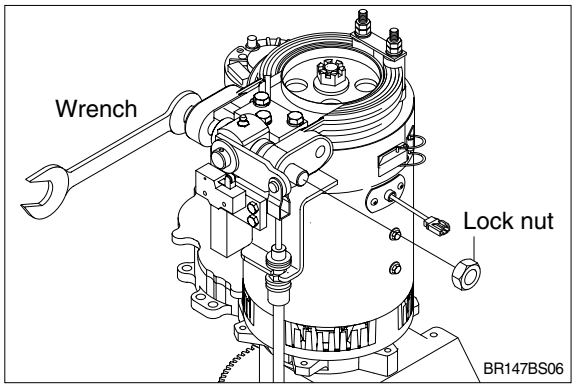
· Tightening torque : 14.6~16kgf · m
(106~116lbf · ft)

※ Apply loctite #277



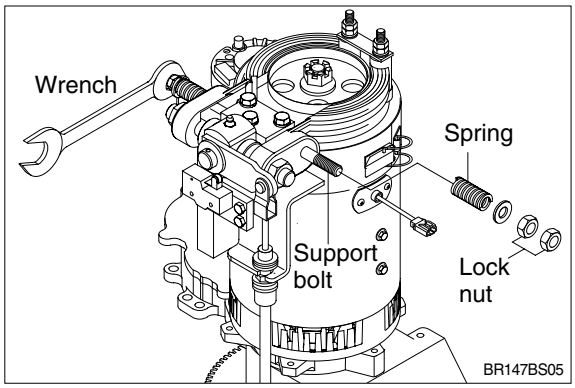
③ Adjusting bolt lock nuts.

· Tightening torque : 11.4~12.6kgf · m
(82~91lbf · ft)



④ Support bolts lock nuts.

· Tightening torque : 2.3~2.8kgf · m
(16.6~20.3lbf · ft)



5. INSPECTION

1) Lining inspection

(1) Contact normally?
(2) Any injuries?
(3) Any one sided contact?
(4) Service limit : 1.5mm(0.059")

※ Lining should be replaced together with brake shoe.

2) Brake drum inspection

(1) Any damage or wear?
If so, plane the drum for revising.
(2) Drum die should not exceed ; under 3㎜(0.012")

3) Spring inspection

(1) Are the springs weakened or damaged?

GROUP 2 OPERATIONAL CHECKS AND TROUBLESHOOTING

1. OPERATIONAL CHECKS

1) BRAKE PEDAL OPERATION

(1) Once the pedal released, the machine must remain stopped.
(2) Check the free play of pedal is 10~15㎜(0.4~0.6in).
(3) Check the pedal height is 58~63㎜(2.3~2.5in).

2) BRAKE SYSTEM OPERATION

(1) Check the operation of brake cam.
(2) Measure lining at point with most wear, and check that lining thickness is at least 2.0㎜(0.08in).
(3) Measure inside diameter of drum and check that it is within the specification limit. (see 4-1 table)

3) BRAKING FORCE

(1) Select a dry, flat, paved surface and drive truck at maximum speed when signal is given, stop truck immediately and measure distance from point where signal was given to point where truck stopped. (Unloaded)
 · Stopping distance : Within 5m(16' 5")
(2) Check that there is no pulling of steering wheel, pulling by brakes to one side or abnormal noise when making emergency stops.

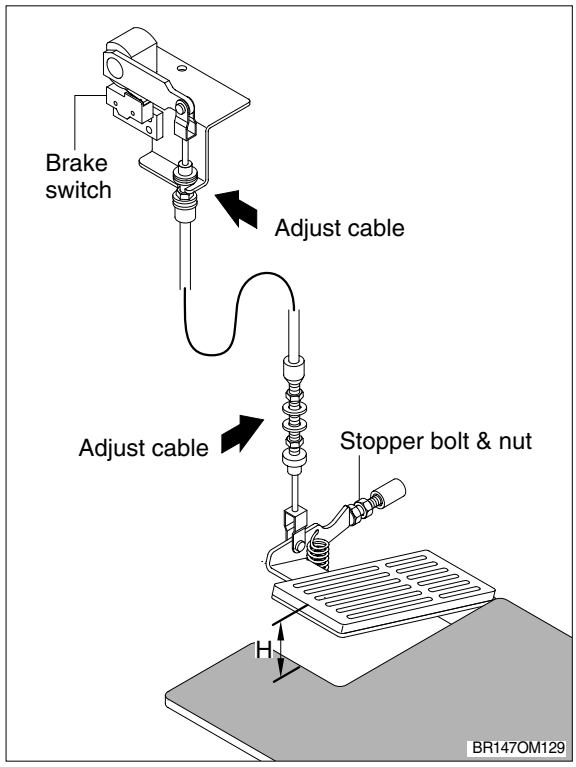
2. TROUBLESHOOTING

Problem	Cause	Remedy
Brake drags	· Brake spring out of adjustment. · Brake spring broken. · Brake drum worn or rusted. · Brake switch defective. · Brake pedal play excessive. · Brake lining insufficient contact. · Motor shaft key broken. · Motor shaft damage.	· Check and adjust. · Replace. · Check, and replace if defective. · Check, and replace if defective. · Adjust brake pedal play. · Adjust and replace if defective. · Replace. · Replace.
Poor braking effect	· Brake spring out of adjustment. · Brake spring broken or deteriorated. · Brake pedal play excessive. · Faulty return due to rusting of parts. · Brake shoes worn.	· Check and adjust. · Replace. · Adjust brake pedal play. · Disassemble and clean or replace. · Replace.
Brake squeaks	· Brake shoe glazed or dirty, brake shoe worn, brake dust accumlation. · Brake drum warped or scored. · Defective adhesion between brake shoe and lining.	· Replace brake shoe, clean brake drum circumference. · Repair or replace. · Replace.
Brake shoe not releasing	· Heavy tightening of stopper. · Wheel cylinder damaged. · Master cylinder damaged.	· Adjust. · Check for oil leakage, volume, air mixing, and repair if defective. Replace wheel cylinder if defective. · Check connection between master cylinder and pedal, and replace master cylinder if defective.

GROUP 3 TEST AND ADJUSTMENT

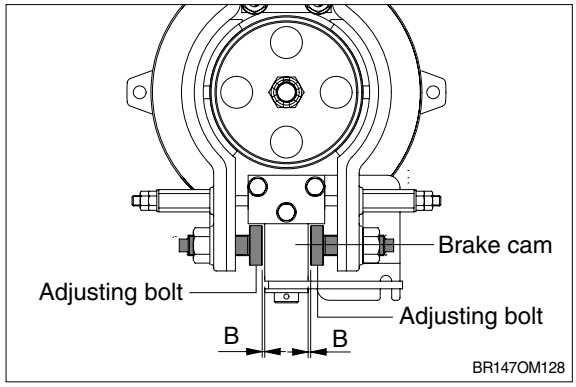
1. BRAKE PEDAL AND CABLE

1) Check the pedal height and adjust the stopper bolt if the height is too high or too low.
   · H : 58~63mm(2.3~2.5in)
2) After adjusting the pedal height set vertically the brake cam and set the brake cable. Tighten nut for brake cable.
3) Check the brake switch to be operating condition while the pedal is depressed.



2. BRAKE SYSTEM

1) Check the gap between brake cam and adjusting bolt.
   · B : 1.5~2.0mm(0.06~0.08in)
   If the gap is too long and short adjust the adjusting bolt.
   · Adjust bolt tightening torque
   11.4~12.6kgf · m(82.5~91.1lbf · ft)
2) Check the brake lining wear or any damage. If brake lining is contacted any one side or lining thickness is under 1.5mm, brake lining and shoe assy should be replaced together.

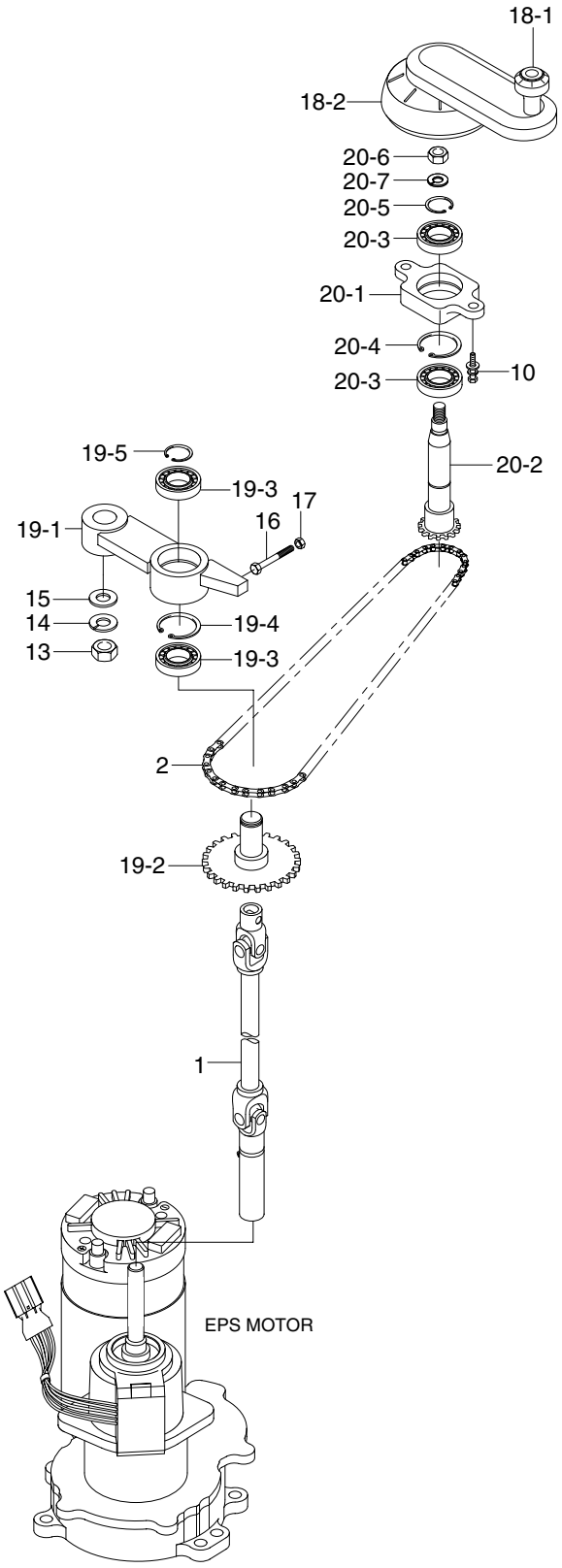


SECTION 5 STEERING SYSTEM

SECTION 5 STEERING SYSTEM

GROUP 1 STRUCTURE AND FUNCTION

1. OUTLINE



1	U-joint assy
1-1	Straight pin
1-2	Snap ring
2	Roller chain
10	Hexagon bolt
13	Hexagon nut
14	Spring washer
15	Plain washer
16	Bolt
17	Hexagon nut
18-1	Steering wheel
18-2	Steering wheel knob
19-1	Steering bracket
19-2	Sprocket assy
19-3	Ball bearing
19-4	Retaining ring
19-5	Retaining ring
20-1	Steering wheel bracket
20-2	Steering wheel shaft
20-3	Ball bearing
20-4	Retaining ring
20-5	Retaining ring
20-6	Hexagon nut
20-7	Spring washer

BR147SE03

2. SPECIFICATIONS AND SERVICE STANDARD

Type		1st stage	Chain
		2st stage	Gear
Steering wheel diameter (mm)		ø 268	
Steering wheel free play (mm)		25~50	
Steering chain slack (mm)		3~5	
Steering angle	Right turn	79°	
	Left turn	101°	
Minimum turning radius (mm)	HBR 14	1550	
	HBR 15	1640	
	HBR 18	1775	
	HBR 20	1795	
	HBR 25	1985	

3. TROUBLE SHOOTING

Problem		Cause	Remedy
Heavy steering	At traveling	· Damage of bearing at steering pinion	· Replace bearing
		· Damage of bearing of steering shaft of drive unit	· Replace bearing
		· Lack of grease of bearing	· Lubricate grease
	At releasing joint at spline	· Damage of bearing in steering racket	· Replace bearing
		· Over tension of roller chain	· Adjust the tension
Steering play is large (STD : 25~50mm)		· Looseness of roller chain	· Ajust the tension
		· Extention of roller chain	· Adjust the tension or replace the chain
		· Looseness of rubber coupling is large	· Replace coupling
		· Looseness of spline and joint is large	· Replace
		· Backlash of steering pinion and gear is large	· Replace
Steering wheel is robbed in one way during traveling		· Eccentric wear of tire	· Replace
		· Transformation of drive unit-rear axle	· Repair or replace
		· Transformation of frame	· Repair or replace

GROUP 2 DISASSEMBLY AND ASSEMBLY

1. TOOL

1) Standard tool

2) Universal puller

3) Vernier caliper

2. DISASSEMBLY

1) Remove the cap of steering wheel(18-2) and remove the hexagon nut(20-6) by means of box spanner.

2) Remove the steering wheel(18-2).

3) Loosen the nut(13) fixing the steering bracket(19-1).
   · Tightening torque(13) : 16±2kgf · m
   (116±4.5lbf · ft)

4) Loosen the bolt(16) that extends chain.

5) Remove the bolt(10) fixing the steering wheel bracket(20-1).
   · Tightening torque(10) : 7±0.7kgf · m
   (50.6±5.1lbf · ft)

6) Lift up the cover straighting up and remove the cover.

7) Remove the steering wheel bracket(20-1).

8) Take off the steering wheel shaft(20-2) after removing the snap ring(20-5).

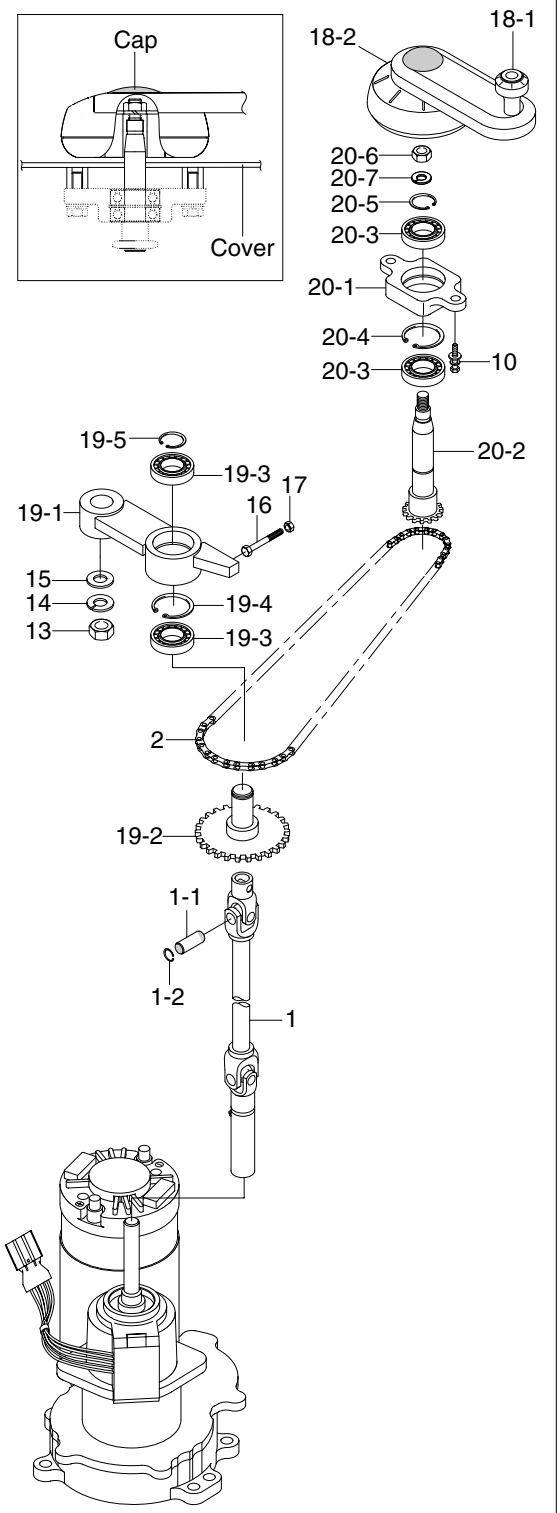
9) Remove the steering bracket(19-1).

10) Take off the sprocket assy(19-2) after removing the snap ring(19-5, 1-2) and straight pin(1-1).

11) Remove the U-joint assy(1).

3. ASSEMBLY

Perform the disassembly in reverse order.



4. INSPECTION

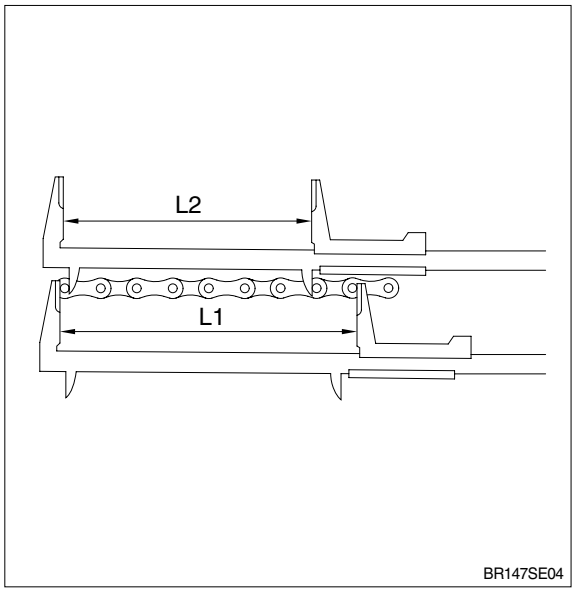
1) Inspect the steering chain for extension, cracks and damage and replace if defective.

$$L = \frac{L1 + L2}{2}$$

Standard : L = 76.20mm(3.00in)
Limit : L = 77.34mm(3.04in)

2) Inspect the sprockets assy and steering wheel shaft for cracks and damage, and replace if defective.

3) Inspect the rubber coupling for cracks and the universal joint for faulty operation, and replace if defective.



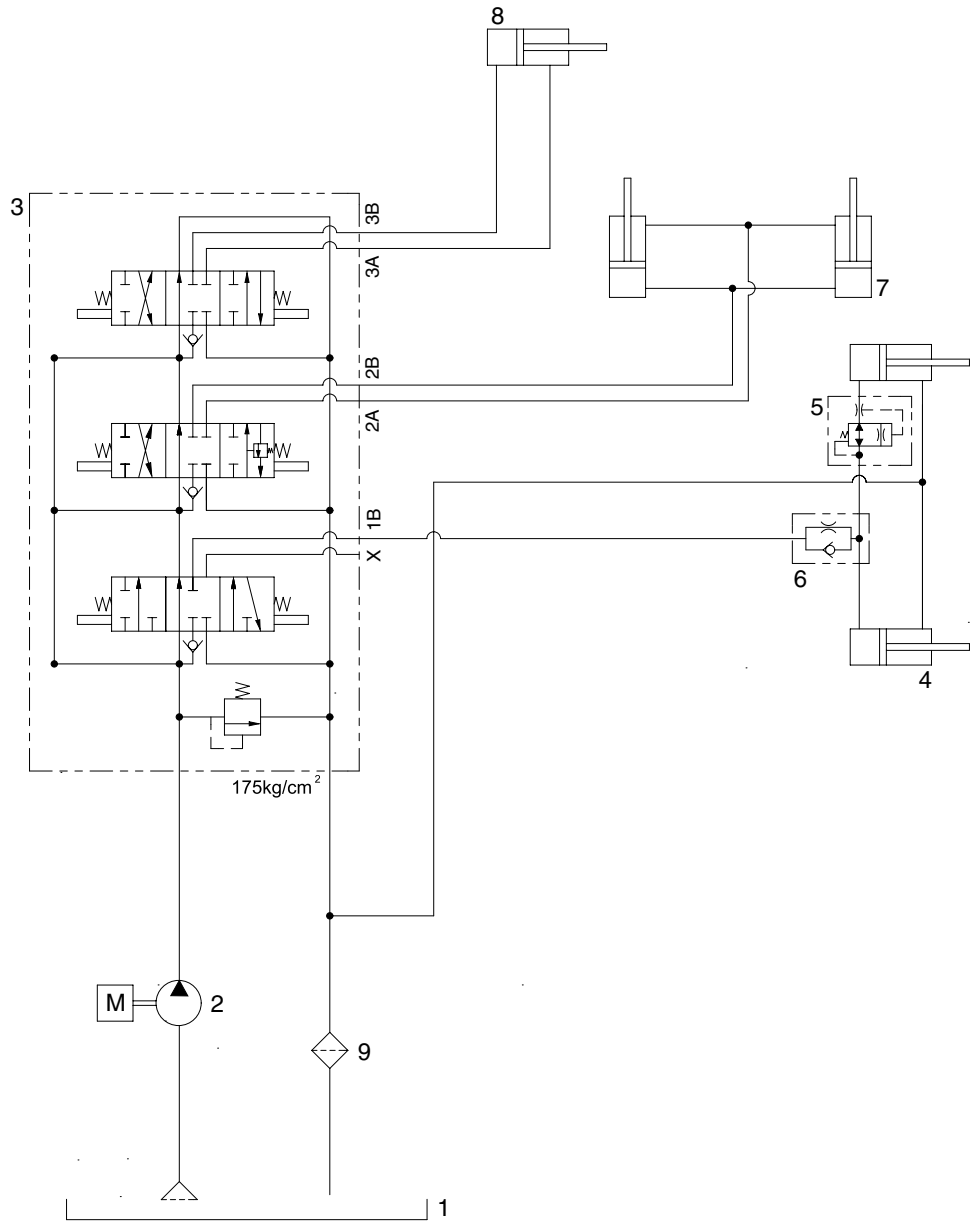
5. ADJUSTMENT

- Adjust the steering chain tension through the adjusting link so that the chain deflection will be 3-5mm(0.12~0.20in).
- Adjust the steering play to 25-80mm(1.0~3.0in).
- Adjust the steering wheel to close to operator's stand through fixing of spline in traveling.

SECTION 6 HYDRAULIC SYSTEM

GROUP 1 STRUCTURE AND FUNCTION

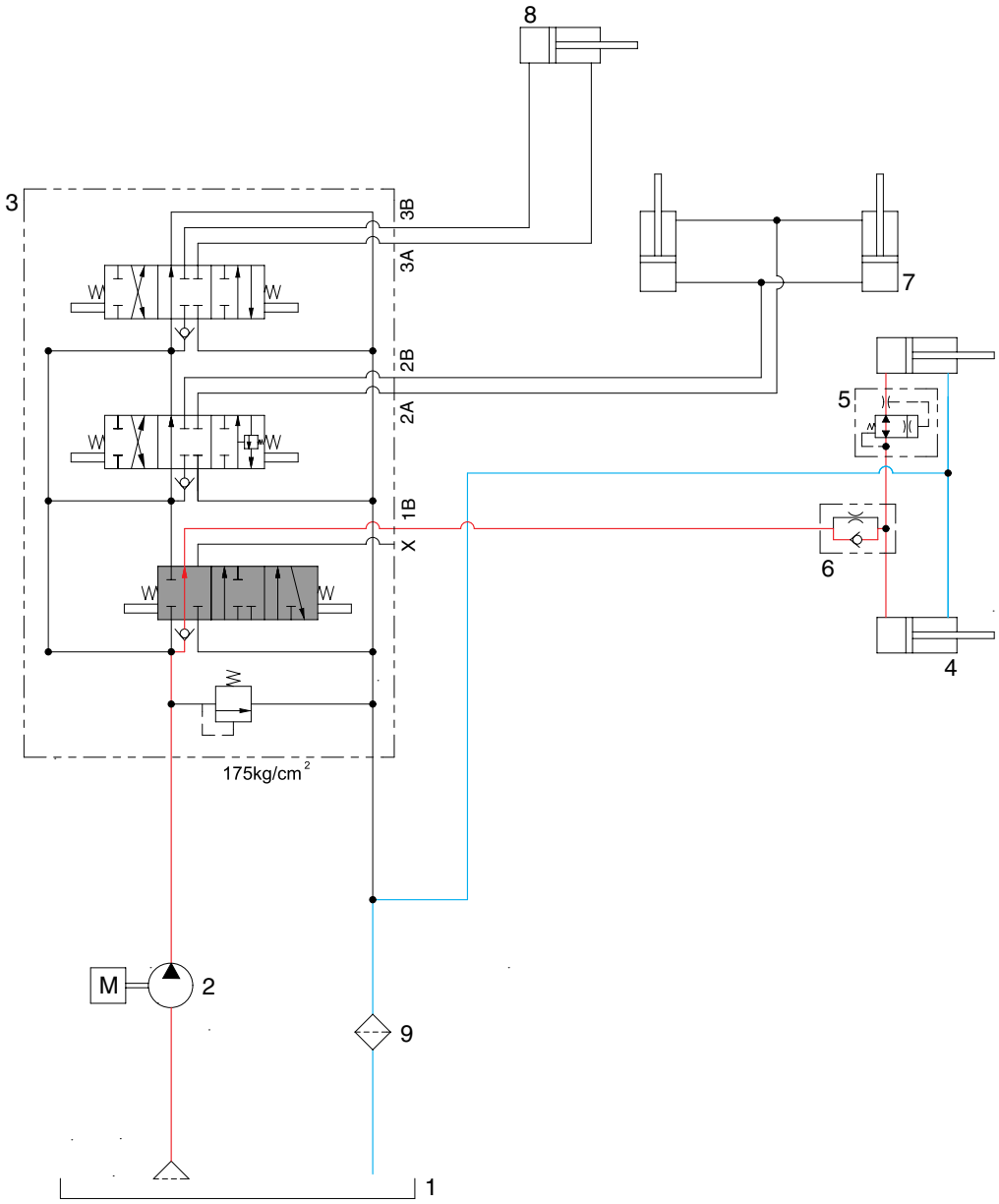
1. HYDRAULIC CIRCUIT



BR147HS01

1 Hydraulic tank
2 Hydraulic pump
3 Main control valve
4 Lift cylinder
5 Down safety valve
6 Down control valve
7 Tilt cylinder
8 Reach cylinder
9 Return filter

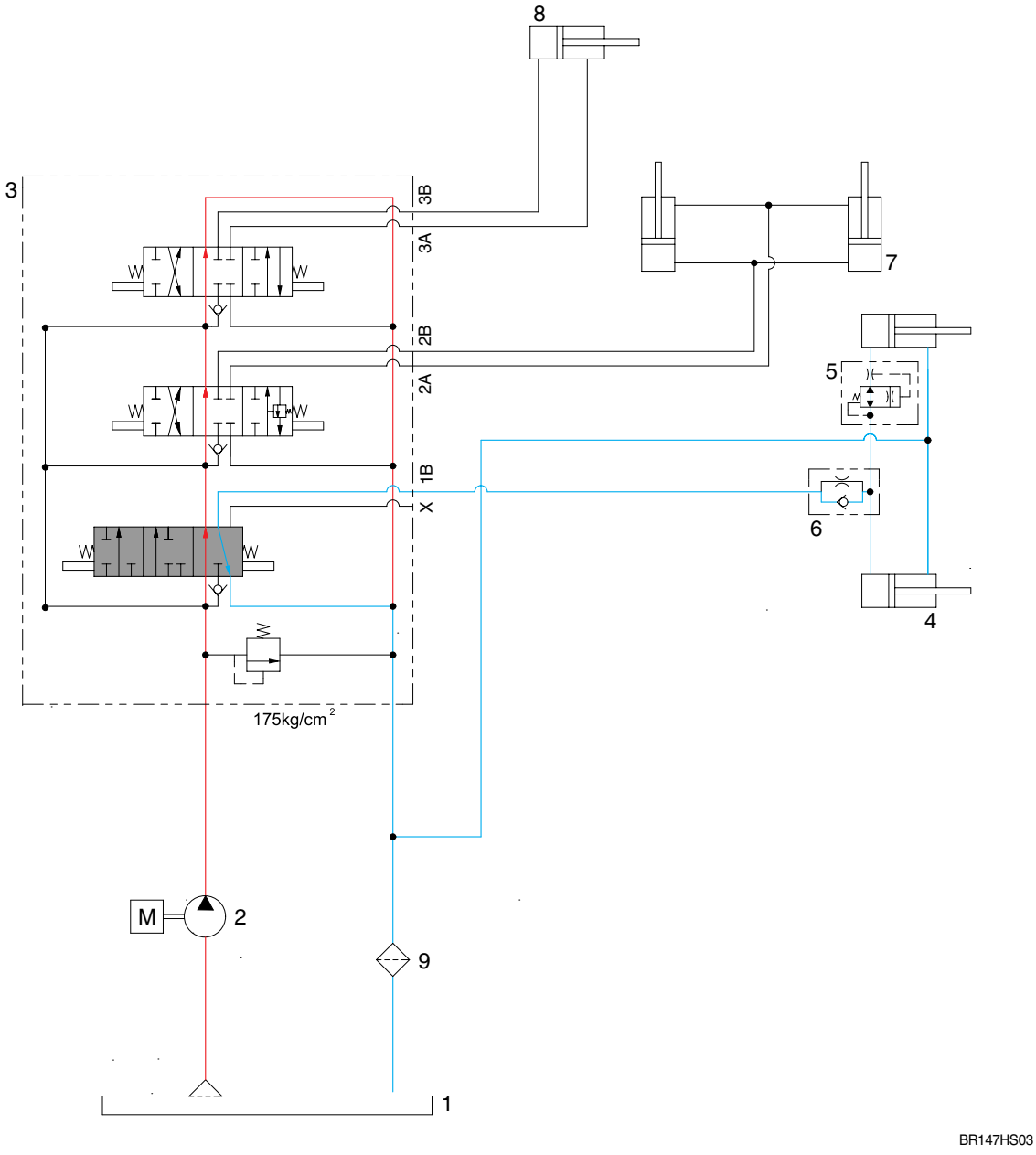
1) WHEN THE LIFT CONTROL LEVER IS IN THE LIFT POSITION



BR147HS02

When the lift control lever is pulled back, the spool on the first block is moves to lift position.
The oil from hydraulic gear pump(2) flows into main control valve(3) and then goes to the large chamber of lift cylinder(4) by pushing the load check valve of the spool.
The oil from the small chamber of lift cylinder(4) returns to hydraulic oil tank(1) at the same time.
When this happens, the forks go up.

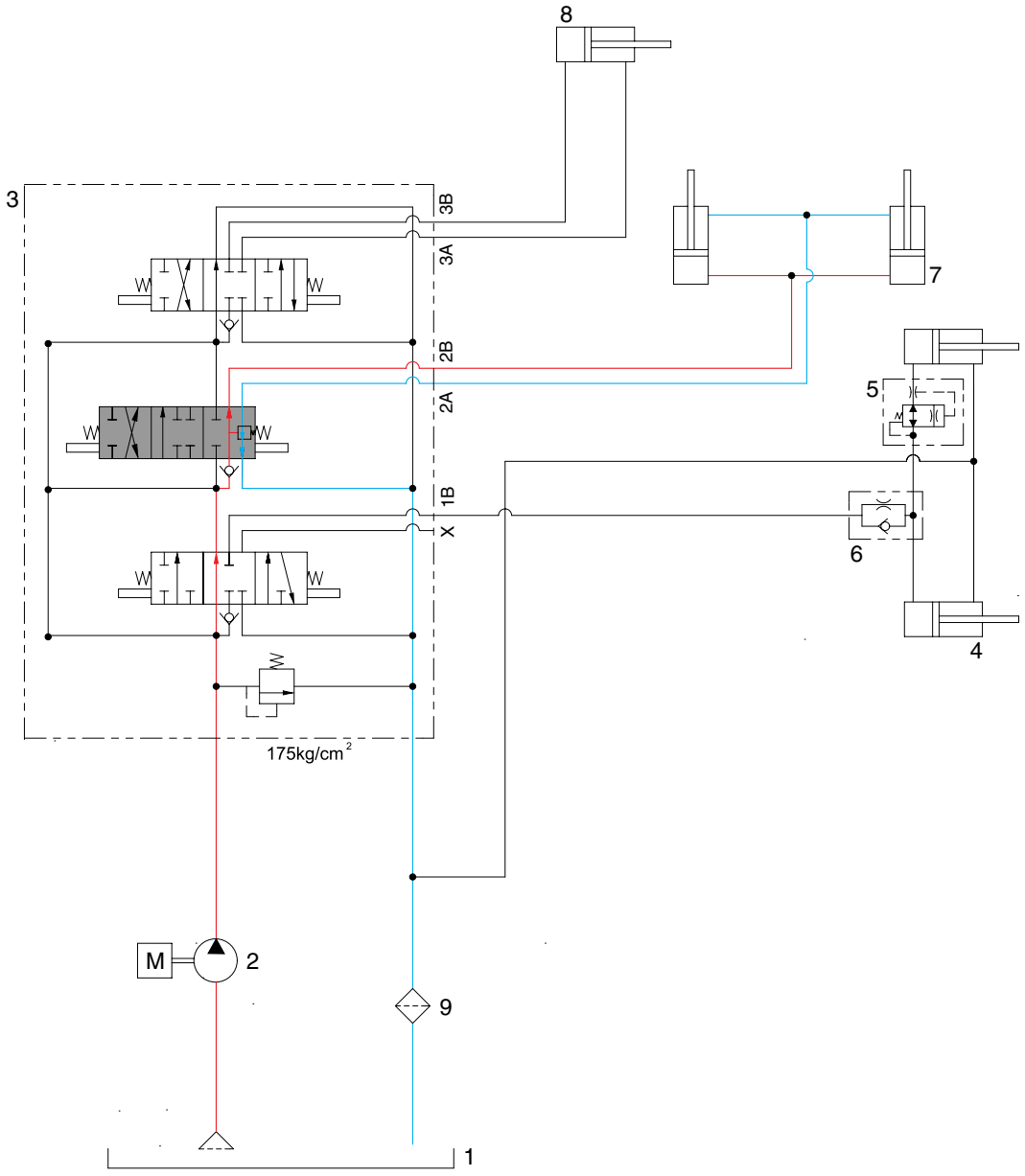
2) WHEN THE LIFT CONTROL LEVER IS IN THE LOWER POSITION



BR147HS03

When the lift control is pushed forward, the spool on the first block is moved to lower position.
The work port(1B) and the small chamber and the large chamber are connected to the return passage, so the lift will be lowered due to its own weight.

3) WHEN THE TILT CONTROL LEVER IS IN THE FORWARD POSITION



BR147HS04

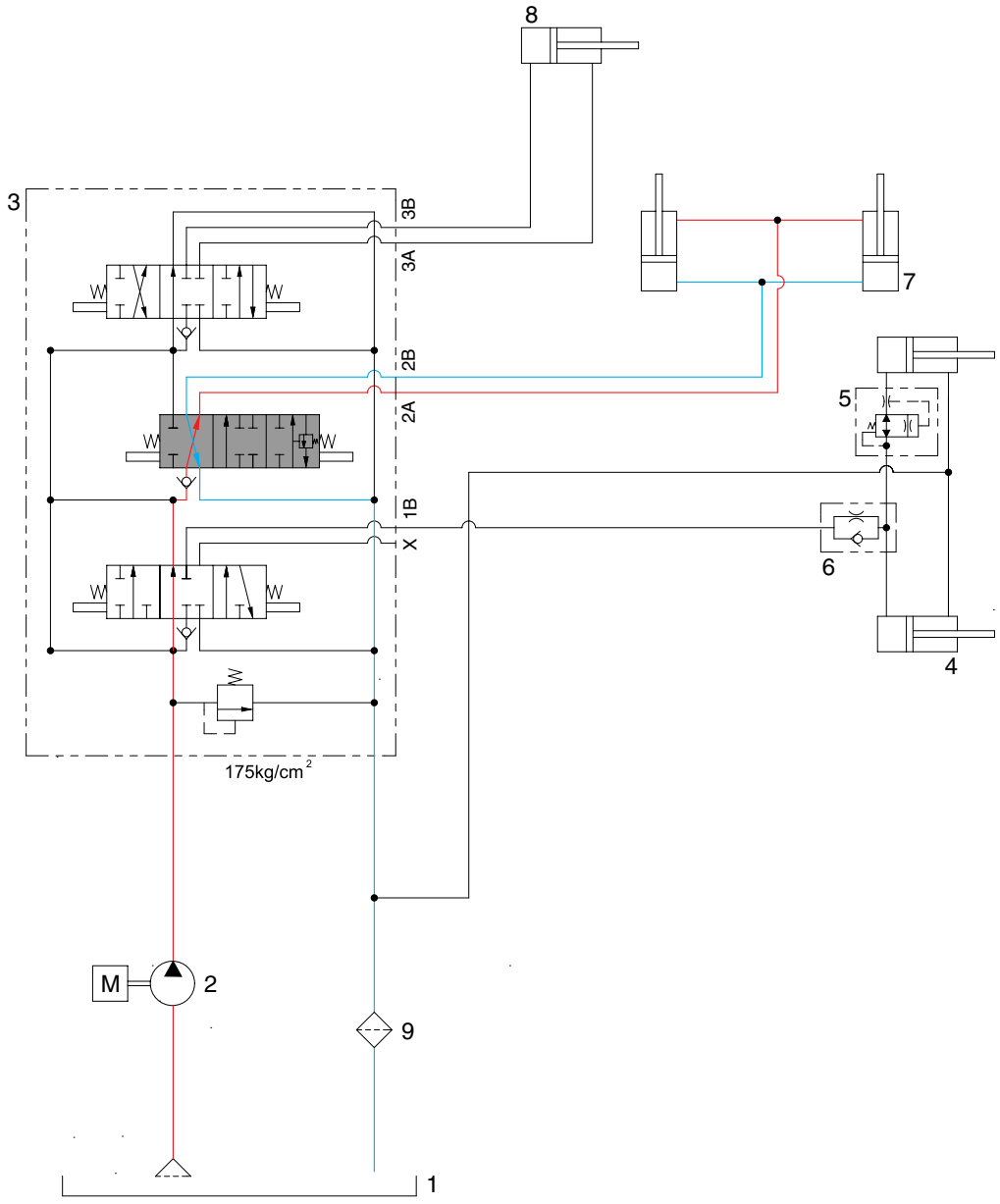
When the tilt control lever is pushed forward, the spool on the second block is moved to tilt forward position.

The oil from hydraulic gear pump(2) flows into main control valve(3) and then goes to the large chamber of tilt cylinder(7) by pushing the load check valve of the spool.

The oil at the small chamber of tilt cylinder(7) returns to hydraulic tank(1) at the same time.

When this happens, the mast tilt forward.

4) WHEN THE TILT CONTROL LEVER IS IN THE BACKWARD POSITION



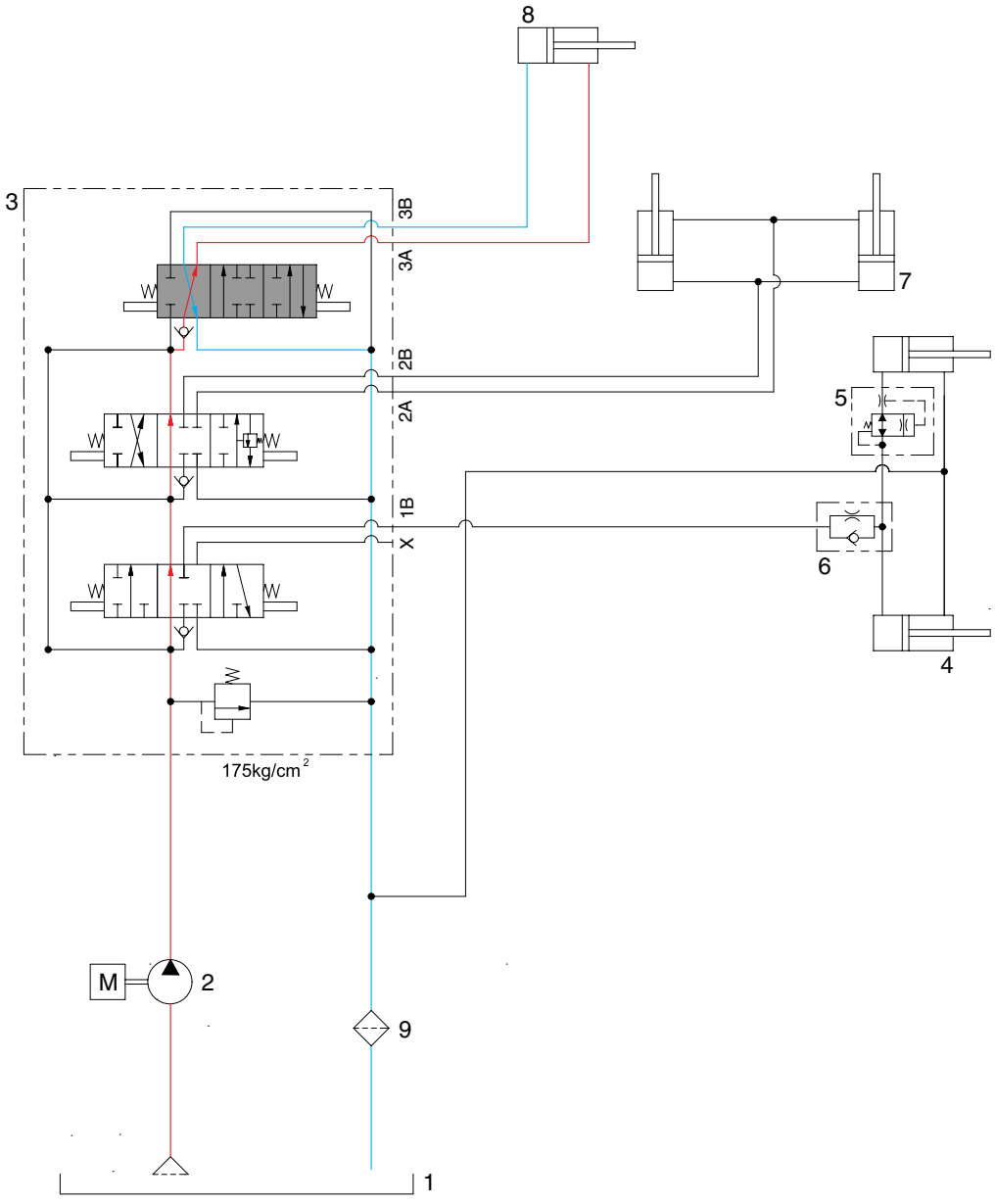
When the tilt control lever is pulled back, the spool on the second block is moved to tilt backward position.

The oil from hydraulic gear pump(2) flows into main control valve(3) and then goes to the small chamber of tilt cylinder(7) by pushing the load check valve of spool.

The oil at the large chamber of tilt cylinder(7) returns to hydraulic tank(1) at the same time.

When this happens, the mast tilt backward.

5) WHEN THE REACH CONTROL LEVER IS IN THE BACKWARD POSITION



BR147HS06

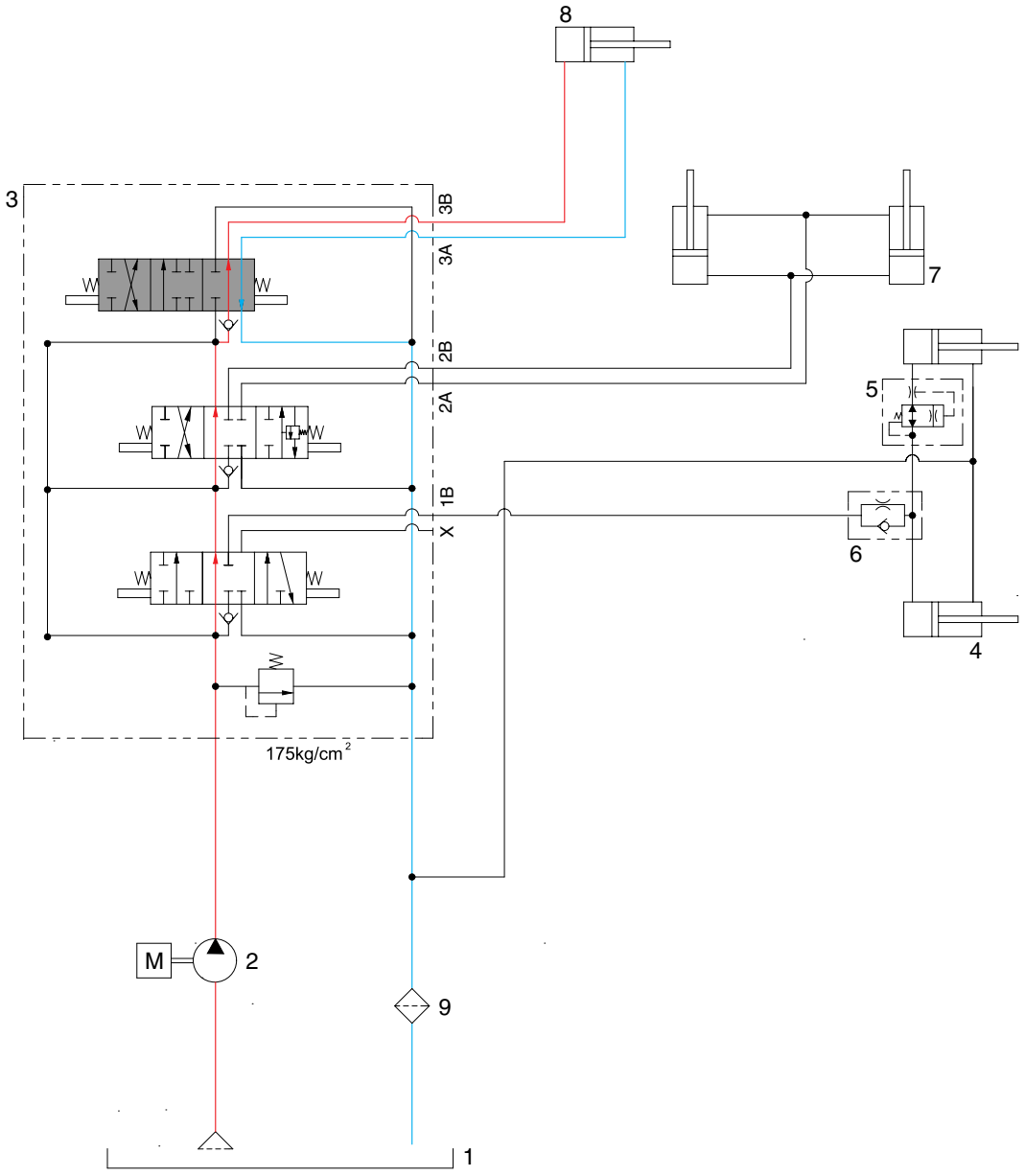
When the reach control lever is pushed backward, the spool on the third block is moved o reach backward position.

The oil from hydraulic gear pump(2) flows into main control valve(3) and then goes to the small chamber of reach cylinder(8) by pushing the load check valve of spool.

The oil at the large chamber of reach cylinder(8) returns to hydraulic tand(1) at the same time.

When this happens, the mast reaches backward.

6) WHEN THE REACH CONTROL LEVER IS IN THE FORWARD POSITION



BR147HS07

When the reach control lever is pushed forward, the spool on the third block is moved to reach forward position.

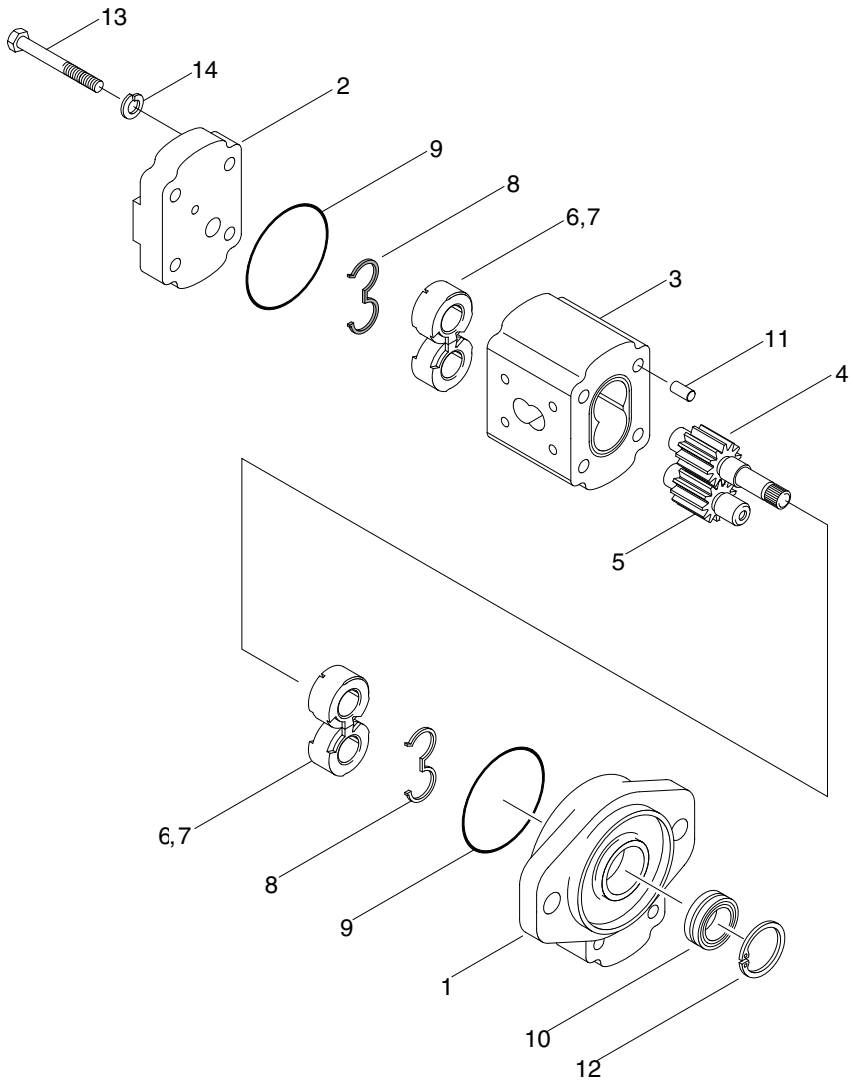
The oil from hydraulic gear pump(2) flows into main control valve(3) and then goes to the large chamber of reach cylinder(8) by pushing the load check valve of spool.

The oil at the small chamber of reach cylinder(8) returns to hydraulic tank(1) at the same time.

When this happens, the mast reaches forward.

2. HYDRAULIC GEAR PUMP

1) STRUCTURE



BR147HS08

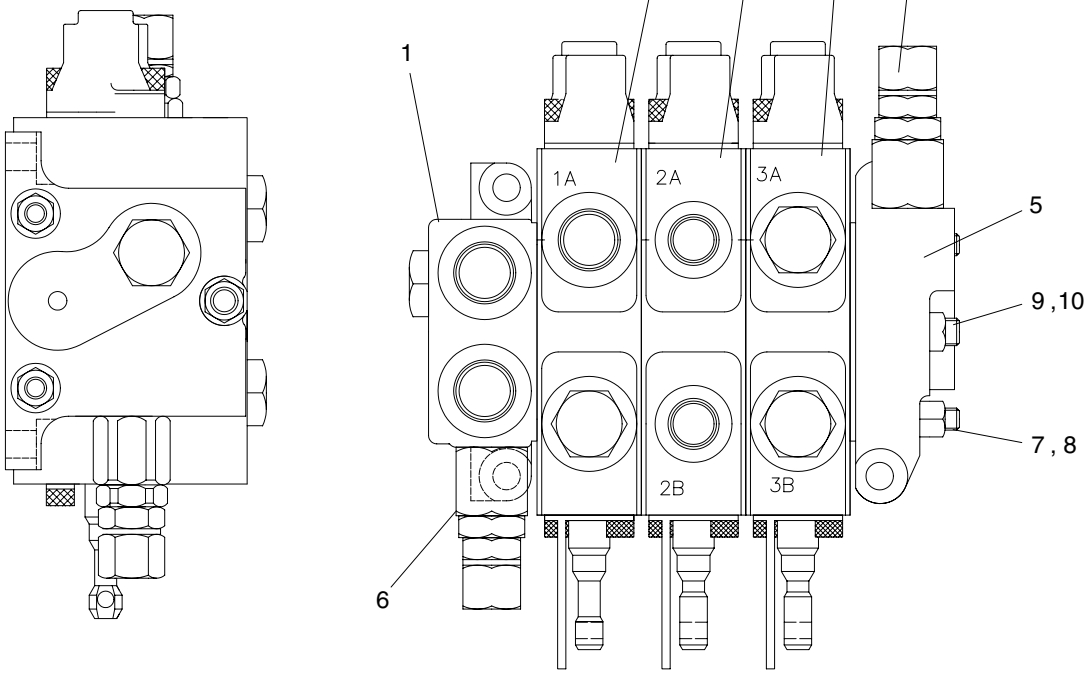
1	Front cover	6	Bushing block	11	Dowel pin
2	Rear cover	7	Dry bearing	12	Snap ring
3	Gear housing	8	Channel seal	13	Socket head bolt
4	Drive gear	9	Square seal	14	Spring washer
5	Driven gear	10	Lip seal		

2) OPERATION

This pump comprises of an rear cover, a body, bushings and a housing bolted together with socket bolts. The gear journals are supported in side plate within pressure balanced bushings to give high volumetric and mechanical efficiencies.

3. MAIN CONTROL VALVE

1) STRUCTURE (3 Spool)

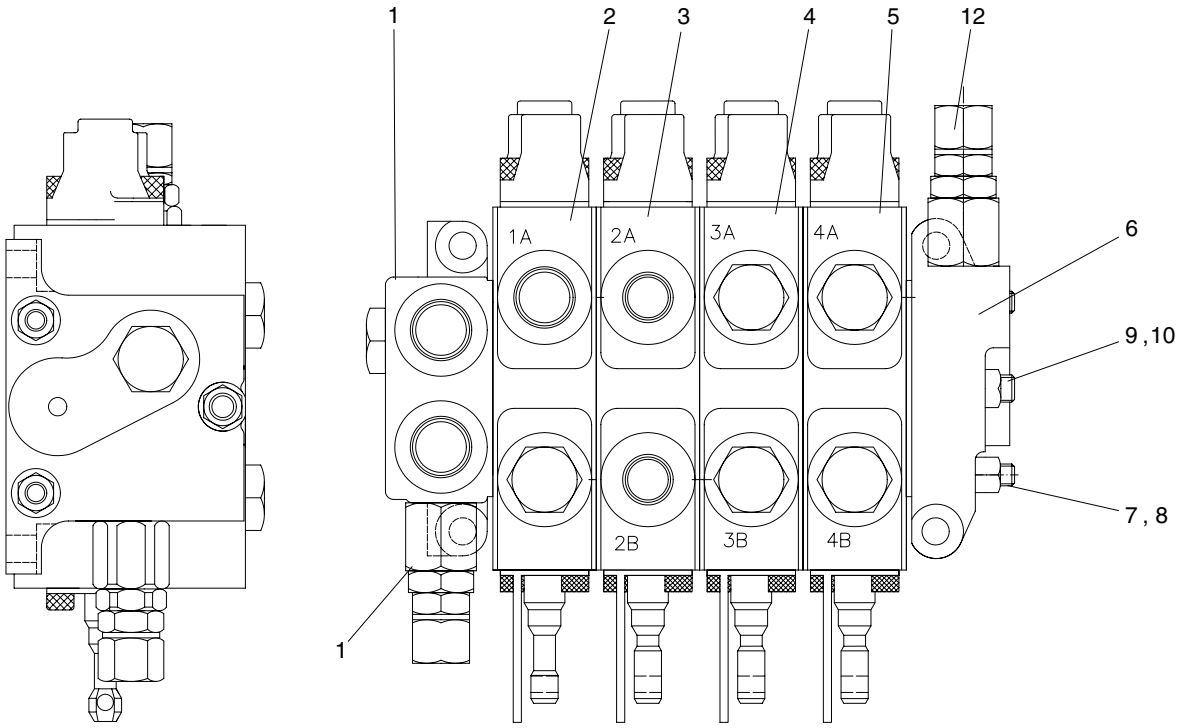


Port name	Size
Inlet port	PF 1/2
Outlet port	PF 1/2
Gauge port	PF1/4
Work port	2 - PF 3/8

B207HS07

1 Inlet block assy
2 Lift block assy
3 Tilt block assy
4 Aux 1 block assy
5 Outlet block assy
6 Relief valve assy
7 Rod
8 Nut
9 Rod
10 Nut
11 Relief valve assy

2) STRUCTURE(4 Spool)



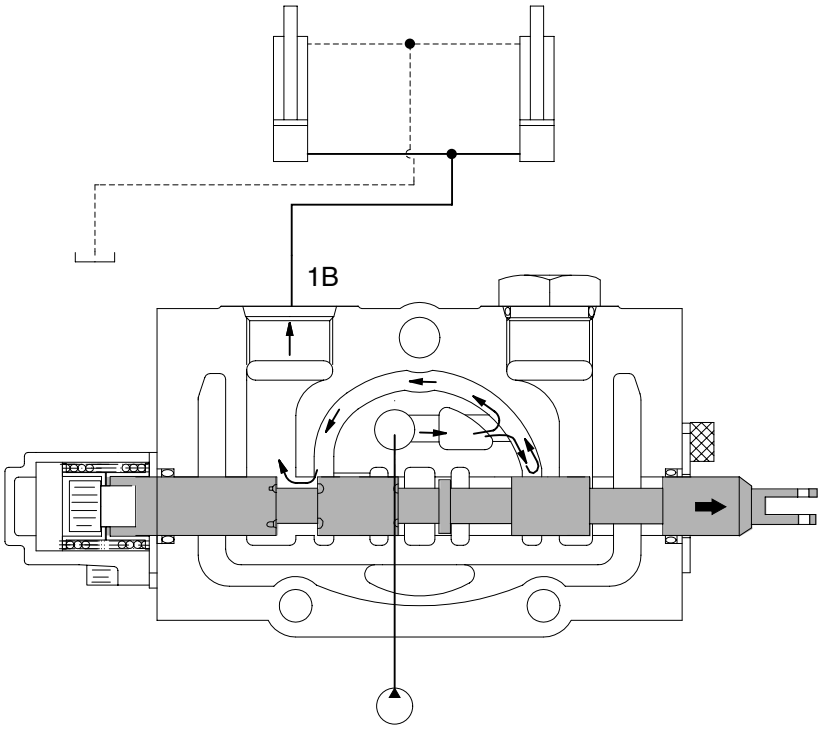
Port name	Size
Inlet port	PF 1/2
Outlet port	PF 1/2
Gauge port	PF1/4
Work port	2 - PF 3/8

B207HS08

1	Inlet block assy	7	Relief valve assy
2	Lift block assy	8	Rod
3	Tilt block assy	9	Nut
4	Aux 1 block assy	10	Rod
5	Aux 2 block assy	11	Nut
6	Outlet block assy	12	Relief valve assy

3) INLET SECTION OPERATION

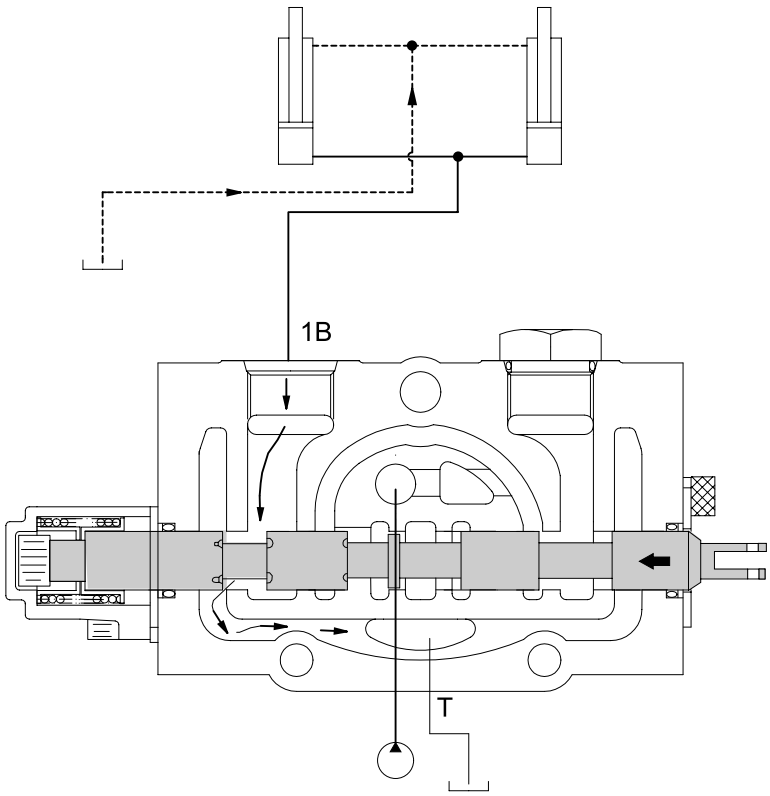
(1) Structure and description



D155HS09

When the lift control lever is pulled back, the spool moves to the right and the neutral passage is closed.
The oil supplied from the flow into lift cylinder port(1B).
The pump pressure reaches proportionally the load of cylinder and fine control finished by shut off of the neutral passage.
The return oil from cylinder flows into the tank.

(2) Lower position

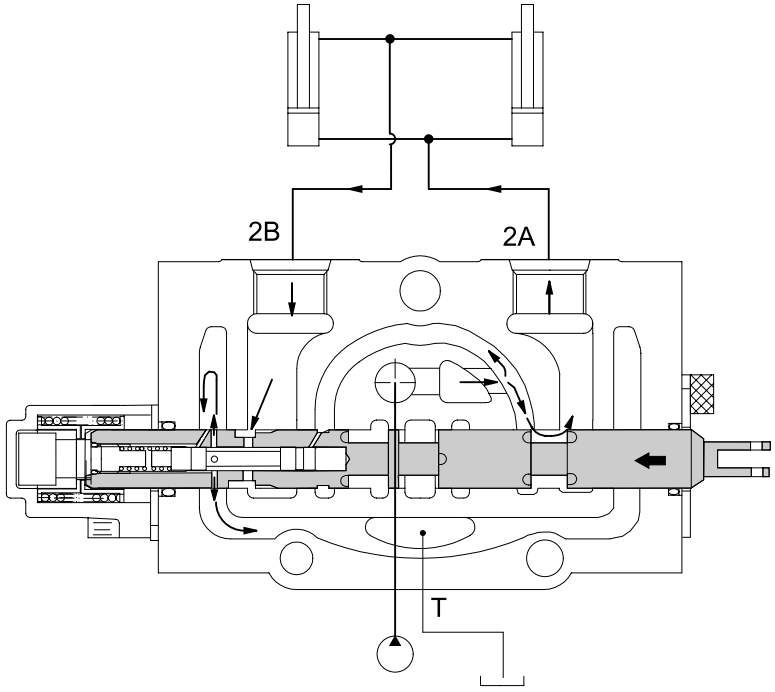


D155HS10

When the lift control lever is pushed forward, the spool moves to the left and the neutral passage is closed.
The spool moves to the lift lower position, opening up the neutral passage to tank and (1B)→T.
In lift lower position the fork drops due to its own weight.

4) TILT SECTION OPERATION

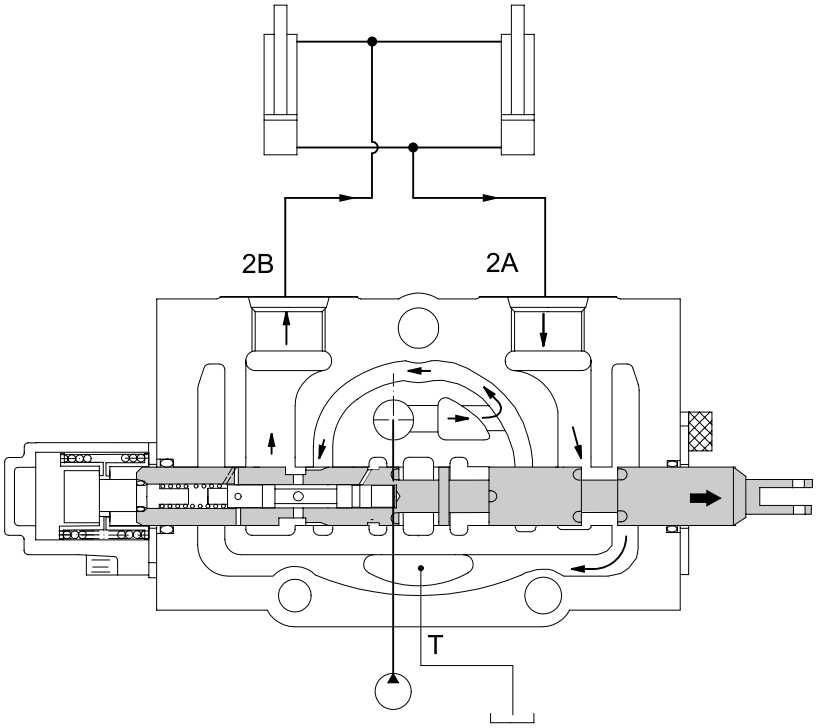
(1) Tilt forward position



D155HS11

When the tilt control lever is pushed forward, the spool moves to the left and the neutral passage is closed.
The oil supplied from the pump and flow into tilt cylinder port(2A).
The pump pressure reaches proportionally the load of cylinders and fine control finished by closing the neutral passage.
The return oil from cylinder port(2B) flows into the tank through the hole of the tilt lock spool.

(2) Tilt backward position



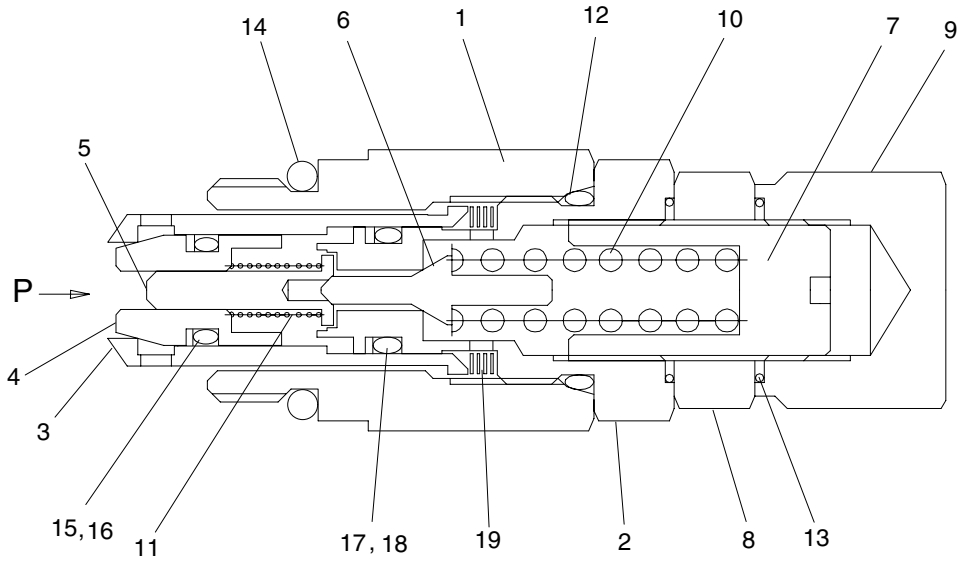
D155HS12

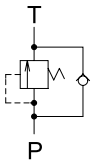
When the tilt control lever is pulled back, the spool moves to the right and the neutral passage is closed.
The oil supplied from the pump pushes up the load check valve(1) and flows into tilt cylinder port(2B). The pump pressure reaches proportionally the load of cylinder and fine control finished by shut off of the neutral passage.
The return oil from cylinder port(2A) flows into the tank via the low pressure passage.

5) MAIN RELIEF VALVE

This valve is a type of pilot piston to prevent hydraulic components and pipes from being broken by high pressure so, it keeps under pressure limited.

Relief valve pressure varies by 130kgf/cm² in accordance with 1 revolution of adjust bolt.





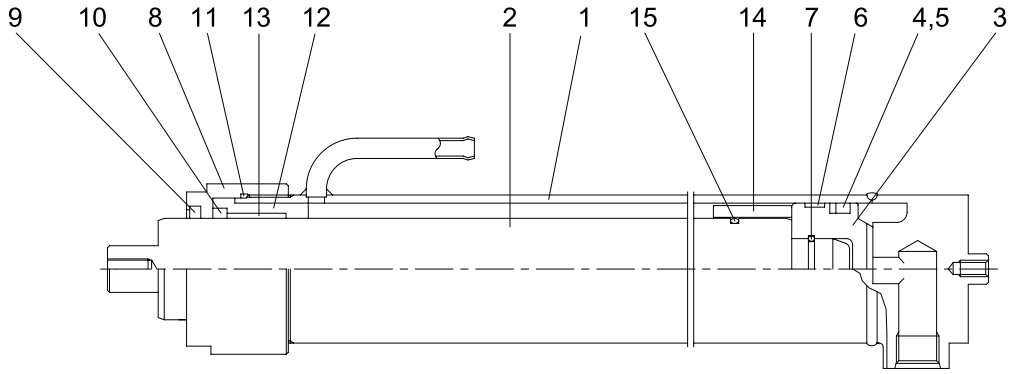
· Main relief valve : 190 kgf/cm²
· Secondary main relief valve : 140 kgf/cm²
(For 3,4 spool only)

NOTE : 1) Max. pressure of relief valve : 250 kgf/cm²
2) Used pressure of hyd. control valve : 210 kgf/cm²

D155HS22

1	Housing	8	Nut	14	O-ring
2	Body	9	Cap nut	15	O-ring
3	Socket	10	Pilot spring	16	Back up ring
4	Main poppet	11	Main spring	17	O-ring
5	Plunger	12	O-ring	18	Back up ring
6	Pilot poppet	13	O-ring	19	Wave washer
7	Adjust screw				

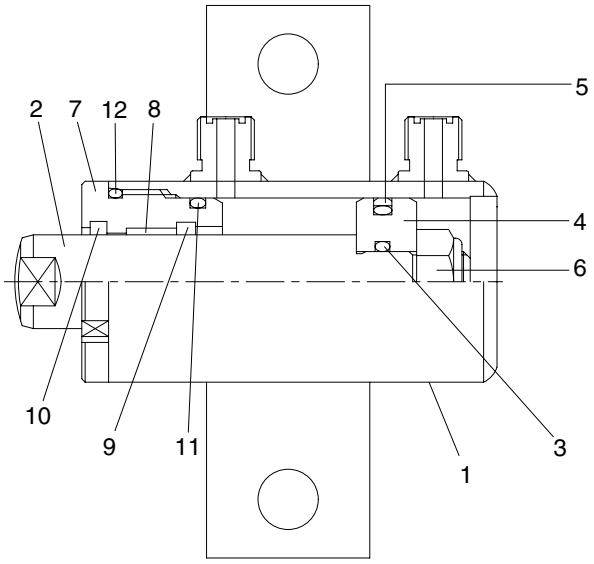
4. LIFT CYLINDER



D155HS13

1	Tube assy	6	Wear ring	11	O-ring
2	Rod	7	Retaining ring	12	Stopper
3	Piston	8	Rod cover	13	Du bushing
4	U-packing	9	Dust wiper	14	Spacer
5	Back up ring	10	U-packing	15	O-ring

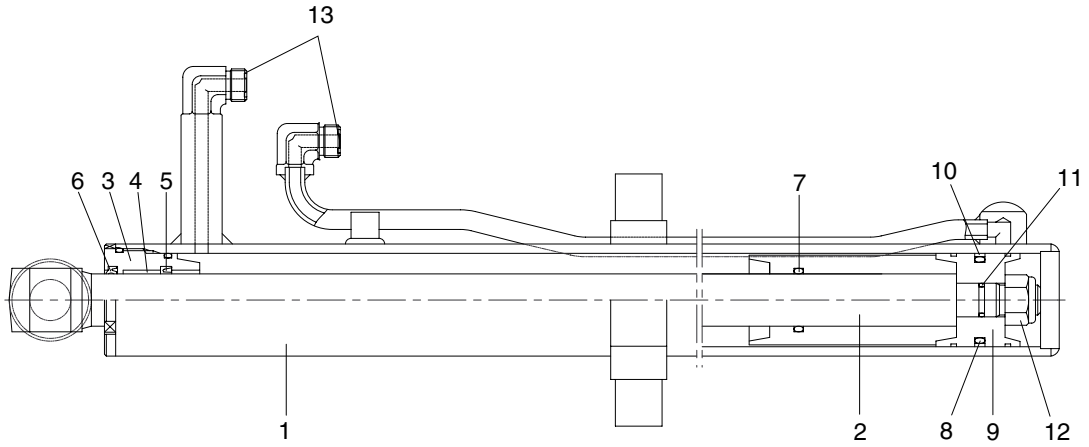
5. TILT CYLINDER



D255HS19

1	Tube assembly	5	Piston seal	9	Rod seal
2	Rod assembly	6	Nylon nut	10	Dust wiper
3	O-ring	7	Gland	11	O-ring
4	Piston	8	DU bushing	12	O-ring

5. REACH CYLINDER



BR147HS14

1	Tube assembly	6	Dust wiper	11	O-ring
2	Rod assembly	7	O-ring	12	Nylon nut
3	Gland	8	O-ring	13	O-ring
4	DU bushing	9	Piston	14	Spacer
5	Rod seal	10	Piston seal		

GROUP 2 OPERATIONAL CHECKS AND TROUBLESHOOTING

1. OPERATIONAL CHECKS

1) CHECK ITEM

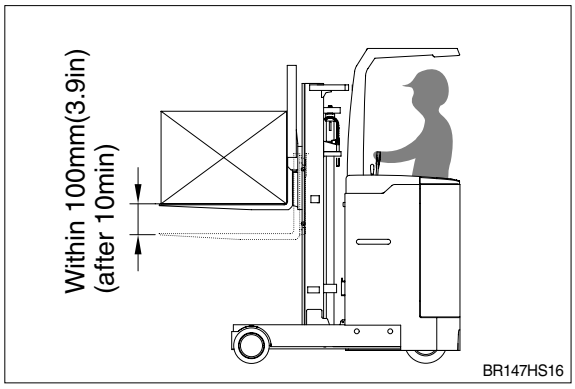
(1) Check visually for deformation, cracks or damage of rod.

(2) Load maximum load, set mast vertical and raise 1m from ground. Wait for 2 minutes and measure hydraulic drift(amount forks move down and amount mast tilts forward).

· **Hydraulic drift**

- Down(Downward movement of forks)
  : Within 100mm(3.9in)
- Forward(Extension of tilt cylinder)
  : Within 5°

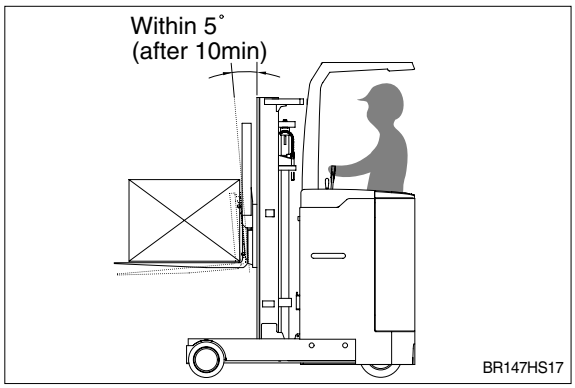
If the hydraulic drift is more than the specified value, replace the control valve or cylinder packing.



(3) Check that clearance between tilt cylinder bushing and mounting pin is within standard range.

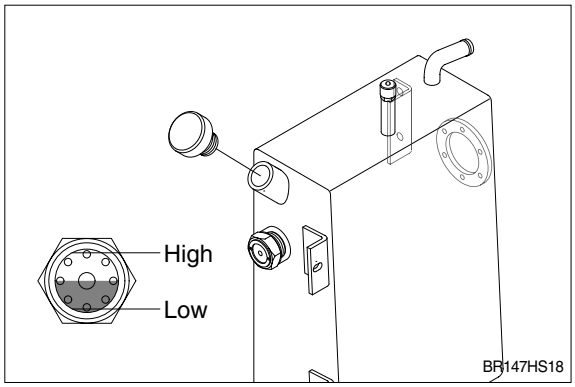
mm (in)

Standard	Under 0.6 (0.02)



2) HYDRAULIC OIL

(1) Lower the fork in its lowest position on an even ground. Check for the hydraulic oil level with the oil level gauge. When the level is low, refill.



3) CONTROL VALVE

(1) Raise forks to maximum height and measure oil pressure.
Check that oil pressure is 175kgf/cm^2.
(2490psi)

2. TROUBLESHOOTING

1) SYSTEM

Problem	Cause	Remedy
Large fork lowering speed	· Seal inside control valve defective. · Oil leaks from joint or hose. · Seal inside cylinder defective.	· Replace spool or valve body. · Replace. · Replace packing.
Large spontaneous tilt of mast	· Tilting backward : Check valve defective. · Tilting forward : tilt lock valve defective. · Oil leaks from joint or hose. · Seal inside cylinder defective.	· Clean or replace. · Clean or replace. · Replace. · Replace seal.
Slow fork lifting or slow mast tilting	· Lack of hydraulic oil. · Hydraulic oil mixed with air. · Oil leaks from joint or hose. · Excessive restriction of oil flow on pump suction side. · Relief valve fails to keep specified pressure. · Poor sealing inside cylinder. · High hydraulic oil viscosity. · Mast fails to move smoothly. · Oil leaks from lift control valve spool. · Oil leaks from tilt control valve spool.	· Add oil. · Bleed air. · Replace. · Clean filter. · Adjust relief valve. · Replace packing. · Change to SAE10W, class CD engine oil. · Adjust roll to rail clearance. · Replace spool or valve body. · Replace spool or valve body.
Hydraulic system makes abnormal sounds	· Excessive restriction of oil flow pump suction side. · Gear or bearing in hydraulic pump defective.	· Clean filter. · Replace gear or bearing.
Control valve lever is locked	· Foreign matter jammed between spool and valve body. · Valve body defective.	· Clean. · Tighten body mounting bolts uniformly.
High oil temperature	· Lack of hydraulic oil. · High oil viscosity. · Oil filter clogged.	· Add oil. · Change to SAE80W-90LSD, class API GL-5 gear oil. · Clean filter.

2) HYDRAULIC GEAR PUMP

Problem	Cause	Remedy
Pump does not develop full pressure	· System relief valve set too low or leaking. · Oil viscosity too low. · Pump is worn out.	· Check system relief valve for proper setting. · Change to proper viscosity oil. · Repair or replace pump.
Pump will not pump oil	· Reservoir low or empty. · Suction strainer clogged.	· Fill reservoir to proper level. · Clean suction strainer.
Noisy pump caused by cavitation	· Oil too thick. · Oil filter plugged. · Suction line plugged or too small.	· Change to proper viscosity. · Clean filters. · Clean line and check for proper size.
Oil heating	· Oil supply low. · Contaminated oil. · Setting of relief valve too high or too low. · Oil viscosity too low.	· Fill reservoir to proper level. · Drain reservoir and refill with clean oil. · Set to correct pressure. · Drain reservoir and fill with proper viscosity.
Foaming oil	· Low oil level. · Air leaking into suction line. · Wrong kind of oil.	· Fill reservoir to proper level. · Tighten fittings, check condition of line. · Drain reservoir, fill with non-foaming oil.
Shaft seal leakage	· Worn shaft seal. · Worn shaft in seal area.	· Replace shaft seal. · Replace drive shaft and seal.

3) MAIN RELIEF VALVE

Problem	Cause	Remedy
Can't get pressure	· Poppet D, E or K stuck open or contamination under seat.	· Check for foreign matter between poppets D, E or K and their mating parts. Parts must slide freely.
Erratic pressure	· Pilot poppet seat damaged. · Poppet C sticking in D.	· Replace the relief valve. · Clean and remove surface marks for free movement.
Pressure setting not correct	· Normal wear. Lock nut & adjust screw loose.	· See *Test of main control valve.
Leaks	· Damaged seats. · Worn O-rings. · Parts sticking due to contamination.	· Replace the relief valve. · Install seal and spring kit. · Disassemble and clean.

★ A good pressure gauge must be installed in the line which is in communication with the main relief. A load must be applied in a manner to reach the set pressure of the main relief unit.
Then, follow these steps:

- Loosen lock nut.
- Set adjusting nut to desired pressure setting.
- If desired pressure setting cannot be achieved, add or remove shims as required.
- Tighten lock nut.
- Retest in similar manner as above.

4) LIFT CYLINDER

Problem	Cause	Remedy
Oil leaks out from rod cover through rod	· Foreign matters on packing. · Unallowable score on rod. · Unusual distortion of dust seal. · Chrome plating is striped.	· Replace packing. · Smooth rod surface with an oil stone. · Replace dust seal. · Replace rod.
Oil leaks out from cylinder rod cover thread	· O-ring damaged.	· Replace O-ring.
Rod spontaneously retract	· Scores on inner surface of tube. · Unallowable score on the inner suface of tube. · Foreign matters in piston seal.	· Smooth rod surface with an oil stone. · Replace cylinder tube. · Replace piston seal.
Wear(clearance between cylinder tube and wear ring)	· Excessive clearance between cylinder tube and wear ring.	· Replace wear ring.
Abnormal noise is produced during tilting operation	· Insufficient lubrication of anchor pin or worn bushing and pin. · Bent tilt cylinder rod.	· Lubricate or replace. · Replace.

1. HYDRAULIC GEAR PUMP

1) DISASSEMBLY

(1) Put the unit back side down to your work place.


B207PMP01

(2) Remove all fasteners, bolts and nuts.


B207PMP02

(3) Put all removed parts on a safe place.


B207PMP03

(4) Remove the mounting flange.


B207PMP04

(5) Remove the gear set and remove the balance plate from bottom of the body.


B207PMP05

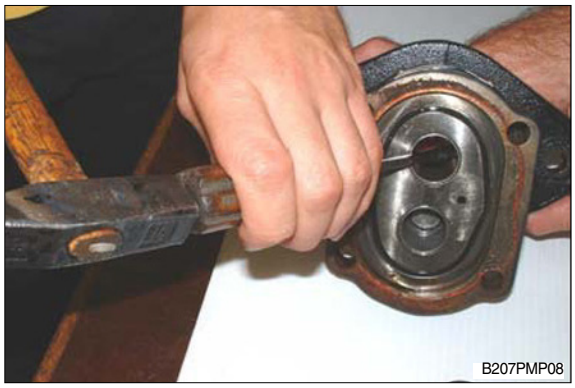
(6) Remove the snap ring(located in front of the shaft seal ring).


B207PMP06

(7) Use proper and safe tools for this operation.


B207PMP07

(8) Push out the shaft seal.


B207PMP08

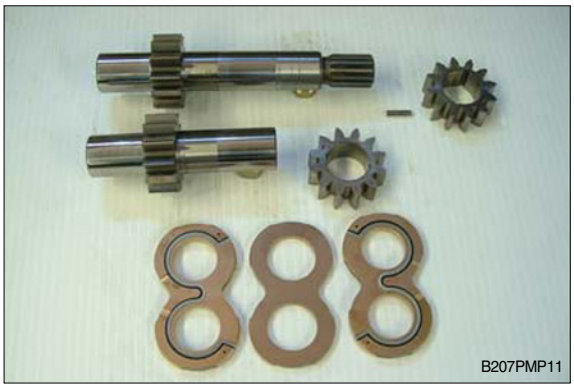
(9) Check balance plates, the mid plate and the sealing parts.


B207PMP09

(10) Assemble new sealing parts, the rubber seal first, the plastic seal on top.


B207PMP10

(11) Check all parts of the gear set including the key for the split gear.


B207PMP11

(12) Remove the section seal from mounting flange.


B207PMP12

2) ASSEMBLY

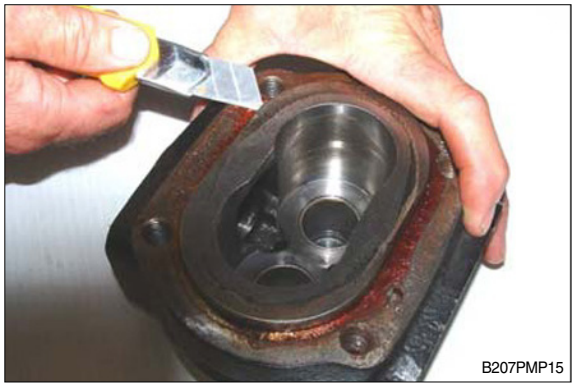
(1) Clean all mounting faces of the mounting flange from sealant and dirt.


B207PMP13

(2) Be careful, avoid mechanical surface damages.


B207PMP14

(3) Clean all mounting faces of the body from sealant and dirt.


B207PMP15

(4) Assemble the lower balance plate into the body, sealing parts can be fixed with grease. Position is rotation sensitive.


B207PMP16

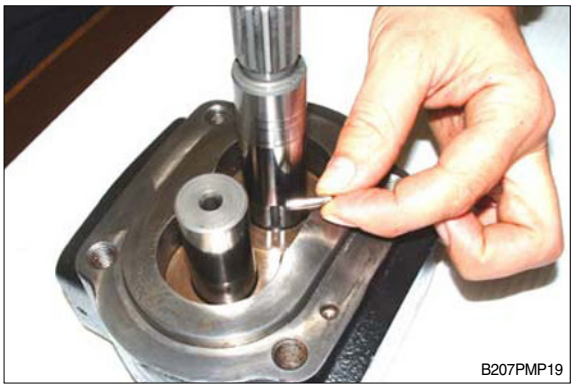
(5) Assemble the basic gears into the body, journals and other contact faces should be oiled with clean hydraulic fluid.


B207PMP17

(6) Assemble the mid plate to the gear set. The center plate is not rotation sensitive.


B207PMP18

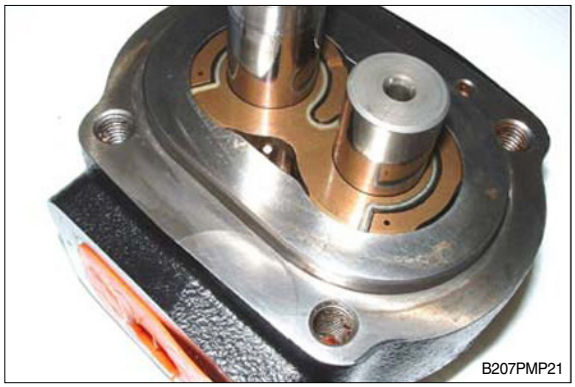
(7) Fit the key to the drive shaft. The key should be fixed with grease.


B207PMP19

(8) Assemble careful the sliding gears to the basic gears. Check that the key is in the correct position.


B207PMP20

(9) Put the upper balance plate on top of the gear set. Position is rotation sensitive.


B207PMP21

(10) Prepare the shaft seal for assembly. Use a proper assembly fixture.


B207PMP22

(11) The shaft seal should be packed with some grease.


B207PMP23

(12) Press in the shaft seal to bottom of the shaft seal bore.

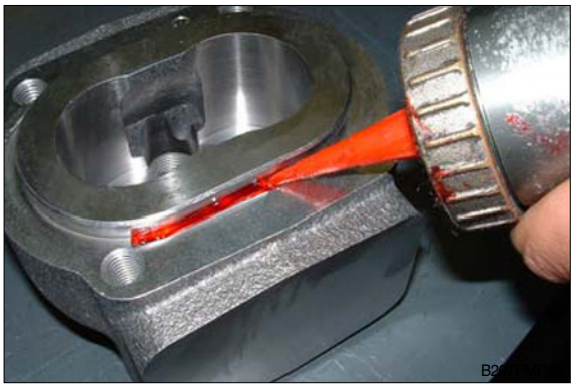

B207PMP24

(13) Assemble the snap ring.

(14) Check the section seal. Use of a new one is recommended in each case.

(15) Clean all assembly faces again.

(16) Put a rope of loctite sealant out side the interlock track on the body(it's for corrosion protection).



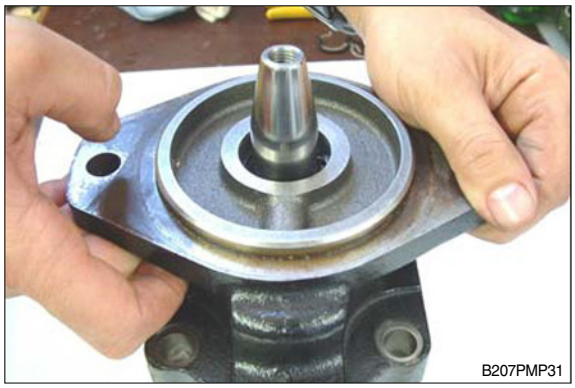
(17) Fit an assembly fixture for shaft seal protection to the drive shaft.


B207PMP29

(18) The assembly fixture should be oiled with clean hydraulic fluid to lubricate the shaft seal lip during assembly.


B207PMP30

(19) Fit the mounting flange careful from top down to the body. Fit the interlock track correct.


B207PMP31

(20) Remove the shaft seal protection fixture careful.


B207PMP32

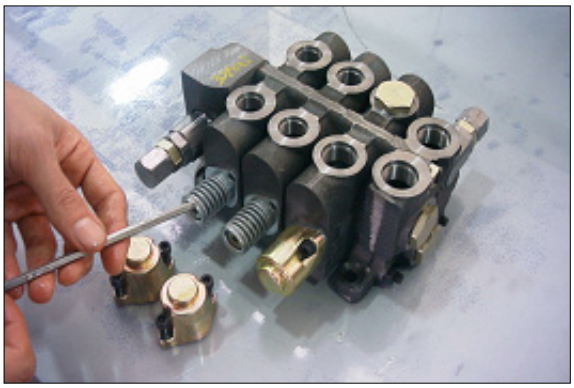
(21) Fit fasteners, bolts or nuts with correct assembly torque, according to values shown on unit assembly drawing.

2. MAIN CONTROL VALVE

1) DISASSEMBLY

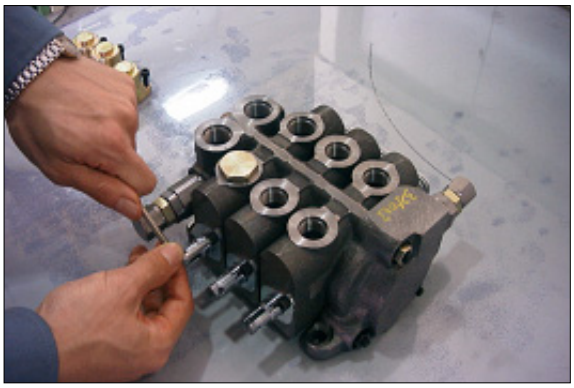
(1) Remove spool cap.

※ **Put disassembled parts orderly on the clean work bench.**



B207CVD01

(2) Remove socket bolts from the opposite side.



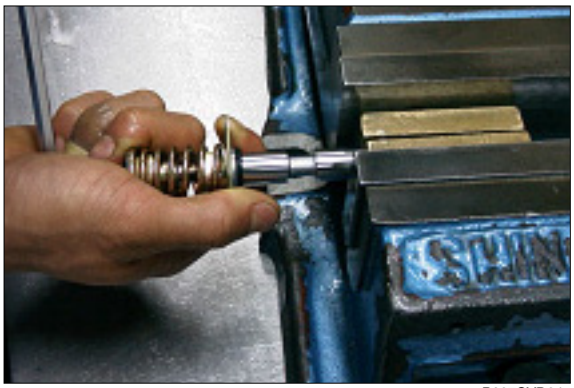
B207CVD02

(3) Disassemble spool assembly carefully from the section body.
In case of not being pulled out easily, push it into body again and then pull out smoothly by rotating the assembly.

B207CVD03

(4) Vise a spool assembly, using a jig.
Untighten special bolts and then remove spring seat, spring, seal plate, O-ring and dust wiper.

※ **Put disassembled parts orderly on the clean work bench.**



B207CVD04

(5) Disassembly of main relief valves(2EA).

B207CVD05

(6) Remove tightening nut of stud bolt.

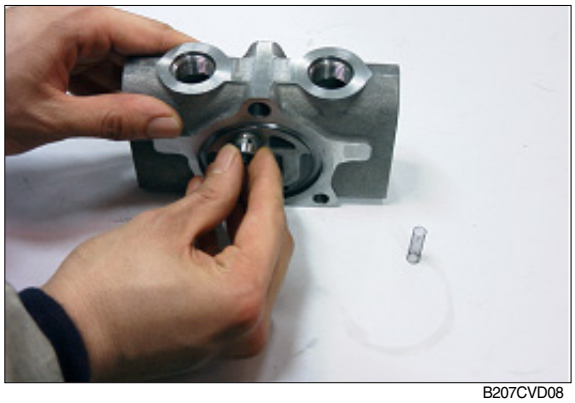
※ **Do not untighten stud bolt but replacing of O-ring or load check poppet.**

B207CVD06

(7) Put each section orderly on the clean work bench.
Place the O-rings between sections near section block.

B207CVD07

(8) Removal of load check valve.
Remove check poppet and spring from the block.
Between check poppet and body, the seat is structured during operation.
So be careful not being mixed up.



B207CVD08

2) ASSEMBLY

(1) Assembly of load check valve.
Install check poppet, spring, O-ring orderly to each section.

B207CVA01

(2) Array inlet, lift, tilt, aux and outlet block orderly and assemble them with stud bolts so that the O-rings and springs are not to fall off.

(3) Tighten nuts at following torque.
- Tighten in diagonal order.
- Keep the torque value when assembling.
- Tightening torque

M10 : 2.7~3.3kgf · m (19.5~23.9lbf · ft)
M8 : 2.4~2.9kgf · m (17.3~21.0lbf · ft)2EA

B207CVA02

(4) Vise the spool assembly, using a jig.
Install in the order of O-ring, dust wiper, seal plate, spring seat, spring, and special bolt.

※ **Install dust wiper with its wing side facing outside.**
- Tightening torque 1.8~2.2kgf · m (13.0~15.9lbf · ft)

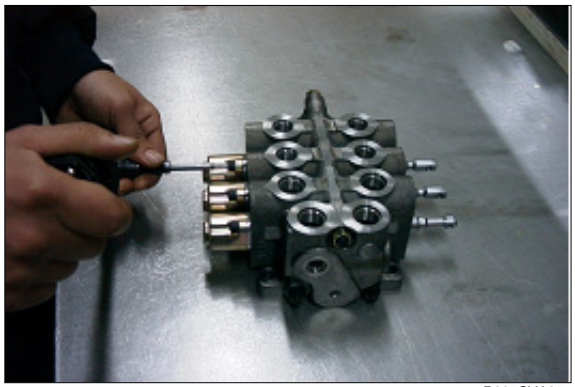
B207CVA03

(5) Install spool assembly to section body smoothly.
- Be careful of damaging the body by forcing the spool into the body.

B207CVA04

(6) Install return cap to the return spring side of spool assembly and then tighten socket bolts at following torque.

· Tightening torque 0.9~1.1kgf · m
(6.5~8.0lbf · ft)



B207CVA05

(7) Install O-ring, dust wiper, seal plate orderly to the opposite side of return cap.

※ **Install dust wiper with its wing side facing outside.**

· Tightening torque 0.9~1.1kgf · m
(6.5~8.0lbf · ft)

B207CVA06

(8) Assembly of main relief valve.
Install main relief valve into inlet block section at following torque.

· Tightening torque 4.5~5kgf · m
(32.5~36.2lbf · ft)

B207CVA07

3) TEST OF MAIN CONTROL VALVE

(1) Checking spool operation

① Spool moves smoothly.

② Spool comes back to neutral position by spring tention.

(2) Checking the pressure of relief valve

① Install a gauge to gauge port of inlet block to check out pressure and then.

(3) Checking the pressure of main relief valve

① Make relief by tilting in.

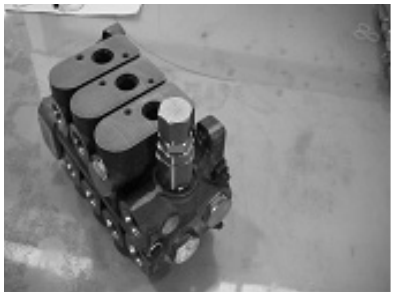
② Tighten adjust bolt of 2nd pressure relief valve carefully.

③ Where the pressure indcation of gauge stops is main relief pressure, so note the value.

④ Adjust pressure with adjust bolt and then lock the nut.
(Tightening torque : 2±0.5kgf · m)

⑤ Shifting the tilt spool 2~3times between NEUTRAL and IN position, check the relief pressure.

Adjustment of relief valve pressure.

		
Prepare relief valve	Loosen cap nut	Adjust with screw driver

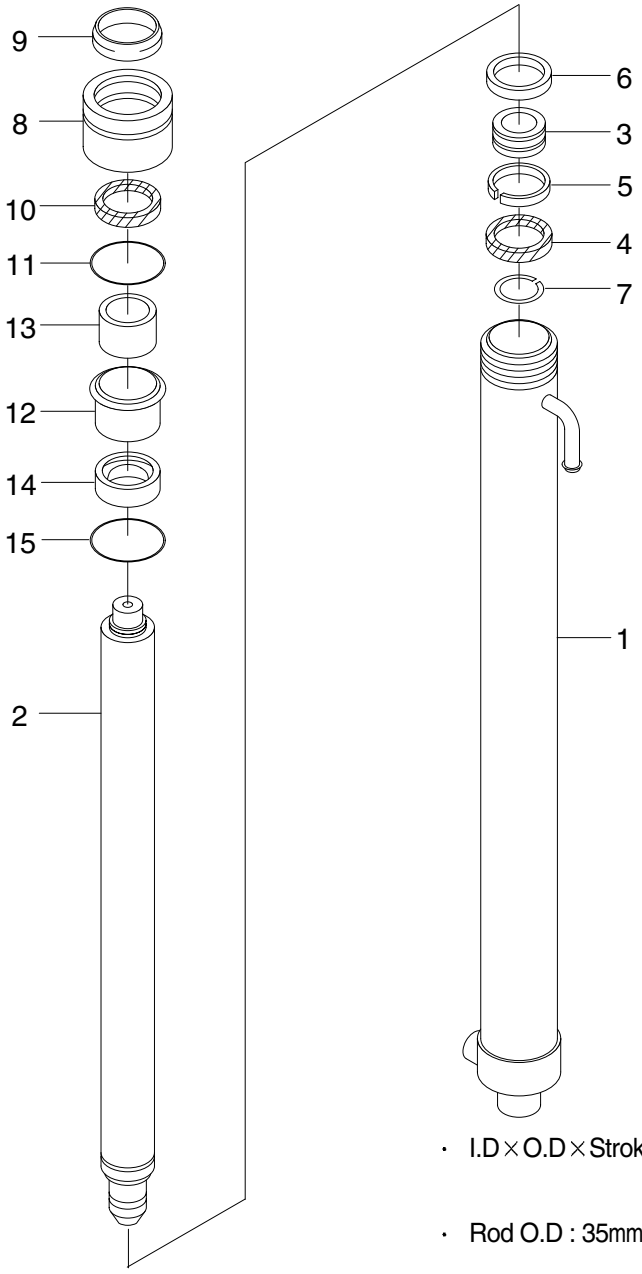
(4) Check the oil leakage of main control valve

· Perform in the state of unload.

· Reliving pressure for 1~2 minutes by lifting, check the oil leakage.

3. LIFT CYLINDER

1) STRUCTURE



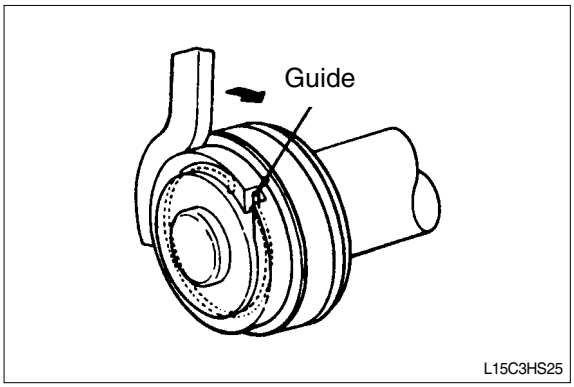
- I.D × O.D × Stroke : 45 × 55 × 1245mm
  (1.7 × 2.2 × 49~108in)
- Rod O.D : 35mm (1.4 in)

D155HS16

1	Tube assy	6	Wear ring	11	O-ring
2	Rod assy	7	Retaining ring	12	Stopper
3	Piston	8	Rod cover	13	Du bushing
4	U-packing	9	Dust wiper	14	Spacer
5	Back up ring	10	U-packing	15	O-ring

2) DISASSEMBLY

(1) Hold the cylinder tube in a vice, loosen the cylinder head and remove it.
Remove the spacer from the cylinder tube and knock out the bushing. Hook a wrench in the hole in the retainer at the piston end and turn. Lever up the edge of the guide, then turn the guide in again and the guide can be removed.



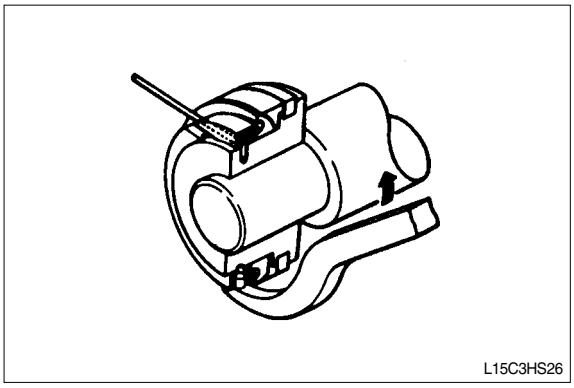
3) CHECK AND INSPECTION

mm(in)

Check item	Standard size	Repair limit	Remedy
Clearance between cylinder rod & bushing	0.072~0.288 (0.003~0.011)	0.5 (0.020)	Replace bushing
Clearance between piston ring & tube	0.05~0.030 (0.002~0.012)	0.5 (0.020)	Replace piston ring

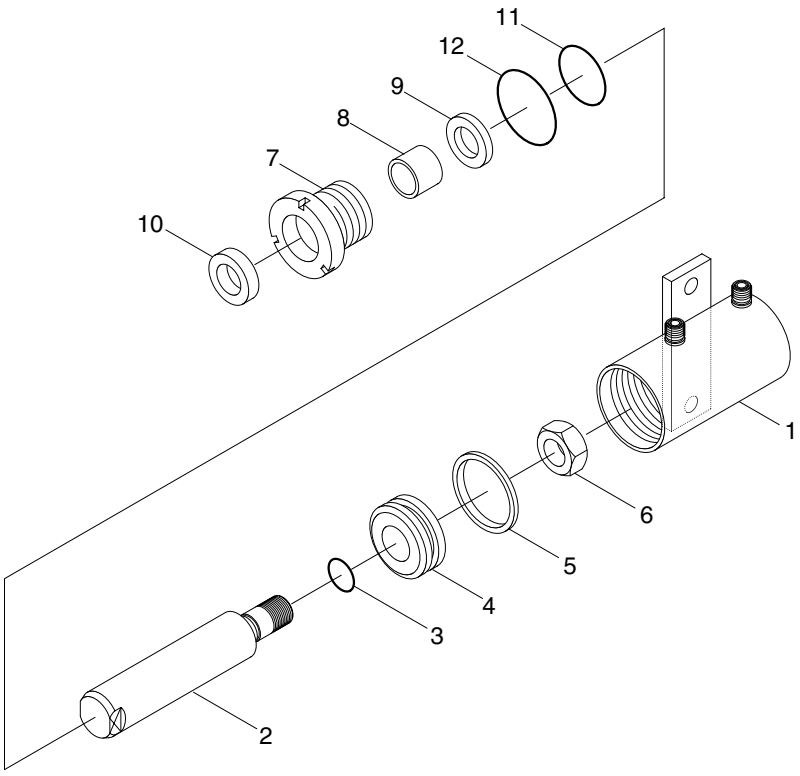
4) ASSEMBLY

(1) Soak the piston ring in hydraulic oil at a temperature of 40 to 50℃, expand the inside diameter and assemble on the piston. Install a piston seal.
Bend the edge of the guide and rotate it to install the guide completely.



4. TILT CYLINDER

1) STRUCTURE

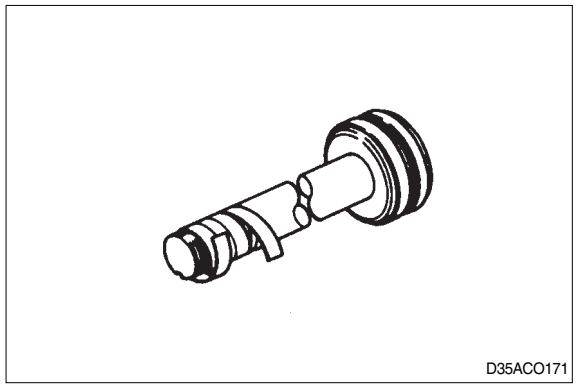


BR147HS15

1	Tube assy	5	Piston seal	9	Rod seal
2	Rod	6	Nut	10	Dust wiper
3	O-ring	7	Gland	11	O-ring
4	Piston	8	DU bushing	12	O-ring

2) DISASSEMBLY

(1) Hold the parallel parts of the cylinder tube bottom in a vice and mark the rod head end to show how much it is screwed in, then remove the rod head. Next, hook a wrench into the notch at the cylinder head and remove the cylinder head from cylinder tube.
When doing this, wind tape round the threaded part of the rod and be careful not to damage the dust seal and rod seal inside cylinder head.



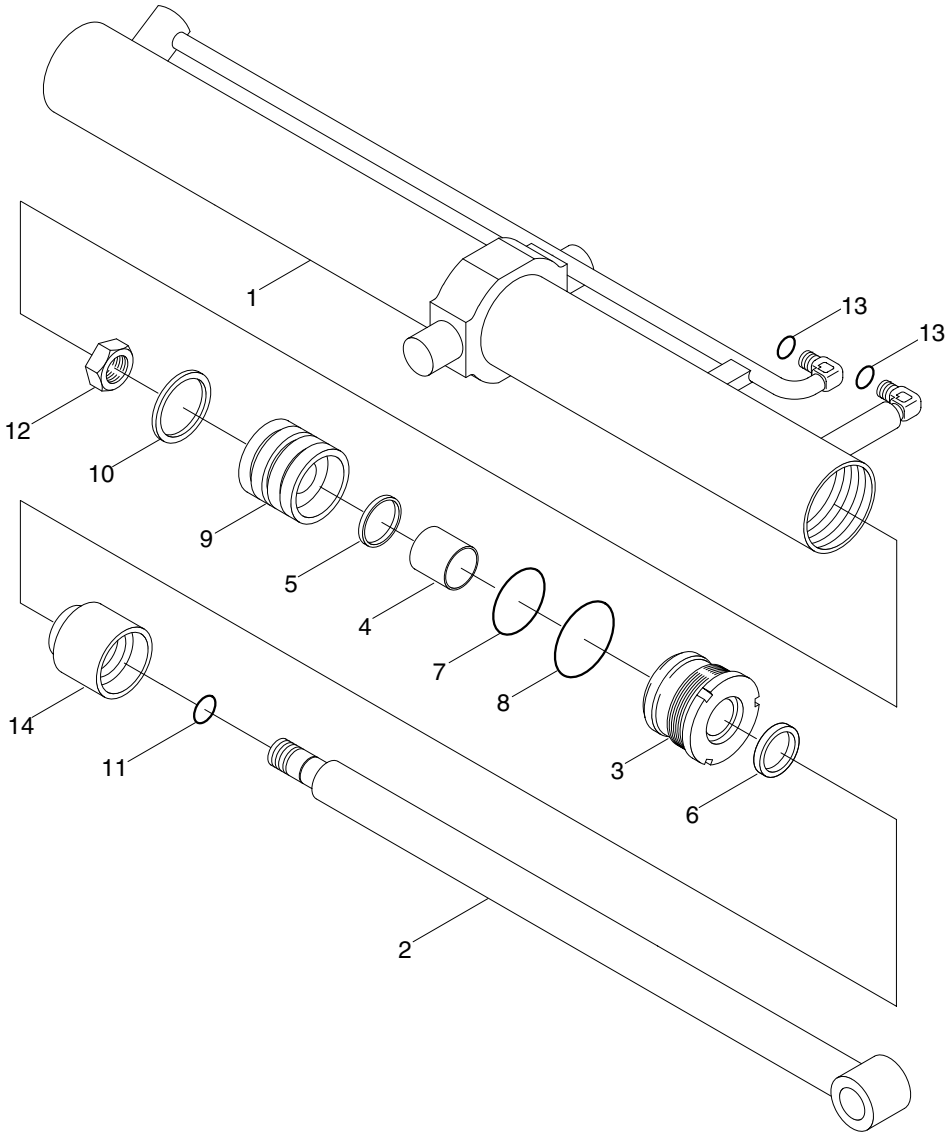
3) CHECK AND INSPECTION

mm(in)

Check item	Standard size	Repair limit	Remedy
Clearance between cylinder rod & bushing	0.072~0.288 (0.003~0.011)	0.5 (0.020)	Replace bushing
Clearance between rod head bushing & pin	0.10~0.35 (0.004~0.014)	0.6 (0.024)	Replace bushing

5. REACH CYLINDER

1) STRUCTURE

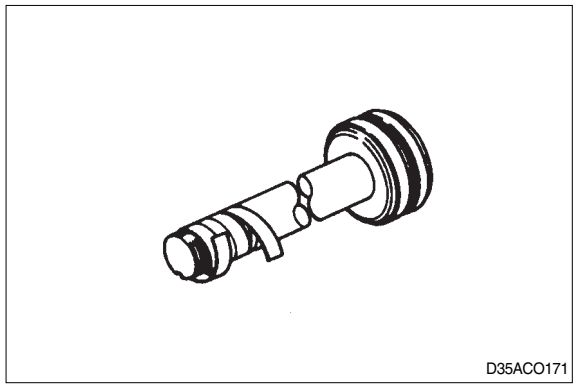


BR147HS21

1	Tube assy	6	Dust wiper	11	O-ringl
2	Rod assy	7	O-ring	12	Nylon nut
3	Gland	8	O-ring	13	O-ring
4	DU bushing	9	Piston	14	Spacer
5	Rod seal	10	Piston seal		

2) DISASSEMBLY

(1) Hold the parallel parts of the cylinder tube bottom in a vice and mark the rod head end to show how much it is screwed in, then remove the rod head. Next, hook a wrench into the notch at the cylinder head and remove the cylinder head from cylinder tube.
When doing this, wind tape round the threaded part of the rod and be careful not to damage the dust seal and rod seal inside cylinder head.



3) CHECK AND INSPECTION

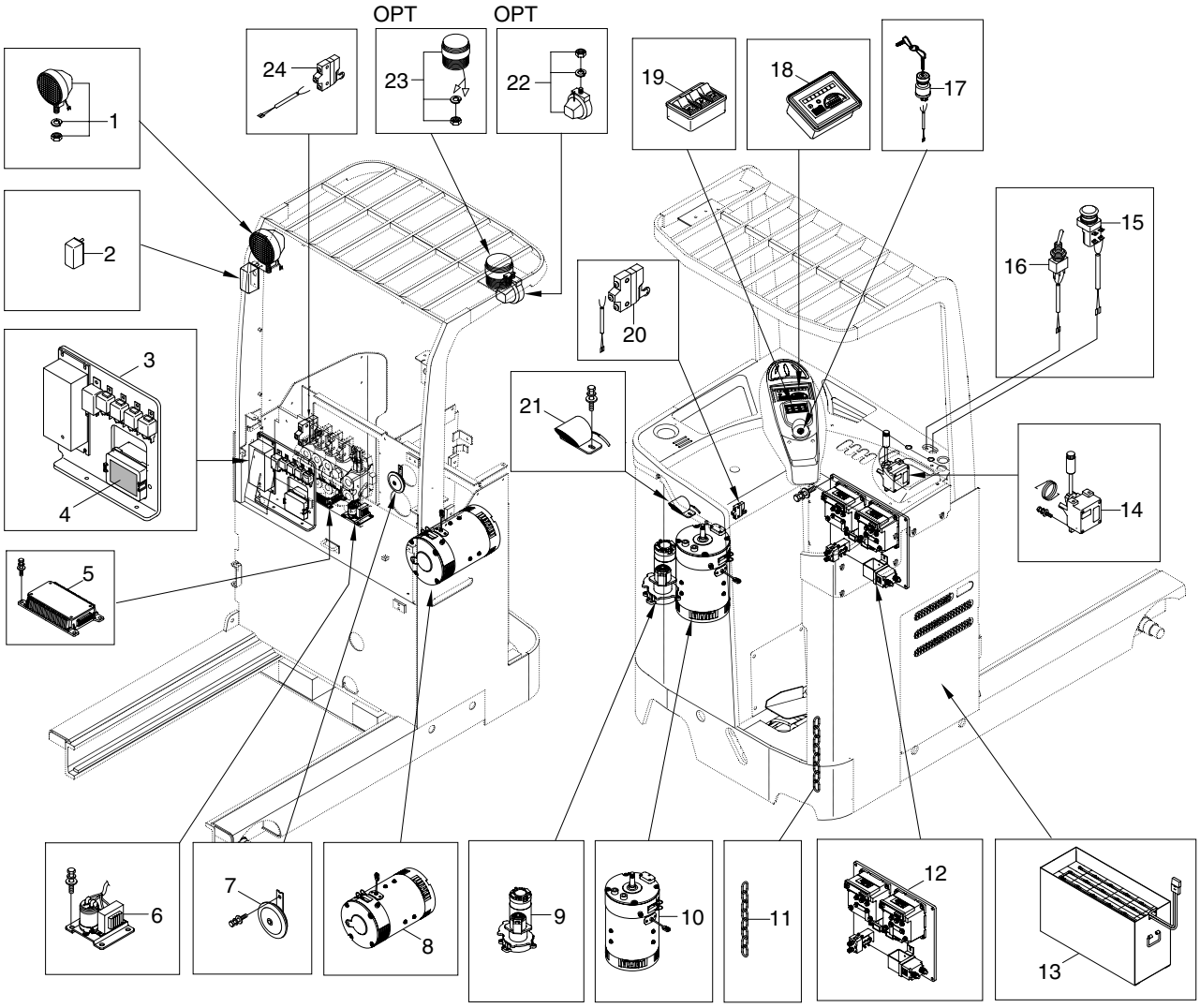
mm(in)

Check item	Standard size	Repair limit	Remedy
Clearance between cylinder rod & bushing	0.072~0.288 (0.003~0.011)	0.5 (0.020)	Replace bushing
Clearance between rod head bushing & pin	0.10~0.35 (0.004~0.014)	0.6 (0.024)	Replace bushing

SECTION 7 ELECTRICAL SYSTEM

SECTION 7 ELECTRICAL SYSTEM

GROUP 1 COMPONENT LOCATION

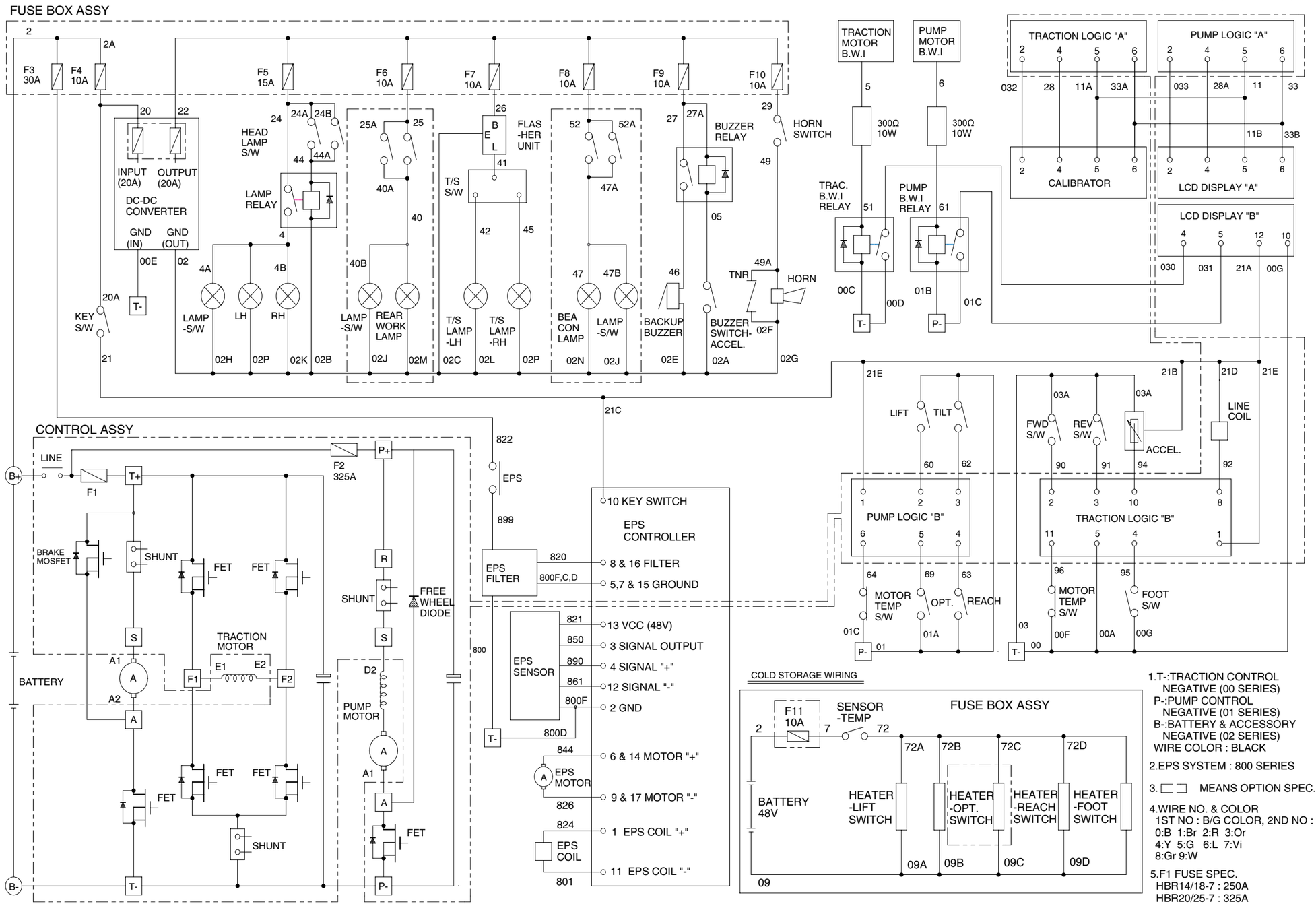


BR147EL01

1	Head lamp	9	EPS motor	17	Start switch
2	Flasher lamp	10	Drive motor	18	Monitor panel
3	Relay assy	11	Static chain	19	Switch assy
4	Fuse box	12	Control panel assy	20	Micro switch
5	EPS controller	13	Battery assy	21	Back buzzer
6	EPS filter	14	Accelerator assy	22	Rear work lamp(opt)
7	High horn assy	15	Horn switch	23	Beacon lamp(opt)
8	Pump motor	16	Flasher lamp switch	24	Micro switch

GROUP 2 ELECTRICAL CIRCUIT

HBR14-7(-#0006), HBR15-7(-#0018), HBR18-7(-#0022)
HBR20-7(-#0023), HBR25-7(-#0010)



1.T-:TRACTION CONTROL
NEGATIVE (00 SERIES)
P-:PUMP CONTROL
NEGATIVE (01 SERIES)
B-:BATTERY & ACCESSORY
NEGATIVE (02 SERIES)
WIRE COLOR : BLACK

2.EPS SYSTEM : 800 SERIES

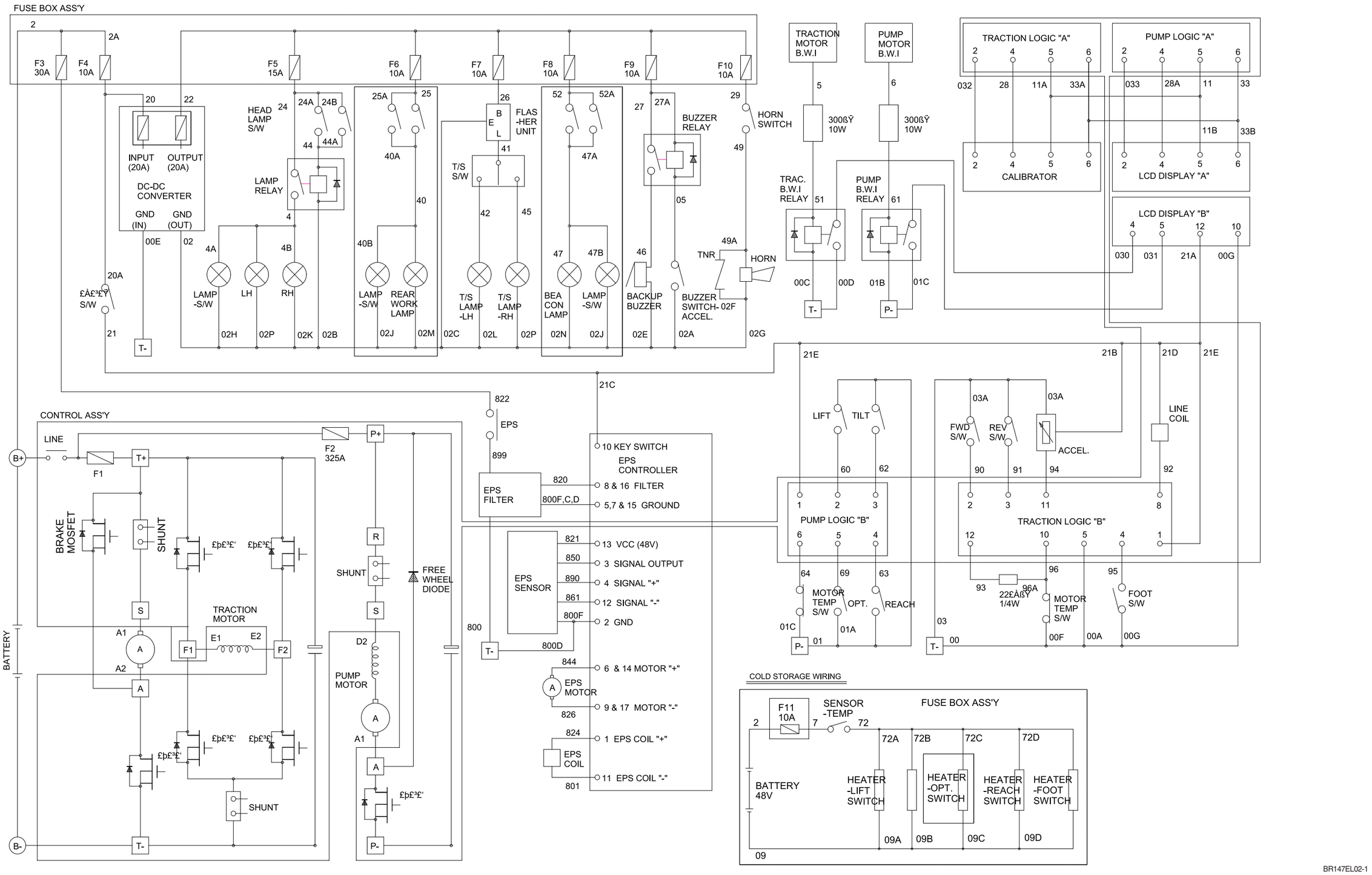
3. ⊏ ⊐ MEANS OPTION SPEC.

4.WIRE NO. & COLOR
1ST NO : B/G COLOR, 2ND NO : STRIPE COLOR
0:B 1:Br 2:R 3:Or
4:Y 5:G 6:L 7:Vi
8:Gr 9:W

5.F1 FUSE SPEC.
HBR14/18-7 : 250A
HBR20/25-7 : 325A

BR147EL02

HBR14-7(#0007-), HBR15-7(#0019-), HBR18-7(#0023-)
HBR20-7(#0024-), HBR25-7(#0011-)



BR147EL02-1

GROUP 3 ELECTRIC COMPONENTS

1. FUNCTIONS OF BATTERY FORKLIFT TRUCK AND ELECTRIC COMPONENTS.

The major functions of forklift truck can be divided into DRIVING FUNCTION and LOADING & UNLOADING FUNCTION.

All the components that work DRIVING and LOADING & UNLOADING functions are driven by MOTORS. And as the BATTERY works as power source of these motors, a charging device is needed.

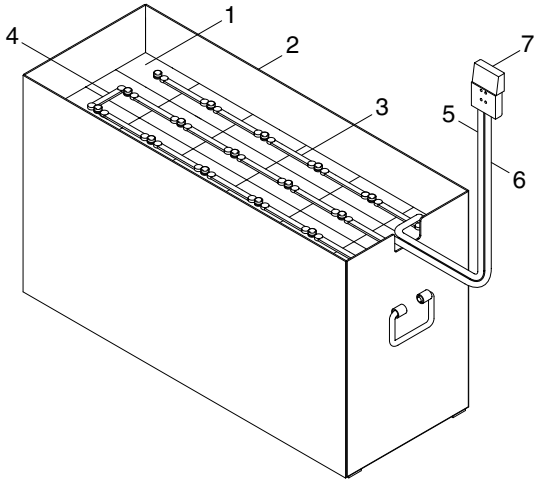
To drive the fork lift truck, a DRIVING CONTROL SYSTEM and some electric components such as direction change lever(forward/reverse section switch) and accelerator are required to select the driving direction and to control the speed of driving motor.

The CONTROL SYSTEM includes some protective circuits that protect the equipment and components from malfunctioning.

A MONITORING SYSTEM is installed in the monitor panel, which monitors the equipment and working condition, and let the operator take proper action. For the monitoring system, there are many sensors such as current sensors, hydraulic pressure sensors, and temperature sensors. The HYUNDAI HBF series are equipped with the most advanced DRIVING CONTROL SYSTEM currently available world-widely. The operator friendlyness features enable him to set the vehicle conditions properly according to each working circumstance easily on his seat, and the SELF-DIAGNOSTIC function displays current status of vehicle in working.

2. BATTERY

1) STRUCTURE

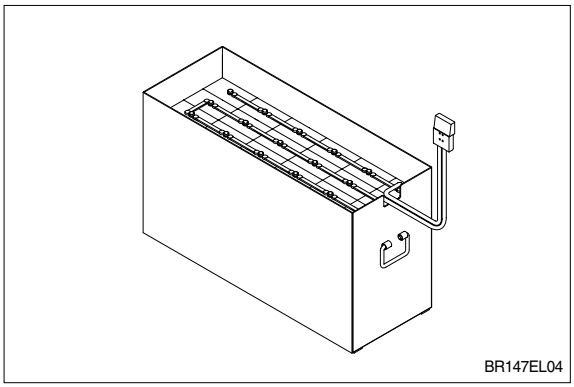


BR147EL03

1	Cells	5	Negative leading cable
2	Steel box	6	Positive leading cable
3	Cell connector	7	Connector
4	Row connector		

2) GENERAL

As in the battery forklift, the battery is an energy source, the handling of the battery is very important. The life and performance of the battery greatly depend on the ordinary handling and maintenance.
Therefore, be sure to check and maintain the battery so that it may be kept best.



3) SPECIFICATION AND SERVICE DATA

(1) HBR14/15/18-7

Item	Unit	HBR14/15-7(STD)	HBR14/15-7(OPT) HBR18-7(STD)
Model	-	VCF 280	VCI 335
Rated voltage	V	48	
Capacity	AH/hr	280/5	335/5
Electrolyte	-	WET	
Dimension(W×D×H)	mm	994×378×581.7	
Connector(CE spec)	-	SB350(SBE320)	
Weight	kg	480	560

(2) HBR20/25-7

Item	Unit	HBR20/25-7
Model(Type)	-	VCI 335
Rated voltage	V	48
Capacity	AH/hr	335/5
Electrolyte	-	WET
Dimension(W×D×H)	mm	994×378×581.7
Connector(CE spec)	-	SB350(SBE320)
Weight	kg	560

Fully charged specific gravity	1.280(25°C)
End of discharge specific gravity	1.130(25°C)
Discharge end voltage	48V
Electrolyte	Refined dilute sulfuric
Replenishment fluid	Refined water(pure water)
Insulation resistance	More than 1MΩ

4) SAFETY PRECAUTIONS

(1) When a sulfuric acid contact with skin

For acid contact with skin, eye or clothing, flush with water immediately. If swallowed, drink a large amount of water or milk. Seek medical attention immediately. When handling acid, always wear eye goggles or a face shield and rubber gloves.

(2) Strict prohibition of fire and ventilation

Since batteries generate explosive hydrogen gas, no fire should be drawn near. Before the battery charging, keep the steel tray cover open and check the ventilation status. Charging in an enclosed space can cause a explosion.

(3) Never place metallic articles on the batteries

If done so, it may cause “short circuit” accidents(dangerous especially while charging).
Sparks will be generated which is equally dangerous as open fires.

(4) Handling of charger

When connecting or disconnecting a battery from a charger or attempting maintenance, make sure switches are all off. Ensure that the charger and the battery are matched. If a 300Ah battery is used with a charger designed to charge a 500Ah battery, it will severely overcharge the battery.

5) OPERATION PRECAUTIONS

(1) Avoid over-discharge

If over-discharged, it will be difficult to restore the batteries to the original state by recharge. In order to maintain the batteries in use for long period of time, it is recommended to use the batteries with discharge amount not exceeding 80% of the rated capacity. Further care should be taken for preventing the unit cell voltage from falling below 1.5V.

(2) Avoid over-charge

If overcharged, the rise in battery temperature will become excessive, resulting in deterioration of plates and other parts and markedly shortening of battery life.

(3) Avoid excessive elevation of temperature

Be sure to open the cover of battery housing tray before charging. If there is a possibility of temperature to exceed 55℃, discontinue the charge operation temporarily, or reduce the charge current.

6) INSTRUCTION

(1) Unpacking

Electric traction storage batteries(herein after refer to as “batteries”) are delivered to customers in dry-charged condition. At unpacking, check whether the batteries and accessories have been damaged. If there are observed defects, you should notify the condition to our branch office or agent. Never remove the sealing plug until the battery is put into service.

(2) Filling electrolyte

The cells should be filled with electrolyte being sulfuric acid solution, 1.280±0.01 specific gravity at 25℃, before initial charge is fulfilled. The temperature of the cells and filling electrolyte should be between15℃ and 30℃. Electrolyte level comply with the page7-10. The cells are allowed to stand for more than 2 hours and then the levels are adjusted by the addition of electrolyte in 1.280 ±0.01 specific gravity at 25℃, to the proper levels.

(3) Performance and maintenance of batteries

① Initial charge

Dry-charged battery gradually decrease its capacity during storage. In order to provide sufficient discharge capacity in the first discharge, the good initial charge is required. The conditions of initial charging are seen as below at room temperature.

a. By modified constant voltage charger

Connect the battery to the charger and turn on the equalizing charge "ON". The battery will be fully charged and terminated automatically.

b. By constant voltage constant current charger

Connect the battery to the charger and turn on the equalizing charge "ON". The battery will be fully charged and terminated automatically.

c. By constant current charger

Connect the charger to the battery and charge the battery by 0.1C×5 hour rate nominal capacity current for 24 hours or more. The charge shall be terminated when one of the following condition is identified.

- When a constant value is indicated for more than 1 hour after the battery voltage has reached the maximum value.
- When more than 1 hour of charge is continued after the electrolyte specific gravity has risen fully and becomes constant.

② Discharge and capacity

The capacity of batteries is indicated at 5 hour rate capacity which means the battery can be discharged for 5 hours with the discharge current calculated by dividing the capacity value by 5 until the unit cell mean voltage reaches down to 1.7V at the electrolyte temperature of 30° C.

That is, the capacity is indicated by AH(ampere hour) being calculated as the product of ampere(A) and time(H). However, even in the same type of batteries, the capacity varies with the discharge conditions(discharge current, battery temperature and specific gravity of electrolyte) Even if the batteries discharged its full capacity, if immediately charged to full, there will be no harmful effects remained. Ideal charging amount(AH) is 110-125% of the amount of previous discharge.

③ Specific gravity of electrolyte

Specific gravity of electrolyte drops at discharge and rises at charge. When the batteries are fully charged, it becomes almost constant and shows no further rise. The specific gravity value varies with the change in temperature. Therefore specific gravity measurement should be made with temperature of electrolyte at the same so the measured specific gravity value could be corrected to that at the standard temperature of 25°C by the following formula.

$$S_{25} = S_t + 0.0007(t-25)$$

Where, S_{25} : Specific gravity at 25°C

S_t : Actually measured specific gravity at t °C

t : Electrolyte temperature (°C)

The standard specific gravity for this type of battery is 1.280±0.01(25℃) at full charge condition.

If the electrolyte is decreased naturally while using, distilled water shall be replenished up to the specified level. (Never refill sulfuric acid)

Only when large quantity of electrolyte is lost due to spillage, etc., dilute sulfuric acid specified in gravity shall be added.

④ **Normal charge**

Charge the discharged batteries as quickly as possible. The temperature of electrolyte before starting the charging operation shall preferably be below 45℃, and the temperature during the charge should be maintained at no higher than 55℃. (Under any unavoidable situations, it should never be above 55℃). Methods of charging varies in precise meaning with the types of chargers used. A standard charging method is described hereunder. (If a special method is mentioned to be adopted, follow that instruction).

a. Charging by modified constant voltage automatic charger

There is almost automatic charger today which complete the charging just only connecting the plug between battery and charger without outer operating timer but if your charger has it, after setting the timer for 3-4 hours and turn on the charger and the charger is left as it is, then the charge will be made automatically. In principle, regardless of the amount of previous discharge, it is not required to alter the setting of timer time. The recommendable current value of this type of charger is "5 hour rate current $\times$1.0~1.5" at the start of charging, and at the final stage it is "5 hour rate current $\times$0.15~0.25". Normally the charge is terminated within 8~12 hours automatically.

b. Charging by constant current constant voltage automatic charger

After a lapse of specified charging time after the switch is turned on, the charge will be completed by turning off the switch. The charging time can be calculated by the following formula.

$$\text{Charging time} = \frac{\text{Amount of previous discharge(AH)}}{\text{Capacity of charger(A)}} + 2\sim3\text{(H)}$$

When the amount of previous discharge is not known, use the 5 hour rate rated capacity of the batteries. At immediately after charging, the charge current is allowed up to 3 times 5 hour rate current. For charger provided with a timer, the charge will terminate automatically if the timer is set at the specified time according to the operation manual.

⑤ **Equalizing charge**

When large number of cells are used in a set of battery, the voltage and specific gravity of respective cells tend to become unequal, resulting in necessity of charging all the cells at an appropriate time in order to equalize them. This is called equalizing charge. Normally the equalizing charge should be carried out once every month. The methods are in normal type charger, extend the charge for 5 more hours after full charge at the final stage current, and in automatic charger which are in most cases provided with timer, extend the time setting for 3-6 more hours.

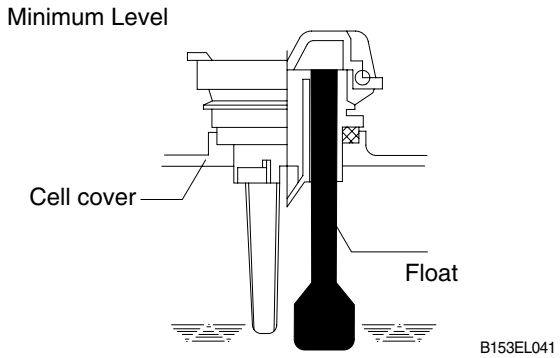
⑥ **Water replenishment**

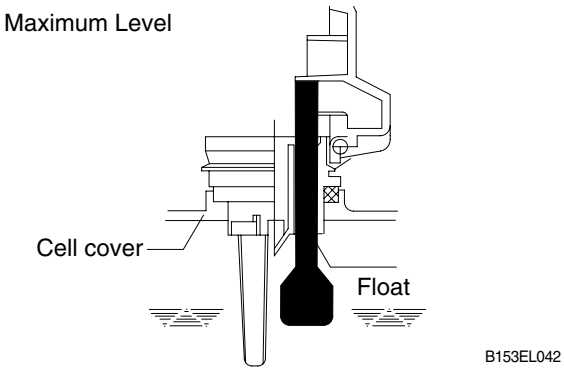
Only the water content of electrolyte is decreased due to electrolysis of water during charge and natural evaporation. If a battery used with the electrolyte decreased excessively, plates will deteriorate resulting in markedly shortening of battery life. Be sure to check the electrolyte level once every week. If the electrolyte level is lowered, replenish distilled water up to the specified level. In this case, never attempt to replenish sulfuric acid or tap water. Use only distilled water for battery replenishment. If the amount of water required for weekly addition to a unit cell for 100AH of battery capacity is in excess of 45cc, it is assumed that the cell is receiving overcharge. Accordingly, be sure to reduce slightly the daily charge amount. Under the normal conditions, the addition of water per week is 45cc or less. Incidentally, water replenishment should be made before charging to the contend of minimum level.

(for the purpose of uniform stirring of electrolyte by charging). If the electrolyte level is improper after completion of charging, you may topping up the electrolyte level to the maximum level .

a. Determination of replenishment time and methods(cell with ONE TOUCH CAP)

Confirm the electrolyte level by looking at the float in the ONE TOUCH CAP. If too low as shown in figure, replenish water. Replenishment shall be performed after opening the cover of the plug using syringe and jug. When refilling is completed, close each cover completely until “click” sound is heard.





⑦ Cleaning

If electrolyte spills or the cells are polluted with dust or stains, it will cause generation of leak current. Wipe off dust and stains with moist cloth and clean in such a manner that the cells are kept in dry condition. In the case of plastic containers or covers, never use such organic solvents as paint thinner and gasoline. If used, the plastic containers or covers may suffer cracking. If you are forced to use them, be sure to use white kerosene.

⑧ Notice on charging

The charging area must be well ventilated to facilitate exhaust of gas generated from the battery during charging. Charge the battery in an area free from iron working, welding, etc. Further the battery generates hydrogen, oxygen, acid mist and on rare occasions, hydrogen sulfide during charging depending on the case. Special care may be required in the case of equipment and objects near the battery that may contaminated or damaged. Do not pull out the charging plug during charging, as it will cause sparks. Since hydrogen gas generated during charging may remain in the area surrounding the battery after charging, never bring fire or flame close to this area. In case of counter-balance type vehicles, open the battery cover before charging.

⑨ Repair of failure cell

a. To remove a cell from the circuit or battery from steel tray, it is first necessary that the intercell connector be removed.
b. Before performing any repairs, you must open one-touch caps for gas purging of all cells. After you have finished that, must remove connector covers and on-touch caps from failure cell including surrounding cells. All vent holes of cells removed of one-touch caps must cover by four layers of water dampened cloth and then proceed with repairs. Using an acid syringe withdraw sufficient electrolyte from failure cell to reduce the liquid levels until minimum level indicating of one touch caps.
c. The safe and most efficient method of removing a connector is with hand or electric drill(ø 25㎜) from failure cell as well as all surrounding cells.

⚠ You must make sure to clear of explosive hydrogen gas in the cells before repairs. Be careful not to drill to far into the cell and damage the unit. During drilling operation make sure lead curls produced do not contact opposite cell poles and cause a spark.

d. Upon completion of drilling the intercell connectors, can be lifted off.
e. Lifted off the failure cell from circuit after removing of intercell connector.
f. Installing new cell and connector.
g. With surfaces properly cleaned and neutralized, position the connectors.
h. Place damp rags around each lead head. Hold tip of the welder in center of post move welder completely around top of post and out to the area where the post meets the connector. Move welder back to center of post and add molten lead until area is filled to top of connector. Again, move welder completely around area, with tip on molten lead. If you have jig for welding connector, have easier and better welding work.
i. When replacing electrolyte in a repaired cell, use sulphuric acid of the same specific gravity that is found in the balance of the battery.
j. Finally, rejoin connector covers and one-touch caps to the cells.

⑩ **Summary of daily maintenance**

a. Avoid overcharge. After discharge, charge the batteries immediately. The standard frequency of equalizing charge is more than once every month.
b. Check the electrolyte level once a week. If found decreased, replenish distilled water up to the specified level.
c. The top surface of battery cells should be kept clean and dry.
d. Be sure to keep open the cover of battery housing tray during charge.
e. Never draw near open fires such as lighted cigarettes or burning matches during charge.

(3) Others

① **Storage of batteries**

When batteries are stored, keep them distant from room heaters or other heat generating sources. Clean, cool and dry place where no direct sunlight is directed is suited for battery storage. Before putting into storage, it is important to charge the batteries and keep the electrolyte level at the specified level. When the temperature in storage location is higher than 20℃, check the specific gravity once a month, and when lower than 20℃, check it once every two months. If the measurements show values lower than 1.230(20℃), it is required to charge the battery in accordance with the method described in NORMAL CHARGE.

② **Maintenance record**

It is recommended to keep maintenance record in order to know the operational conditions of batteries. Daily charge and discharge, equalizing charge requirements, and water replenishment requirements can be clarified at a glance. Measurements of specific gravity and temperatures once every two to four months after equalizing charge and maintenance thereof will serve for battery health diagnosis.

③ **Electrolyte temperature**

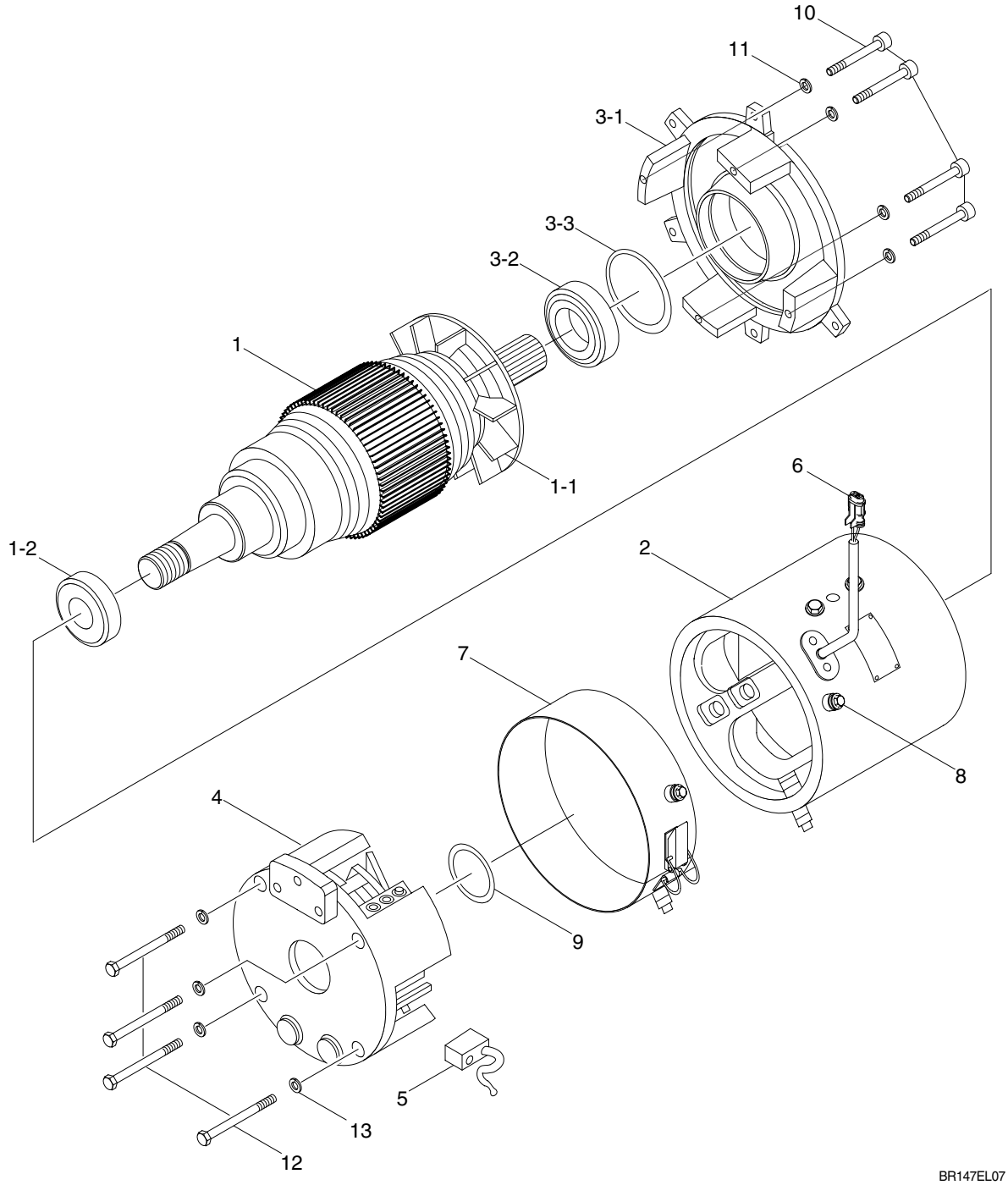
The operating temperature range of batteries is -10~45°C(temperature of electrolyte). If the batteries are exposed to cold atmosphere in discharged condition, the electrolyte may freeze, and in extreme cases, the capacity will be decreased, but, if not frozen, no adverse effects will be exerted over the life. Contrarily if the temperature is high, especially if used at above 55℃, the battery life will be considerably shortened. Care must be taken so that the temperature during charge will be maintained at 55°C or lower. Even under unavoidable circumstances it should not exceed 55°C.

7) TROUBLESHOOTING

Nature of trouble	Symptoms	Causes	Repair
Deformation	· Deformation of container, lid or one touch cap	· Excessive temperature rising or external impact	· Replace
Breakage	· Electrolyte leakage according to breakage of container, lid or one touch cap	· External impact, improper handling, excessive vibration	· Replace or install a new one
	· Termination of connector or pole post etc.	· Excessive temperature rising or vibration/external impact	· Replace
Sulfate	· Specific gravity drops and capacity is decreased.	· When left in state of discharge or left long without equalizing charge.	· Need equalizing charge
	· Charge voltage rises rapidly with immature gassing in earlier stage but specific gravity does not rise and charge can't be carried out.	· Insufficient charge.	· Need equalizing charge
		· When electrolyte is so decreased that plate is deposed.	· Need equalizing charge
		· When concentration of electrolyte rises.	· Adjust specific gravity
		· When impurities are mixed in electrolyte.	· Replace electrolyte
Decrease and falling of specific gravity	· May be easily detected by measurement of the specific gravity.	· Rise of temperature due to such trouble.	· Replace
		· When left long period without refilling of water.	· Refill water in regular period
		· Short circuit.	· Replace
Rise of specific gravity	· May be easily detected by measurement of the specific gravity.	· Diluted sulfuric acid is used in refilling.	· Adjust specific gravity after full charge.
		· When the electrolyte level excessively drops.	· Refill distilled water.
Mixing of impurities	· Decrease of capacity.	· Metals such as iron, copper, nickel and manganese.	· Under a fully discharged condition, pour out the electrolyte. Then pour in an acid of the specific gravity higher by 0.03~0.05 than that of the drained acid. Charg fully and adjust the specific gravity to the specified value.
	· Drop of charge and discharge voltage.	· Impurities such as sea water, chloric acid, nitric acid etc.	
	· Odor of generated gas and coloring of the electrolyte.	· Filling of impure water.	

3. DRIVE MOTOR

1) STRUCTURE



BR147EL07

1	Armature assy	3-3	Retaining ring	10	Hexagon bolt
1-1	Fan	4	Endbell comm assy	11	Spring washer
1-2	Bearing	5	Brush kit	12	Hexagon bolt
2	Field & frame assy	6	Thermostat	13	Spring washer
3	Endbell de assy	7	Headband assy		
3-1	Endbell de	8	Terminal		
3-2	Bearing	9	Wave washer		

2) SPECIFICATION

Item	Unit	HBR14/15/18-7	HBR20/25-7
Model	-	KUDF4003	KNAS4005
Type	-	SEM, self ventilated	
Rated voltage	V	48	
Rated output	KW	5.0	
Brush size	mm	16×32×30	
Insulation	-	Class H	

3) EXTERNAL INVOLUTE SPLINE DATA

(Unit : mm)

Item	HBR14/15/18-7	HBR20/25-7
Involute spline shaft	25×13×1.667	DIN5480-25.1×1.25×30×18
Adendum modification	+0.800	+0.5625
Number of teeth	13EA	18EA
Pitch circle dia	Ø21.667	Ø22.5

(1) Tooth

(Unit : mm)

Item	HBR14/15/18-7	HBR20/25-7
Tooth type	Stub tooth	Stub tooth
Module	1.667	1.25
Pressure angle	20°	30°

(2) Teeth profile

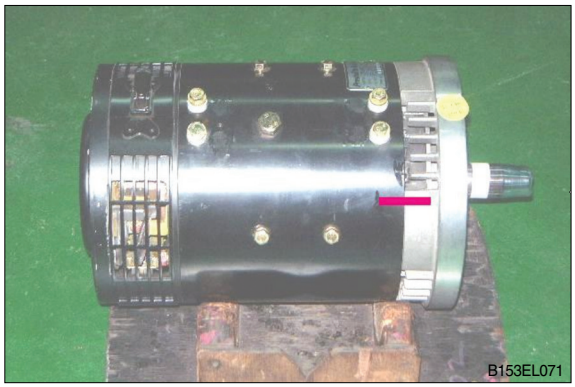
(Unit : mm)

Item	HBR14/15/18-7	HBR20/25-7
Accuracy grade	JIS A grade	DIN 5480
Over pin dia	Ø27.563(Pin dia Ø3)	Ø28.050(Pin dia Ø2.75)
Thickness of tooth	Ø13.516(3EA)	Ø13.446(4EA)

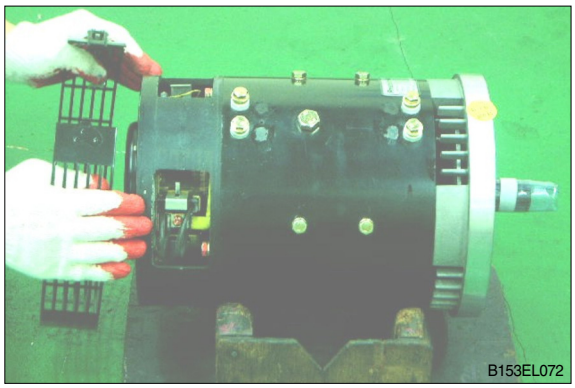
4) DISASSEMBLY

(1) Before starting disassembly, measure the insulation resistance of armature, field coil by insulation resistance(500MΩ).

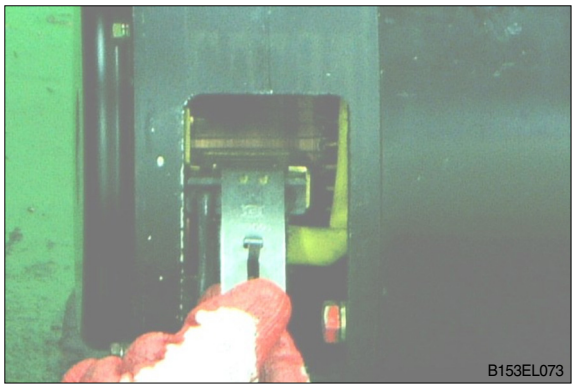
(2) Punch alighning marks on drive side endbell and frame.



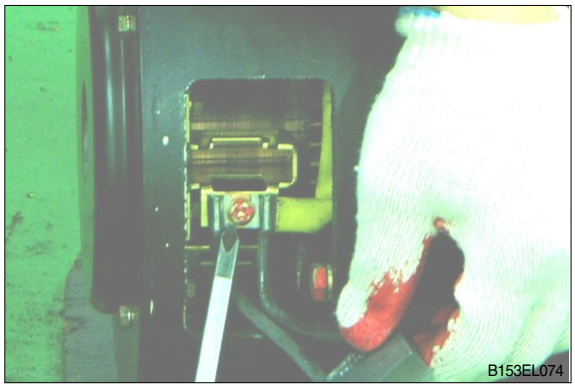
(3) Remove the commutator side cover.



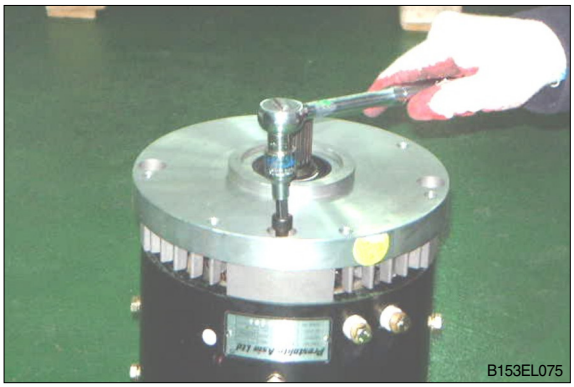
(4) Remove 4 brush springs and 4 brushes.



(5) Remove screws and brushes from brush holder assembly.

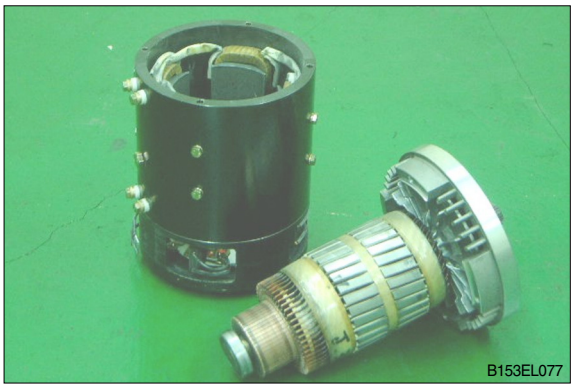


(6) Remove 4 bolts on the drive side endbell, using L wrench.

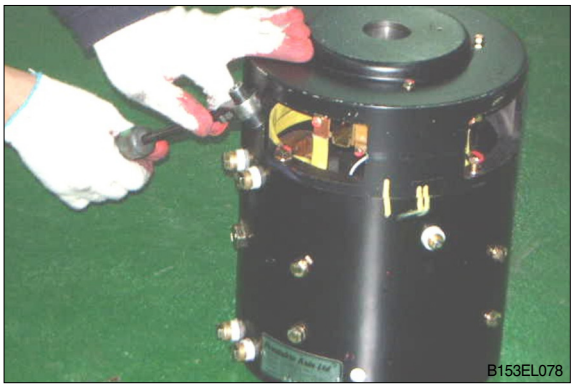


(7) Remove armature and drive-side endbell by lifting up straightly.

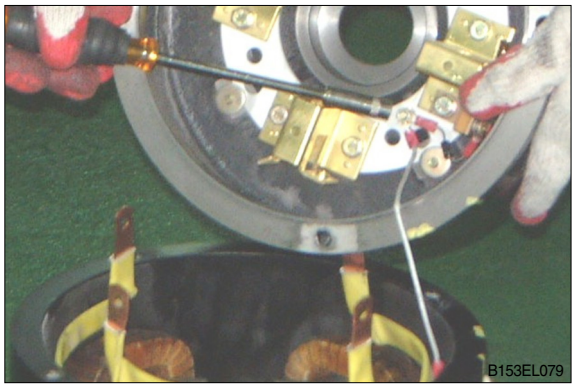
Armature assembly, drive side endbell and field & frame assembly after disassembling from motor.



(8) Remove 4 bolts on the commutator side endbell.

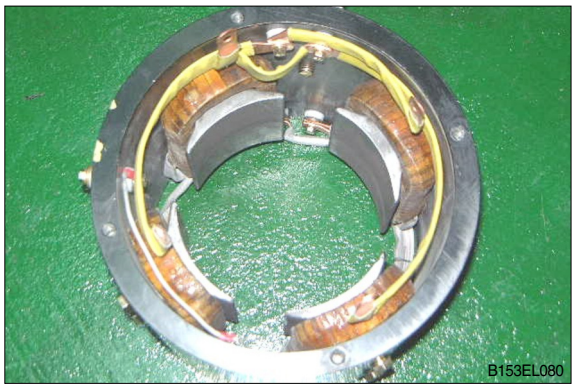


(9) Remove BWI lead wire from commutator side endbell.

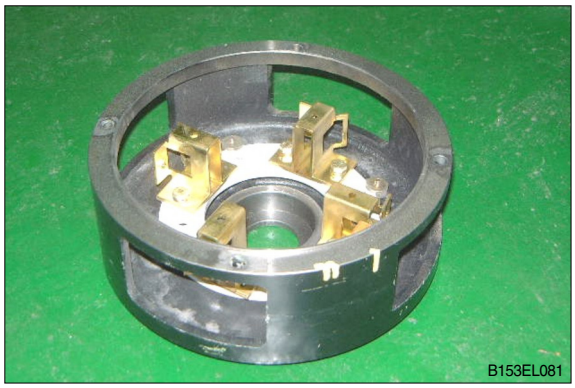


(10) Picture after disassembly

① Field & frame assembly



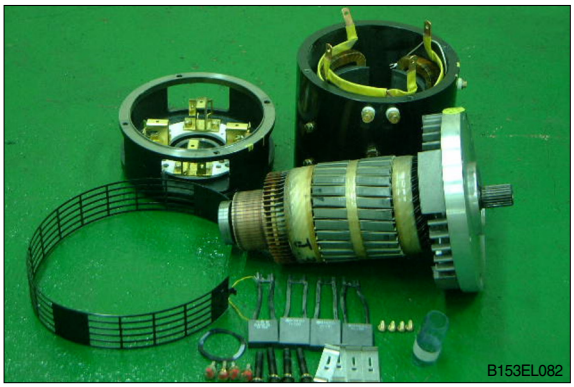
② Brush holder assembly



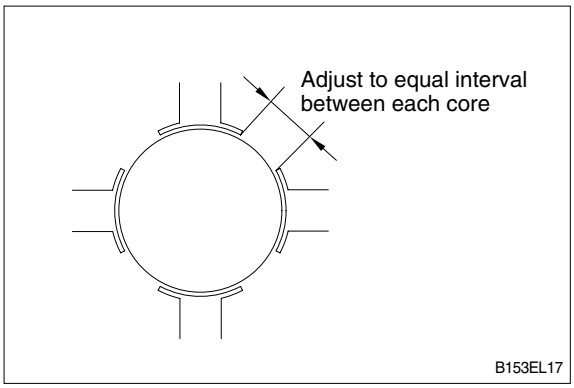
5) ASSEMBLY AND INSTALLATION

(1) Perform the assembly in the reverse order of disassembling.

(2) The motor is composed of four parts. armature assembly, field & frame assembly, endbell commutator assembly, etc.



(3) After removing the field coil from frame, distance between core and core should be adjusted equally at disassembly.



※ **After completing assembly, perform the followings and check.**

(1) Are the bolts, nuts, and other fasteners tightened properly?
(2) Are there errors in wiring, and are the connections tight?
(3) Are the insulation resistance more than 1MΩ?
(4) Are the brushes making good contact with the commutator?
(8) Is the commutator surface clean?
(6) Does the armature turn smoothly when rotated by hand?

⚠ **The series motor when operated without load will rotate up to extremely high speed. To prevent this dangerous condition, never run the series motor without load.**

6) TROUBLE SHOOTING

Problem	Probable cause	Remedy
1. Motor fails to start.	· Brush contact faulty. · Wire breakage of faulty connection. · Field coil shorted or open. · armature coil shorted or open.	· Check brush to commutator contact. · Check connections. · Replace winding. · Check armature winding.
2. Motor turns in reverse direction	· Connection reversed.	· Reverse armature circuit connections.
3. Motor turns but speed fails to rise	· Armature circuit connection defective. · Supply voltage low.	· Replace armature. · Check supply voltage (battery)
4. Motor overheats	· Fault cooling, dirt accumulated. · Coil short circuited. · Load to large.	· Clean motor interior. · Check coils. · Check for dragging brakes, etc.
5. bearing heat up	· Improperly installed. · Bearing defective, grease deteriorated.	· Check installed condition. · Replace with new part.
6. Abnormal noise and vibration	· Loosening in body. · Foreign object inside motor. · Looseness in bearing. · Faulty load coupling. · armature out of balance.	· Tighten loosened part. · Remove foreign object and check other parts. · Check bearing. · Check coupling with load. · Check balance weight.
7. Commutation device	· Commutator defective · Armature winding shorted or open brush improperly positioned. · High mica.	· Check for commutator surface roughening and high mica. · Check armature winding. · Check brush position. · Undercut mica.

7) INSPECTION

(1) Armature inspection

① Check for roughness commutator, high mica, coil insulation, etc. If commutator surface is rough correct it with sandpaper (about No. 400) and throughly clean around the commutator with compressed air. If severely roughened, correct it by machining on lathe.

· Commutator diameter

New part size	82.5㎜
Repair limit	79.5㎜

② After correcting roughness undercut the mica. Undercut standard keeps 1.5~2.0㎜ deep and undercut limit 0.5㎜. If the depth of undercut becomes less than 0.9㎜, adjust the undercut to 1.0~1.5㎜ cutting mica. Cut of corner should be processed as the right figure not with regard to the depth of undercut.

(2) Cleaning armature

Armature should always be cleaned with compressed air. If the dirt will not come off, lightly wipe off with piece of cotton or soft cloth wetted with gasoline, using care not to damage the insulation.

⚠ Do not touch with the oil or grease on surface of commutator.

(3) Armature coil open circuit test. Use a multimeter(Ω range) and check for continuity between 29 piece of commutator tip.

Commutator consists of 57 piece of tip, so numbering 1to 57, check 3 parts between 1 to 30, 30 to 2, and 2 to 31.

If there is the extremely unblance and non conduce, replace with new part.

(4) Armature insulation test

Use insulation resistance meter(500V megger) and measure the insulation resistance between the shaft and a piece of commutator.

· Insulation resistance : More than 1MΩ

Clean and dry in order to insulate more than 1MΩ. If the insulation is defective, replace with new part.

(5) Clean field coils

Field coils should always be cleaned with compressed air. If the dirt will not come off, lightly wipe off with piece of cotton soft wetted with gasoline, using care not to damage the coil insulation.

(6) Field coil open circuit test

Use a multimeter(Ω-range) and check for conduct between the field coil terminals E-F.

There should be conductive. If not, replace with part as an assembly including yoke.

(7) Field coil insulation test

Use insulation resistance meter(500V megger) and measure the insulation resistance between the yoke and field.

· Insulation resistance : More than 1MΩ

Clean and dry in order to insulate more than 1MΩ.

If the insulation is defective, replace with new part.

(8) Brush inspection

Check the brushes to see if worn or contacting improperly.

Brush wear limit : 20㎜

New brush length : 40㎜

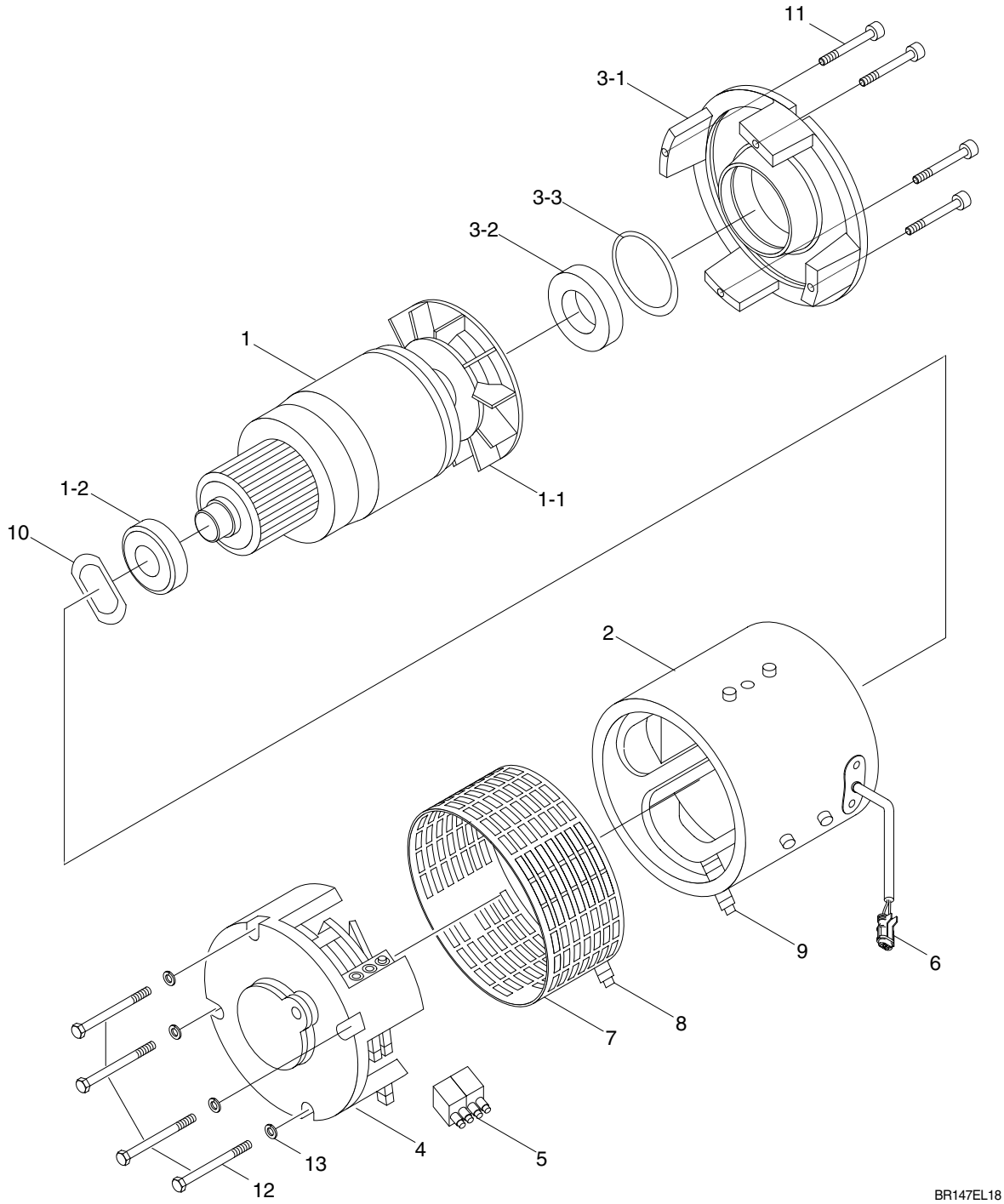
(9) Brush holder and brush pressure inspection

Check the brush holders for loose mounting bolts. And spring for breakage, etc. hook on spring scale to the brush holder spring and measure the spring tension pressing down the brush.

Brush pressure : 1㎏f

4. PUMP DRIVE MOTOR

1) STRUCTURE



1	Armature assy	3-3	Retaining ring	10	Wave washer
1-1	Fan	4	Endbell comm assy	11	Hexagon bolt
1-2	Bearing	5	Brush kit	12	Hexagon bolt
2	Field & frame assy	6	Thermostat	13	Spring washer
3	Endbell de assy	7	Headband assy		
3-1	Endbell de	8	Terminal		
3-2	Bearing	9	Terminal		

2) SPECIFICATION

Item	Unit	Specification
Model	-	KNAQ 4004
Type	-	D.C. series, self ventilated
Rated voltage	V	48
Rated output	kW	9.5
Brush size	mm	16×20×25
Insulation	-	Class H

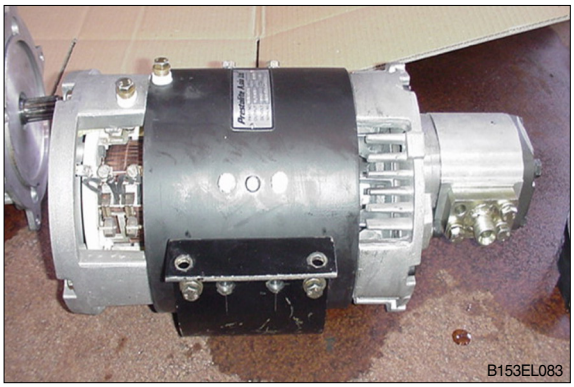
3) INTERNAL INVOLUTE SPLINE DATA

Item	Unit	Specification
Flat root side fit	-	ANSI B92.1 - 970
No of teeth	EA	10
Spline pitch	mm	16/32
Pressure angle	Degree	30
Major diameter	mm	18.110max
Form diameter	mm	17.577
Minor diameter	mm	14.478/14.650
Pin diameter	mm	2.743
Over pins	mm	11.910

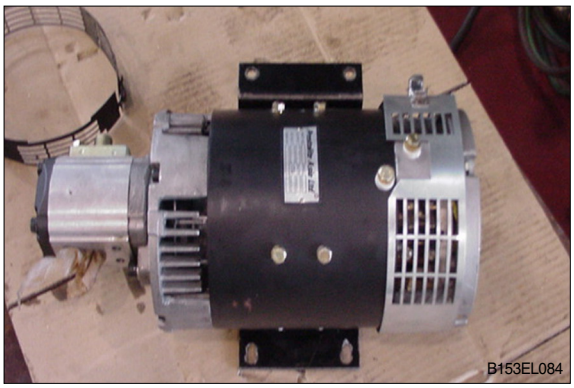
4) DISASSEMBLY

(1) Before starting disassembly, measure the insulation resistance of armature, field coil by insulation resistance(500V Megger).

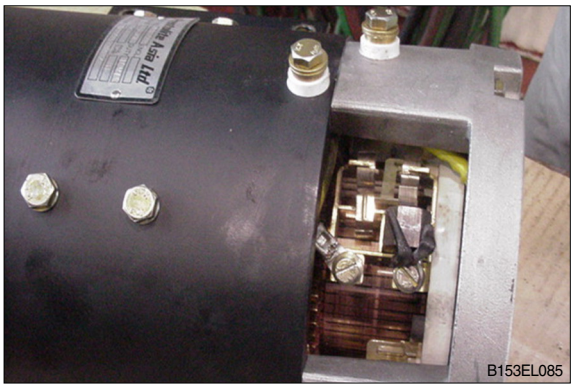
(2) Punch alighning marks on the commutator side cover.



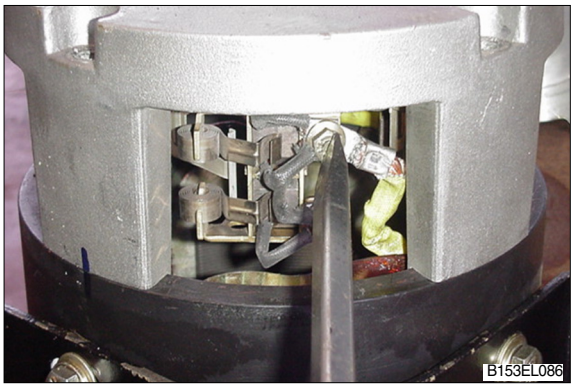
(3) Remove the commutator side cover.



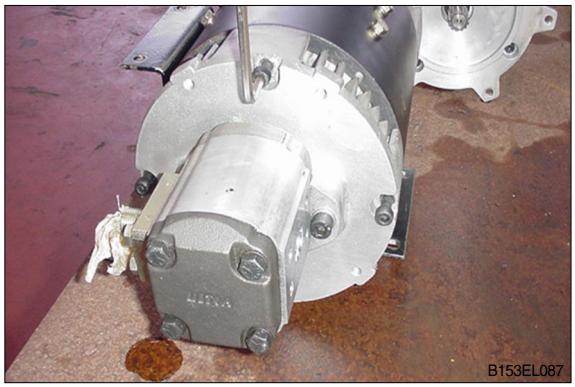
(4) Remove 8 brushes.



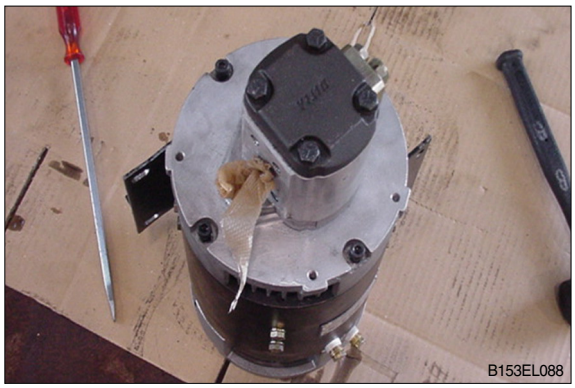
(5) Remove the wiring (+) and (-) from brush holder assembly.



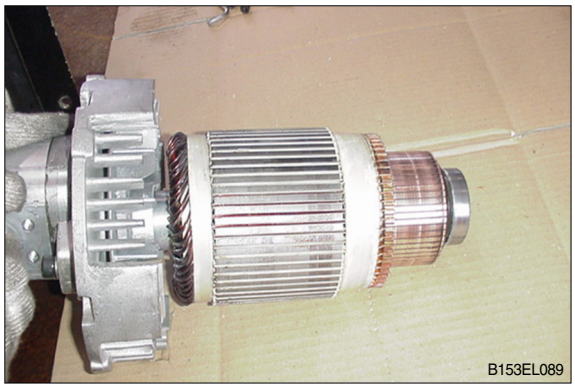
(6) Remove 4 bolts on the drive side endbell, using L wrench.



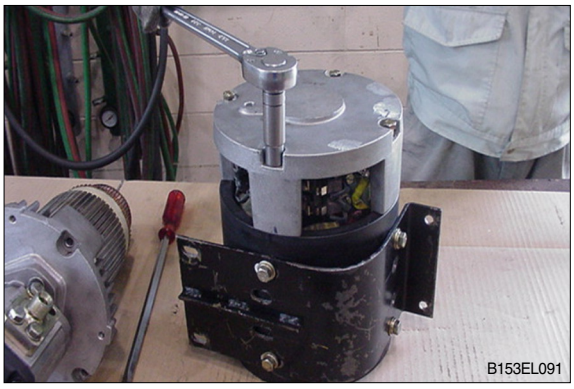
(7) Remove armature and drive side endbell by lifting up straightly. (below)



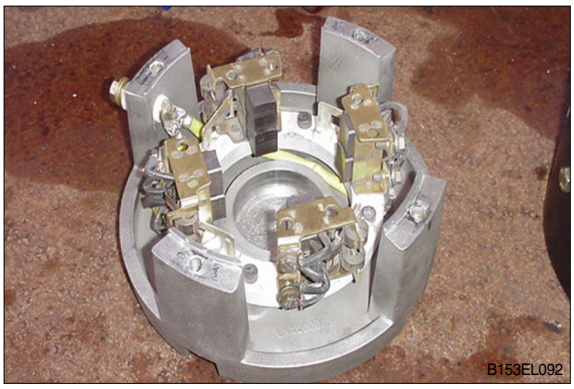
Armature assembly and drive side endbell.



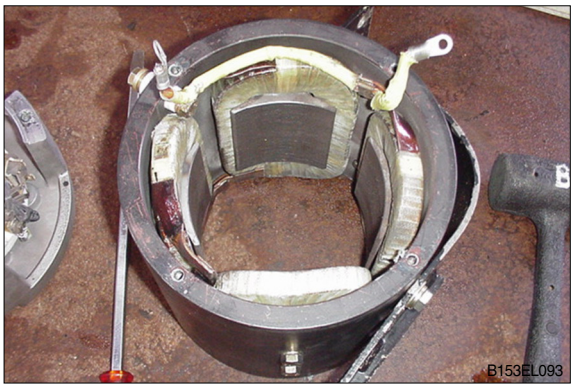
(8) Remove 4 bolts on the commutator side endbell. (below)



① Brush holder assembly



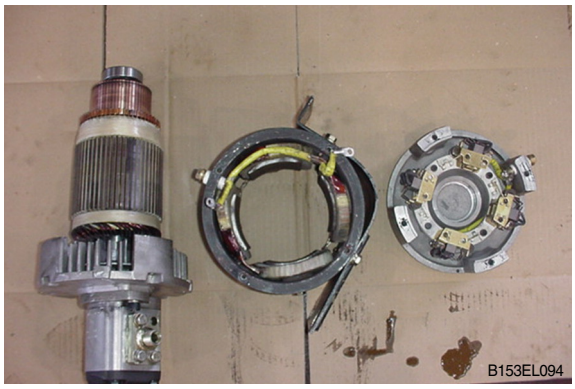
② Frame and field assembly.



5) ASSEMBLY AND INSTALLATION

(1) Perform the assembly in the reverse order of disassembly.

(2) The motor is composed of three parts, armature assembly, frame and field assembly and endbell commutator assemby.



(3) After completing assembly, perform the following check.

① Are the bolts, nuts, and other fasteners tightened properly?
② Are there any errors in wiring, and are the connections tight?
③ Are the insulation resistance more than 1MΩ?
④ Are the brushes making good contact with the commutator?
⑤ Is the commutator surface clean?
⑥ Does the armature turn smoothly when rotated by hand?

⚠ The series motor when operated without load will rotate up to extremely high speed. To prevent this dangerous condition, never run the series motor without load.

6) TROUBLESHOOTING

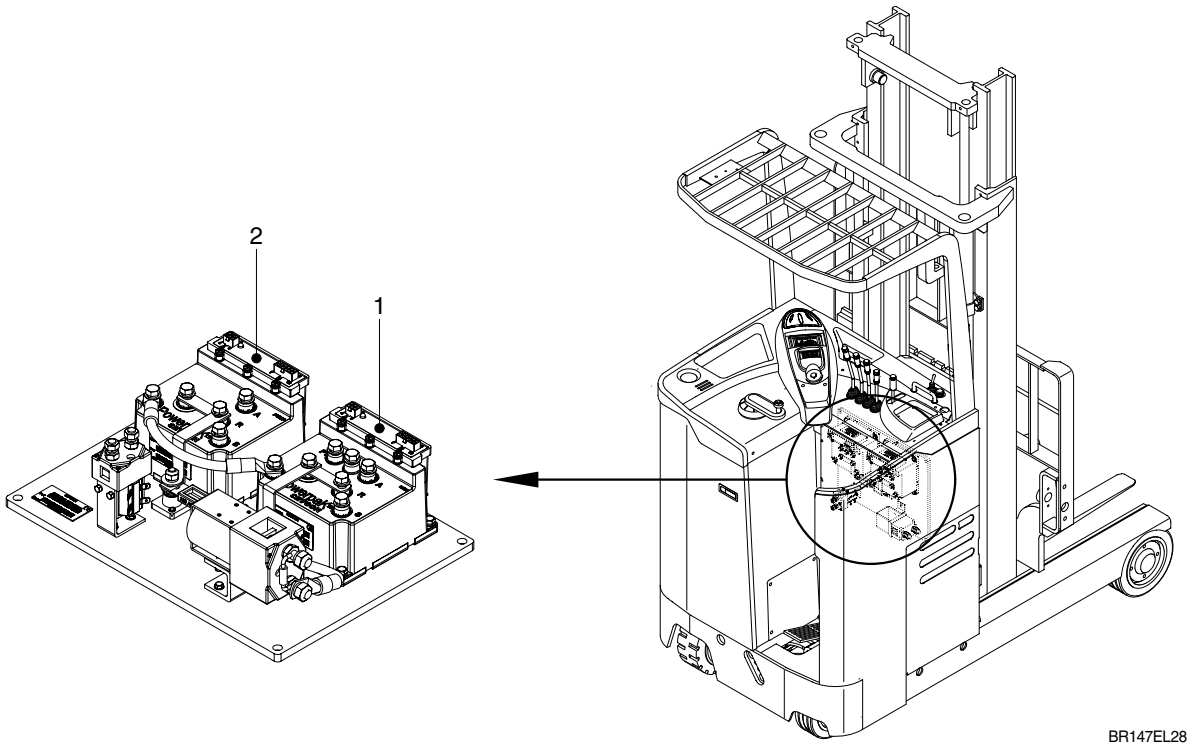
Refer to DRIVE MOTOR TROUBLESHOOTING, page.

7) INSPECTION

Refer to DRIVE MOTOR INSPECTION, page.

5. CONTROLLER SYSTEM

1) STRUCTURE



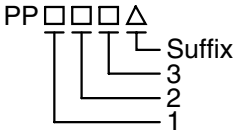
1 Traction controller

2 Pump controller

(1) Specifications

Model	Logic	Application	Type	Power	Actual value
HBR14/15/18-7	SEM low I/O Logic	Traction	SEM	24-48V, 350A/50A	350A
HBR20/25-7	SEM low I/O Logic	Traction	SEM	24-48V, 425A/50A	420A
HBR14/15/18-7 HBR20/25-7	Pump I/O Logic	Pump	SERIES	24-48V, 450A	400A

2) VARIANTS



B153EL028

1st digit (Controller type)	2nd digit (Voltage range)	3rd digit		Suffix
		SERIES	SEM	
2 = Traction	4 = 24 - 48V	3 = 300A	3 = 350A/50A*	L = Low I/O, Traction
3 = Pump	8 = 72 - 80V	4 = 450A	4 = 425A/50A*	M = Medium I/O, Traction
7 = SEM		6 = 650A		H = High I/O, Traction
				P = Low I/O, Pump

* Armature/Field

Model	Power	Configuration	Logic	No. of power terminal	Unit size
PP246M	24-48V 650A	Traction Regen/Plug	Med. I/O	6	142×142×140mm
PP344P	24-48V 450A	Pump	Pump. I/O	4	142×142×140mm
PP346P	24-48V 650A	Pump	Pump. I/O	4	142×142×140mm
PP743	24-48V 350A/50A	Traction SEM	Low I/O	6	142×142×140mm
PP744	24-48V 425A/50A	Traction SEM	Low I/O	6	142×142×140mm

3) CONTROLLER FEATURES WITH THE DIFFERENT LOGIC VARIANTS

(1) SERIES

Logic Feature	Pump Low I/O Logic	Traction Med. I/O Logic
Number of connectors	2	3
Number of digital switch inputs	6	8
Number of analogue inputs	2	2
Number of contactor drive outputs(2 Amps)	0	5
24V - 80V operation	YES	YES
Can cater for current limit range of 300A to 650A	YES	YES
Logic case enclosed to IP65, power case to IP55	YES	YES
Microprocessor control	YES	YES
High frequency (silent operation)	YES	YES
Internal watchdog monitoring microprocessor operation	YES	YES
Arcless contactor switching and built in coil suppression	N/A	YES
Use of 24V contactors at all voltages possible	N/A	YES
Low impedance, active low inputs switched to B-ve	YES	YES
Thermally compensated current limit	YES	YES
Selectable accelerator characteristics	NO	YES
Adjustable creep speed	YES	YES
Bypass with over current dropout + field weakening	N/A	YES
Seat switch timer	N/A	YES
Belly switch operation	N/A	NO
Power steer contactor driver and timer	N/A	YES
Regenerative or plug brake only	N/A	YES
Braking proportional to accelerator position	N/A	YES
Braking in neutral	N/A	YES
Braking with brake pedal	N/A	YES
Under and over-voltage protection	YES	YES
Accelerator wire off detect	N/A	YES

Logic Feature	Pump Low I/O Logic	Traction Med. I/O Logic
Inching and timed burst inching facilities	N/A	YES
Economy pot input	N/A	YES
Short circuit and open circuit contactor detect	N/A	YES
3 traction cutback speeds with independent accel delays	N/A	YES
6 Pump speeds with additive, priority & compensation	YES	N/A
Input to disable pump operation	YES	N/A
Independent power steer speed and compensation settings	YES	N/A
Hardware and software fail-safe systems	N/A	YES
+ 12V output pin	NO	YES
Diagnostic with LED indication	YES	YES
Adjustments made via a calibrator	YES	YES
Serial communications (external module gives RS232)	YES	YES
Can be setup with a PC (via above external module)	YES	YES
CAN serial communications	YES	YES
Hours count displaying key & pulsing hours on calibrator	YES	YES
BDI on calibrator	YES	YES
Dual motor non proportional variant with switches or pot	N/A	NO
Dual motor steer angles can be adjusted	N/A	NO
Dual motor independently ramp up/down delay adjustable	N/A	NO
Speed limit facility optionally available with speed sensor	N/A	YES
Resettable service and fault logs	YES	YES
Foreign languages selectable on calibrator	YES	YES
Standard + full feature dashboard display compatible	YES	YES
Setup menu on calibrator to enable various options	YES	YES

(2) SEM

Logic Feature	PowerpaK
Logic	Separate
Number of connectors	2
Number of digital switch inputs	6
Number of analogue inputs	2
Number of contactor drive outputs	2
Voltage operation range	24-80V
Armature current limit range	350-500A
Field current limit range	30-50A
Armature and field currents independently measured	Yes
Solid state direction control	Yes
Good speed regulation without speed sensor	Yes
Motor curve setup menu	Yes
Armature to field current mapping adjustment	Yes
Case enclosed to IP66	Yes
Microprocessor control	Yes
High frequency(Silent Operation) Armature + Field	Yes
Internal watchdog monitoring microprocessor operation	Yes
24V contactors at all voltages possible + built in suppression	Yes
Low impedance, active low inputs switched to B-ve	Yes
Thermally compensated current limit	Yes
Selectable accelerator characteristics	Yes
Adjustable creep speed	Yes
Variable field weakening without contactor	Yes
Seat switch timer	Yes
Belly switch operation	Yes
Line contactor drive	Yes

Logic Feature	PowerpaK
Power steer contactor driver and timer	Yes
Electric brake driver for walkies	Yes
Regenerative braking down to zero speed	Yes
Braking proportional to accelerator position	Yes
Braking in neutral and with brake pedal	Yes
Under and over-voltage protection	Yes
Accelerator wire off detect	Yes
Inching and timed burst inching facilities	Yes
Economy pot input	Yes
2 traction cutback speeds with independent accel delays	Yes
Hardware and Software fail-safe systems	Yes
+ 12V output pin	Yes
Diagnostics with LED indication	Yes
Adjustments made via a calibrator	Yes
Serial communications(external module gives RS232)	Yes
Can be setup with a PC(via above external module)	Yes
CAN serial communications	Yes
Hours count displaying Key & Pulsing hours on calibrator	Yes
BDI on calibrator	Yes
Dual motor proportional variant with switches or pot	Yes
Dual motor steer angles can be adjusted	Yes
Sensorless speed control	Yes
Resettable service and fault logs	Yes
Foreign languages selectable on calibrator	Yes
Standard + Full feature dashboard display compatible	Yes
Setup menu on calibrator to enable various options	Yes
Additional suppresion for 2 external contactors	Yes

4) SAFETY

(1) Electric vehicles can be dangerous. All testing, fault-finding and adjustment should be carried out by competent personnel. The drive wheels should be off the floor and free to rotate during the following procedures.

(2) The powerpak controller contains a tripple fail-safe system to give a high level of safety.
If the diagnostic LED is not illuminated or flashes, the safety circuit may have tripped and the truck may not drive.

(3) To ensure continued safety of the powerpak system, the fail-safe circuit should be checked whenever the truck is serviced. The period between checks should not exceed 3 months.

⚠ The battery must be disconnected before replacing or attempting any repairs of the controls.

(4) Before working on the controls disconnect the battery and connect the B^+ and B^- controller terminals via a 10 ohm 25 watt resistor to discharge the internal capacitors.

(5) Never connect the controller to a battery with its vent caps removed as an arc may occur due to the controller's internal capacitance when it is first connected.

(6) FAIL-SAFE CHECK

Ensure the drive wheels are clear of the floor and free to rotate.

① Switch on, select seat switch, release brake, select direction and FSI, the wheels should rotate
② and the diagnostic LED should give a steady illumination.
Switch off, disconnect battery and connect the A and B terminals together with, at least, 10㎟
③ cable. Ensure that no other fault that would allow drive is present.
Reconnect battery, switch on key with direction in neutral.
④ The LED should stay off. Select a direction and check that the direction contactors do not close and the wheels do not rotate.
Switch off at key and remove the A/B- connection. Switch on at key, reselect the power-up
⑤ sequence and check that the LED illuminates and the truck wheels rotate.
If the truck drives as described in ④ the controller is faulty and must be replaced.

(7) As blow-out magnets are fitted to contactors(except 24V) ensure that no magnetic particles can accumulate in the contact gaps and cause malfunction. Ensure that contactors are wired with the correct polarity to their power terminals as indicated by the + sign on the top moduling.

(8) The powerpak controller must NOT be used with permanently connected on-board chargers or damage to the system may result.

(9) The SEM controller contains a triple fail-safe system to give a high level of safety. If the diagnostic LED is not illuminated or flashes, the safety circuit may have tripped and the truck may not drive.

(10) To ensure continued safety of the SEM system, the fail-safe circuit should be checked whenever the truck is serviced. The period between checks should not exceed 3 months.

(11) The battery must be disconnected before replacing or attempting any repairs of the controls.

(12) Before working on the controls disconnect the battery and connect the B+ and B- controller terminals via a 10 ohm 25 watt resistor to discharge the internal capacitors.

(13) Never connect the controller to a battery with its vent caps removed as an arc may occur due to the controller's internal capacitance when it is first connected.

(14) The controller must be used with a line contactor as indicated in the wiring diagrams.

(15) As blow-out magnets are fitted to contactors(except 24V) ensure that no magnetic particles can accumulate in the contact gaps and cause malfunction. Ensure that contactors are wired with the correct polarity to their power terminals as indicated by the + sign on the top moulding.

(16) The controller must NOT be used with permanently-connected on-board chargers or damage to the system may result.

5) TECHNICAL SPECIFICATIONS

(1) Electrical

① Voltage specifications

Model	Voltage	Nominal Battery	Absolute maximum operating voltage
PP×4×	48V Units	24 - 48V	14.5 - 75V
PP×8×	80V Units	72 - 80V	43.0 - 100V

② Current specifications

Model	Power	Current limit (1 min)	Safe operating area (SOA)	Continuous current 1 hour rating. Unit mounted on an aluminum base-plate 780×380×10㎜, at 20℃ ambient.
PP344P	48V 450A	450A	30 - 60%	135A
PP246M PP346P	48V 650A	650A	30 - 60%	200A
PP743	48V 350A	350A	30 - 60%	117A
PP744	48V 425A	425A	30 - 60%	167A

③ Switching frequency

16kHz Traction / Regen / Pump Drive and 6kHz plug braking.

④ Electrical isolation

Enclosure to any live part = 1kV. Controller internal insulation specified at > 10MΩ@ 500V DC. Dielectric strength 1000V@50Hz for 1Minute.

⑤ Battery polarity

A Line contactor driven from the keyswitch, with a 2A diode in series with the coil, will prevent line contactor closure if the battery positive and negative connections are reversed.

(2) Environmental

① Protection-logic(Powerpak)

The enclosure is protected to IP66.

1st digit(6) = Protection against dust ingress.

2nd digit(6) = Protection against high pressure jets of water in any direction.

② Protection-power frame(Powerpak)

The enclosure is protected to IP55.

1st digit(5) = Limitted dust ingress permitted.

2nd digit(5) = Protection against low pressure jets of water in any direction.
Limited ingress permitted.

③ Vibration

6G, 40-200Hz for 1 hour, in x, y and z planes.

④ Operating temperature

-30℃ to +40℃ ambient around controller.

⑤ **Storage temperature**

-40℃ to +70℃

⑥ **Humidity**

95% maximum, non-condensing

⑦ **Humidity resistance**

No functional defects after controller is left at 60℃ and 100% humidity for one hour after freezer use(-30℃ minimum)

⑧ **Halt**

Powerpak has been highly accelerated life tested.

(3) Mechanical

① **Unit size (all units)**

Length 142㎜, width 142㎜, height 140㎜ with logic fitted.

(Height is 86㎜ with logic unplugged)

② **Enclosure**

Aluminium die cast base-plate with ABS plastic injection moulded power frame and logic covers.

③ **Power connections**

Aluminium vertical power bushes for M8 connection. M8 for amarture and field connection.

④ **Fixings**

4×M6 clearance holes.

⑤ **Weight**

1.8㎏

(4) Logic I/O specifications

① **Switch/Digital Inputs**

a. Operation

Active-low(The input becomes active when connected to battery negative.)

b. Voltage range

Low(Closed) -1.0 to +1.8V

High(Open) +4.5 to 150V(or open-circuit)

c. Input impedance

Max. resistance to ground for a “low” = 500Ω

Min. resistance to ground for a “high” = 2.7kΩ

⚠ **Negative switch returns must be connected to controller B- terminal and not at battery negative.**

② **Analogue inputs**

0~5V inputs available and 5K potentiometer 3V/5~0V inputs available.

Fully protected i/ps and threshold settable.

③ **Supply output**

An unregulated +12V, 5mA power supply is available for supplying accelerators, speed sensor etc.

④ **Contactor drives**

Maximum Current : 2A

Protection : Drives are protected against direct connection to B+ and B-.

Suppression : Coil suppression built-in

Supply : Logic variant dependant, see wiring diagram

6) CONTROLLER WIRING AND CONNECTIONS

(1) Wiring

① Power connections

See power wiring diagrams for specific connections.

② Power wiring

Minimum cable sizes : Current limits up to 500A 35㎟ and 650A 50㎟ for SERIES.
Current limits up to 270A 25㎟ and 500A 35㎟ for SEM.

③ Fuse ratings

Maximum fuse ratings : current limits up to 300A 325A (SERIES), 180A, 125A(SEM)
(Air break) 450A 500A (SERIES), 270A, 175A(SEM)
650A 700A (SERIES), 350A, 250A(SEM)
500A, 325A(SEM)

(2) Light wiring connections

The following section details the connectors on the minimum, medium and high logics. The minimum logic has 2 connectors, 1 for the vehicle/contactor connections and 1 for serial communications. The medium I/O logic has 3 connectors, 1 for the vehicle connections, 1 for the contactor connections and 1 for serial communications. The high I/O logic also has 3 connectors in total, 1 for the vehicle connections, 1 for the contactor connections, and 1 for serial communications.

Pin No	Vehicle connector socket B Traction Med. I/O Logic. 12 way molex connector 8 Digital i/ps 2 Analog i/ps 1+12V O/P.	Vehicle and panel connector socket B Pump low I/O logic 12 way molex connector 6 Digital i/ps 2 Analog i/ps No contactor drives	POWERPAK SEM vehicle & panel connector socket B 12 way molex connector. 6 digital i/ps 2 analog i/ps 2 contactor drives
1	Key sw	Key sw	Key sw
2	Fwd sw	Pump sw 3(TILT)	Fwd sw
3	Rev sw	Pump sw 4(OPTION)	Rev sw
4	FS1 sw	-	FS1/Belly sw
5	Seat sw	-	Seat/Tiller sw
6	-	-	Digital pin 6
7	-	-	Digital pin 7
8	Handbrake	-	Line contactor O/P
9	Footbrake	-	P.Steer/Pump/Brake/Remote LED O/P
10	Motor temp sensor	Motor temp sensor	Analogue I/P 0V - 5V
11	Accel	Accel 3V5-0V(Pump sw1)	Analogue I/P 3V5 - 0V
12	+12V O/P	+12V O/P	+12V O/P

Pin No	Panel connector socket C Traction Med. I/O Logic 10way molex connector 5 cont . Drives	Communications connector socket A All logics. 6 way molex connector RS232 & CAN	POWERPAK Communications connector socket A 6 way molex connector CAN (External module allows RS232 connection to PC)
1	Cont. O/P	RS232 TXD	+10V5
2	Fwd cont	0V	0V
3	Rev cont	RS232 RXD(TTL Level)	N/C
4	Regen cont	+10V5	+10V5
5	Bypass cont	CAN High	CAN High
6	-	CAN Low	CAN Low

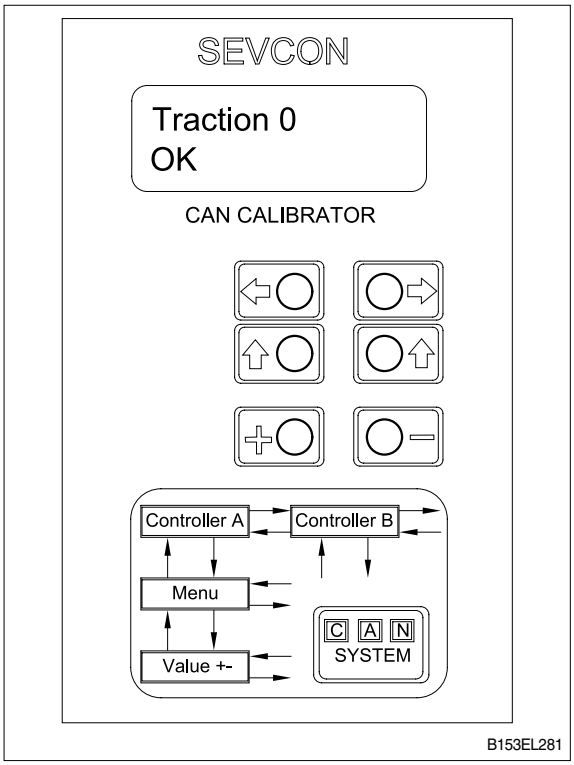
(3) CAN(Controller Area Network)

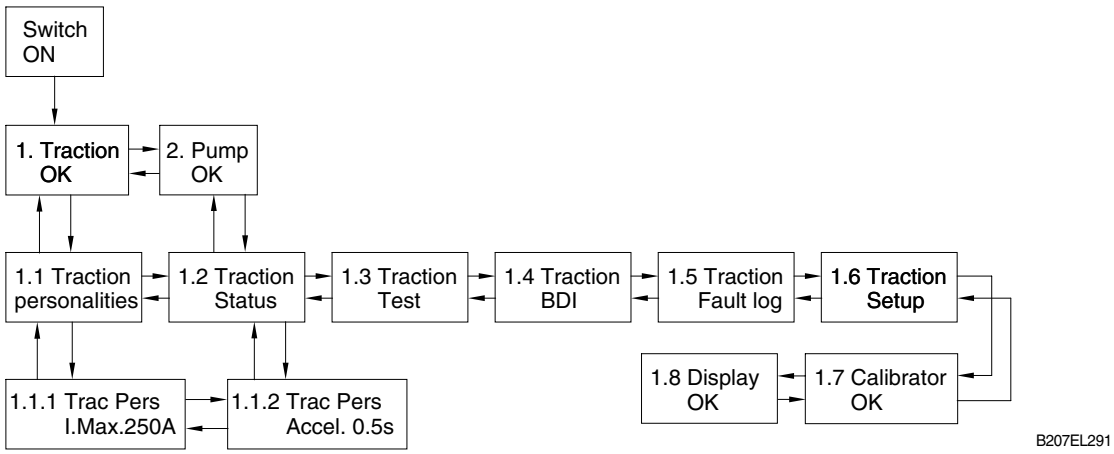
This CAN system is defined as CAN 2.0A(Basic CAN, error active) and is implemented using a Philips Semiconductor chip-set with an 80C250 transceiver chip. The powerpak CAN protocol sets the baud rate to be 100k bits per second.

7) CALIBRATOR AND ADJUSTMENTS

A sophisticated, yet easy to use hand held adjustment unit, called the calibrator is used to make adjustments to the controller and select configurations. The calibrator is also used as a diagnostic tool displaying the status of all voltages, currents and temperatures within the controller together with the condition of all the controller's switch and analogue inputs.

The diagram below describes how the calibrator is used. The left and right arrows move between screens on the same level.
The up down arrows move between levels and the + and - buttons increment or decrement the parameters by the amount indicated in the STEP column of the following tables.
The calibrator can be specified to have various levels of access to certain adjustments.





(1) Traction Controller Personalities(Controller Adjustments)

① SERIES

Cal. Ref	Parameter Adjusted	Logic :	Min adjust (all units)	Max adjust 650A unit	Step size (all units)	Actual value
1.1.1	Current limit	Med i/o	50A	650A	10A	650A
1.1.2	Acceleration delay	Med i/o	0.1S	5.0S	0.1S	1.0S
1.1.2a	Current ramp delay	Med i/o	0.0	2.5S	0.1S	0.0S
1.1.3	Deceleration delay	Med i/o	0.1S	0.5S	0.1S	0.1S
1.1.4	Creep speed	Med i/o	0%	25%	1.0%	4%
1.1.5	Direction plug current	Med i/o	50A	810A	10A	650A
1.1.5a	Plug turn	Med i/o	50A	650A	10A	50A
1.1.6	Neutral plug current	Med i/o	10A(0 disables)	810A	10A	0A
1.1.6a	Plugging threshold	Med i/o	50	255	1	170
1.1.6b	Plug drop	Med i/o	50A	650A	10A	100A
1.1.7	Footbrake plug current	Med i/o	10A (0 disables)	810A	10A	400A
1.1.8	Direction regen current	Med i/o	50A	650A	10A	300A
1.1.8a	Speed limit braking	Med i/o	40 A/KPH	650A	10A	40 A/KPH
1.1.9	Neutral regen current	Med i/o	10A(0 disables)	650A	10A	0A
1.1.10	Footbrake regen current	Med i/o	10A(0 disables)	650A	10A	300A
1.1.11	Regen delay	Med i/o	0mS(0 plug only)	350ms	10ms	150mS
1.1.12	Maximum speed	Med i/o	0%	100%	1.0%	100%
1.1.13	Cutback speed 1	Med i/o	0%	100%	1.0%	100%
1.1.14	Acceleration delay 1	Med i/o	0.1S	5.0S	0.1S	0.1S
1.1.15	Cutback speed 2	Med i/o	0%	100%	1.0%	100%
1.1.16	Acceleration delay 2	Med i/o	0.1S	5.0S	0.1S	0.1S
1.1.17	Cutback speed 3	Med i/o	0%	100%	1.0%	25%
1.1.18	Acceleration delay 3	Med i/o	0.1S	5.0S	0.1S	2.5S
1.1.19	Inch speed	Med i/o	0%	25%	1%	10%
1.1.20	Burst inch delay	Med i/o	0.1S	5.0S	0.1S	2.0S
1.1.21	Bypass over current	Med i/o	10A(0 disables)	970A	10A	750A
1.1.22	Bypass delay	Med i/o	0.5S	5.0S	0.1S	1.5S
1.1.23	Field weak pull in	Med i/o	50A	650A	10A	50A
1.1.24	Field weak drop out	Med i/o	50A	650A	10A	50A
1.1.25	Power steer delay	Med i/o	0S	60S	1.0S	5.0S
1.1.26	Seat switch delay	Med i/o	0S	5.0S	0.1S	2.0S
1.1.27	Electric brake delay	Med i/o	0S	5.0S	0.1S	2.0S
1.1.28	Accelerator zero level	Med i/o	0V	5.0V	0.02V	3.20V
1.1.29	Accelerator full level	Med i/o	0V	5.0V	0.02V	0.60V
1.1.30	Footbrake pot zero level	Med i/o	0V	5.0V	0.02V	0.0V
1.1.31	Footbrake pot full level	Med i/o	0V	5.0V	0.02V	5.0V
1.1.32	Economy pot zero level	Med i/o	0V	5.0V	0.02V	0.1V
1.1.33	Economy pot full level	Med i/o	0V	5.0V	0.02V	3.7V

Cal. Ref	Parameter Adjusted	Logic :	Min adjust (all units)	Max adjust 650A unit	Step size (all units)	Actual value
1.1.34	O.Temp pot zero level	Med i/o	0V	5.0V	0.02V	3.00V
1.1.35	O.Temp pot full level	Med i/o	0V	5.0V	0.02V	4.50V
1.1.36	Speed limit	Med i/o	2kPH(0 disables)	60kPH	1kPH	0kPH
1.1.37	Low voltage init	Med i/o	14.5V	48/80V	0.5V	30V
1.1.38	Low voltage cutback	Med i/o	14.5V	48/80V	0.5V	18V
1.1.39	High voltage init	Med i/o	14.5V	75/100	0.5V	65V
1.1.40	High voltage cutback	Med i/o	14.5V	75/100	0.5V	70
1.1.41	Battery protection	Med i/o	14.5V	48/80V	0.5V	15V
1.1.42	F/B Timer	Med i/o	0.1S	5S	0.1S	2S

※ Depending on controller type and configuration some of the above may not be displayed.
Pressing the calibrator “down arrow” key from 1.1.2 allows access to 1.1.2a, likewise for 1.1.5a, 1.1.6a and 6b.
Pressing the calibrator “down arrow” key from the potentiometer zero and full personalities(1.1.27 to 1.1.32, and 2.1.24 to 2.1.27) jumps directly to the associated voltage measurement in the test menu. Pressing this key from the test menu jumps back to the associated zero level personality.

② SEM

Cal. Ref	Parameter Adjusted	Min adjust (all units)	Max. adjust (350A unit)	Step size all units	*Actual value 1	***Actual value 2**
1.1.1A	Current limit armature	50A	350A	10A	350A	**350A/420A**
1.1.1F	Current limit field	10A	50A	1A	40A	**50A**
1.1.2	Acceleration delay	0.1S	5.0S	0.1S	3.0S	**1.0S**
1.1.3	Deceleration delay	0.1S	0.5S[2]	0.1S	0.3S	**0.1S**
1.1.4	Creep speed	0%	25%	1.0%	2%	**0%**
1.1.5	Direction regen current	50A	350A	10A	150A	**100A**
1.1.5	Direction regen time	0.1S	5.0S	0.1S	1.5S	**0.1S**
1.1.6	Neutral regen current	10A(0 disables)	350A	10A	20A	**10A**
1.1.7	Footbrake regen current	10A(0 disables)	350A	10A	100A	**0A**
1.1.8	Regen delay	0	300ms	10ms	150ms	←
1.1.9	Threshold voltage	0.09V	3.20V	0.01V	0.40V	**1.20V**
1.1.10	Maximum speed	0%	100%	1%	100%	←
1.1.11	Rolloff field	1%(0 disables)	100%	1%	100%	←
1.1.12	Cutback speed 1	0%	100%	1%	70%	**100%**
1.1.13	Acceleration delay 1	0.1S	5.0S	0.1S	1.5S	**1.5S**
1.1.14	Cutback speed 2	0%	100%	1%	50%	**100%**
1.1.15	Acceleration delay 2	0.1S	5.0S	0.1S	1.5S	**1.5S**
1.1.16	Cutback speed 3	0%	100%	1%	100%	**100%**
1.1.17	Acceleration delay 3	0.1S	5.0S	0.1S	1.5S	**1.5S**
1.1.18	Inch speed	0%	25%	1%	0%	**0%**
1.1.19	Burst inch delay	0.1S	5.0S	0.1S	1.0S	**0.1S**
1.1.20	Power steer delay	0S	60S	1.0S	5S	**5S**
1.1.21	Seat switch delay	0S	5.0S	0.1S	2.0S	**2.0S**
1.1.22	Accelerator zero level	0.00V	5.00V	0.02V	3.30V	**0.70V**
1.1.23	Accelerator full level	0.00V	5.00V	0.02V	0.70V	**3.30V**
1.1.24	Footbrake pot zero level	0.00V	5.00V	0.02V	0.10V	**3.50V**
1.1.25	Footbrake pot full level	0.00V	5.00V	0.02V	4.90V	**2.50V**
1.1.26	Economy pot zero level	0.00V	5.00V	0.02V	2.50V	**0.10V**
1.1.27	Economy pot full level	0.00V	5.00V	0.02V	2.00V	**4.90V**
1.1.28	Steer pot left level	0.00V	5.00V	0.02V	1.80V	**0.10V**
1.1.29	Steer center	0.00V	5.00V	0.02V	3.84V	**0.12V**
1.1.30	Steer pot right level	0.00V	5.00V	0.02V	5.00V	**4.90V**
1.1.31	Dual motor inner angle	5°	80°	1.0°	25°	**5°**
1.1.32	Dual motor outer angle	10 °	85°	1.0°	75°	**75°**
1.1.33	Constant speed	4.0KPH	6.0KPH	0.2KPH	5.6KPH	**5.6KPH**
1.1.34	Belly delay	0.5S	5.0S	0.1S	-	**-**
1.1.35	Speed limit	1.0KPH	51.0KPH	0.2KPH	5.0KPH	**11.0KPH**

* Actual value 1 : For 350A(HBF15/18T-5)

Actual value 2 : For 350A/420A(HBR14/15/18-7, HBR20/25-7)

Cal. Ref	Parameter Adjusted	Min adjust (all units)	Max. adjust (350A unit)	Step size all units	*Actual value 1	***Actual value 2**
1.1.36	Speed proportional	0(0 disables)	128	1	0	**32**
1.1.37	Brake proportional	0(0 disables)	128	1	32	**32**
1.1.38	Speed integral	0(0 disables)	16	1	0	**3**
1.1.39	Brake integral	0(0 disables)	16	1	3	**3**
1.1.40	Low voltage init	14.5V	36V/48V	0.5V	24V/30.0V	**24V/30.0V**
1.1.41	Low voltage cutback	14.5V	36V/48V	0.5V	16V/18.0V	**16V/18.0V**
1.1.42	Protection delay	0.1S	2.5S	0.1S	0.5S	**0.5S**
1.1.43	High voltage init	14.5V	50V/75V	0.5V	65.0V	**65.0V**
1.1.44	High voltage cutback	14.5V	50V/75V	0.5V	70.0V	**70.0V**
1.1.45	Foot delay	0S	60S	1S	5S	**2S**

* Actual value 1 : For 350A(HBF15/18T-5)

Actual value 2 : For 350A/420A(HBR14/15/18-7, HBR20/25-7)

Depending on controller type and configuration some of the above may not be displayed.

In speed control mode, deceleration delay has a maximum of 5.0S(all units).

Direction regen current is displayed in torque mode, and direction regen time is displayed in speed control mode.

Pressing the calibrator "down arrow" key from the potentiometer zero and full personalities(1.1.22 to 1.1.29) jumps directly to the associated voltage measurement in the test menu. Pressing this key from the test menu jumps back to the associated zero level personality.

(2) Traction Controller Status Information

Cal. ref.	Parameter displayed	Logic type	Min display	Max display	Step size	Log info.
1.2.1	Battery voltage	Med i/o	0V	127V	0.1V	+
1.2.2	Traction motor voltage	Med i/o	0V	127V	0.5V	
1.2.3	Traction motor current	Med i/o	0A	1200A	6A	+
1.2.4	Traction controller temp	Med i/o	-30℃	+225℃	1℃	+-
1.2.5	Traction mosfet voltage	Med i/o	0V	127V	0.5V	
1.2.6	Capacitor voltage	Med i/o	0V	127V	0.5V	
1.2.7	Speed sensor indication	Med i/o	0 KPH	60 kPH	1.0 kPH	
1.2.8	Key switch hours count	Med i/o	0 Hrs	65279.9 Hrs	0.1 Hrs	
1.2.9	Traction pulsing hours count	Med i/o	0 Hrs	65279.9 Hrs	0.1 Hrs	
1.2.10	CANbus status	Med i/o	0 Hrs	65279.9 Hrs	0.1 Hrs	
-	Service log reset	Med i/o	Press + followed by - to reset service log			

※ Log Info shows where the + and - keys can be used to access the service max and min data.

(3) Traction Controller Test Information

Cal. ref.	Input displayed		Logic type	Min. display	Max. display	Step size
1.3.1	Accelerator %	Range	Med i/o	0%	100%	1%
1.3.2	Accelerator voltage	Range	Med i/o	0.0V	5.5V	0.02V
1.3.3	Footbrake pot. %	Range	Med i/o	0%	100%	1%
1.3.4	Footbrake pot. voltage	Range	Med i/o	0.0V	5.5V	0.02V
1.3.5	Economy pot. %	Range	Med i/o	0%	100%	1%
1.3.6	Economy pot. voltage	Range	Med i/o	0.0V	5.0V	0.02V
1.3.7	Forward	Switch	Med i/o	Open	Closed	-
1.3.8	Reverse	Switch	Med i/o	Open	Closed	-
1.3.9	FS1	Switch	Med i/o	Open	Closed	-
1.3.10	Belly	Switch	Med i/o	Open	Closed	-
1.3.11	Seat	Switch	Med i/o	Open	Closed	-
1.3.12	Tiller	Switch	Med i/o	Open	Closed	-
1.3.13	Speed cutback 1	Switch	Med i/o	Open	Closed	-
1.3.14	Speed cutback 2	Switch	Med i/o	Open	Closed	-
1.3.15	Speed cutback 3	Switch	Med i/o	Open	Closed	-
1.3.16	Inch forward	Switch	Med i/o	Open	Closed	-
1.3.17	Inch reverse	Switch	Med i/o	Open	Closed	-
1.3.18	Handbrake	Switch	Med i/o	Open	Closed	-
1.3.19	Footbrake	Switch	Med i/o	Open	Closed	-
1.3.20	Power steer trigger input	Switch	Med i/o	Open	Closed	-
1.3.21	Pump contactor trigger	Switch	Med i/o	Open	Closed	-
1.3.22	Speed encoder	Data	Med i/o	Low	High	-
1.3.23	Software version/revision		Med i/o	000.00	999.99	-
1.3.24	Controller serial number		Med i/o	00000000	99999999	-

※ As with the personalities, only relevant switch tests will be shown determined by configuration.

(4) BDI Adjustments(if enabled in setup menu)

Cal. Ref.		Parameter adjusted/displayed	Logic type	Min. setting	Max. setting	Step size	Actual value	
SERIES	SEM							
1.4.1	1.4.1	xxx % Charge left	L, M, H, P	Display only				
1.4.2	-	Battery volt xx V	L, M, H, P	24V	96V	2V	Nominal V	
1.4.3	1.4.2	Reset x.xx V/cell	L, M, H, P	2.00V/Cell	2.50V/Cell	0.01V/Cell	2.15V	2.09V
1.4.4	1.4.3	Empty x.xx V/cell	L, M, H, P	1.50V/Cell	1.99V/Cell	0.01V/Cell	1.60V	1.55V
1.4.5	1.4.4	Warning xx %	L, M, H, P	0%	90%	1.0%	20%	
1.4.6	1.4.5	Cutout xx %	L, M, H, P	0%	90%	1.0%	10%	

(5) BDI(Battery Discharge indicator) setup

When the battery is deemed fully discharged all segments will be extinguished, with each 10% drop in capacity extinguishing 1 segment.

When the battery charge drops below an adjustable warning level, typically set to 20%, the remaining lit segments will flash to warn the driver of this. When the charge drops further to below an adjustable cut-out level, typically 10%, all 10 segments will flash. At the cut-out level, pump operation will be inhibited at the end of its present operating cycle, and cutback 2 personalities will be applied to the traction.

When the battery is localized and the operation time of the truck is remarkably short, please check BDI DATA, especially empty level and adjust it properly.

There are 4 adjustments associated with the BDI, adjustable by the hand held calibrator as following :

*( ) shows BDI set of pump controller side.

① **Charge remaining xx%**

Displays remaining battery charge. Display only, no adjustments can be made. After fully battery charged, it should display 100% remaining charge.

② **Battery volt xxV**

Displays battery voltage. Display only, no adjustments can be made.

③ **Reset level x.xx volt/cell**

The BDI will be reset to 100% remaining charge when the actual battery voltage is greater than an adjustable threshold. The customer should measure the cell voltage after charging, and set the threshold just below this. A reset can only occur just after key-on, so adjustments of the threshold will only take effect if the key switch is cycled. If the value set 2.15V then 2.15V$\times$24 batteries = 51.6V. All 10 segments will be ON(reset) if the battery voltage exceed 51.6V. If the value set is too low then all 10 segments will be ON(reset) whenever key recycle. If the value set is too high then all segments will not turn ON(reset) even though the battery is fully charged. The value set only works to decide to turn ON(reset) all 10 segments after charging. It is nothing to do with battery discharging indication.

a. Measure the battery voltage after charging displayed on screen(②) battery volt.
b. Divide the battery voltage into cell numbers(=cell voltage).
c. Subtract 0.05 from cell voltage.
d. Set the result on screen (③) reset level

Ex. If measured battery voltage is 51.36, the cell voltage is 51.36/24=2.14. Therefore the result is 2.14-0.05=2.09. Set 2.09 on screen (③) reset level.

④ **Empty level**

The battery discharging indication will fully depend on this threshold value. The controller uses this threshold value and internal timer to decrease the indication level. The discharge timer only counts “moderate discharge”. i.e. when the battery voltage is below a discharge threshold.

This threshold is calculated by adding an offset to the empty cell voltage. This offset decreases linearly with remaining charge. The value is typically 1.60V as a factory setting. If the value sets higher than 1.60V then the BDI segment will drop quickly. If it sets lower than 1.60V then the BDI segments remains longer. There may be inaccuracy of the BDI operation because of the difference of battery manufacture, nominal temperature etc. In this case, increase/decrease this threshold value to correct BDI but the specific gravity have to be checked to make sure the battery is fully discharged when the (①) indicates 20%. For example, the factory setting value is 1.60V. If the battery is fully discharged then the specific gravity is 1.160 when (①) indicates 20%. If the threshold value is too low then the specific gravity will be dropped more. Then, it will shorten the battery life cycle if the truck driver uses the battery up to 0% of battery segments.

When the remaining charge is reached 20% displayed on screen (①) measure the gravity of battery. If the gravity is checked 1.160/25℃, the Empty level set up is not necessary.

a. If the gravity is higher than 1.160/25℃, set the (④) Empty level down 0.03~0.05.
b. If the gravity is lower than 1.160/25℃, set the (④) Empty level up 0.03~0.05.

※ **When checking the gravity, refer to the battery manual for conversion rate of gravity by temperature variation. Normally, Gravity at 25℃ = checked gravity + 0.007 (checked temperature -25).**

⑤ **Warning level %**

Sets the discharged level at which the warning threshold is reached, at which point the remaining lit segments flash.

⑥ **Cutout level %**

Sets the discharged level at which the cut-out threshold is reached, at which point all the segments flash together and the cut-out action, pump cut-out and traction speed 2 limit initiated.

To confirm the setup values, repeat the upper BDI setup procedure after fully battery charged.

(6) Fault Log

Can be disabled via setup menu.

(7) TRACTION SETUP MENU(ENABLES/DISABLES FEATURES)

① SERIES CONTROLLER

Cal. Ref.	Feature	Logic type	Default
1.6.1	Contactor chopping	L, M, H	Off
1.6.2	Accelerator type	L, M, H	Curved
1.6.3	BDI	L, M, H	On
1.6.4	Power steer trigger	L, M, H	FS1+dir
1.6.5	Economy cuts traction current	M, H	On
1.6.6	Bypass in current limit	M, H	On
1.6.7	SRO	L, M, H	On
1.6.8	Braking	L, M, H	Constant
1.6.9	Plugging style	L, M, H	Constant current
1.6.10	Ride-on/walking truck	L, M, H	Ride-on
1.6.11	Tiller switch	L, M, H	Off
1.6.12	Digital i/p 5 config (Skt B pin 6)	M, H	Speed 1
1.6.13	Digital i/p 6 config (Skt B pin 7)	M, H	Speed 2
1.6.14	Digital i/p 7 config (Skt B pin 8)	M, H	Handbrake
1.6.15	Digital i/p 8 config (Skt B pin 9)	M, H	Footbrake
1.6.16	Analog i/p 1 config (Skt B pin 10)	L, M, H	Accelerator pot
1.6.17	Analog i/p 2 config (Skt B pin 11)	L, M, H	O.Temp
1.6.20	Contactor 3 config. (Skt C pin 4 Med/Hi i/o)	L, M, H	Med I/O logic-regen
1.6.21	Contactor 4 config (Skt C pin 5)	M, H	Bypass
1.6.22	Contactor 5 config (Skt C pin 6)	M, H	Power steering
1.6.25	Seat switch cuts pump	M, H	Off
1.6.26	Fault log	L, M, H	On
1.6.27	Service log	L, M, H	On
1.6.28	Full speed	M, H	20kph
1.6.29	Probe frequency	M, H	100Hz
1.6.30	Mode	L, M, H	CAN master
1.6.31	Switch limits speed	L, M, H	OFF

※ **Changes only take effect after a key-switch recycle.**

② SEM CONTROLLER

Cal. Ref.	Feature	Options
1.6.1	System setup	Standalone / Master / Slave / Dual traction / **Traction + pump** / Dual + pump
1.6.2	Digital IO	**6**
1.6.3	Analogue IP	**13, 14**(#0007-, #0019-, #0023-, #0024-, #0011-)
1.6.4	Contactor chopping	24V / On / **Off**
1.6.5	Accelerator type	Linear / **Curved** / 2* Slope / **Crawl**
1.6.6	BDI	**On** / Off
1.6.7	Power steer trigger	None to **FS1** + Dir + **Brake** + **Seat**
1.6.8	Economy cuts traction current	**On** / Off
1.6.9	SRO	On / **Off**
1.6.10	Braking	Proportional / **Constant**
1.6.11	Control mode	**Torque** / Speed
1.6.12	Tiller up forward	On / **Off**
1.6.13	Fault log	**On** / Off
1.6.14	Service log	**On** / Off
1.6.15	Vehicle full speed	**9.6KPH**
1.6.16	Steer reverse enable	**Off**
1.6.17	Roll off E. Brake	On / **Off**
1.6.18	Battery volt	**36V/48V**(2V Steps)
1.6.19	Seat & Pump	On / **Off**
1.6.20	Analogue as digital configuration	**N/ Open**

※ **Changes only take effect after a key-switch recycle.**

③ MOTOR

Cal. Ref.	Parameter adjusted	Min adjust (all units)	Min adjust (all units)	Step size (all units)	**Typical Default (200A, 270A, 350A, 500A)**
1.7.1	Armature current low	10A	50% of max	10A	**60A(all units)**
1.7.2	Field current low	2.00A	50% of max	0.25A	**7.5A/6.5A(all units)**
1.7.3	Armature current mid	Ia Low	Ia High	10A	**280A**
1.7.4	Field current mid	If Low	If High	1A	**26A**
1.7.5	Armature current high	50% of max	Maximum	10A	**300A**
1.7.6	Field current hight	50% of max	Maximum	1A	**40A**
1.7.7	Armature resistance	0mΩ	255mΩ	1mΩ	**47mΩ**
1.7.8	Field resistance*	0.25Ω	2.50Ω	0.01Ω	**0.43Ω**

*** Important Note : The correct field resistance personality for the SEM motor must be entered at item 1.7.8 for the motor to be controlled correctly**

Cal. Ref.	Feature	Options
1.8.1	Main hours	**Key** / Drv / Pmp
1.8.2	Status	Off / Trac I / Trac V / Pump I / Pump V / **KPH** / MPH/ Accel / Steer / Ver No
1.8.3	Contrast	**35**
1.8.4	Ind 1	**Off** / Trac I / Trac V / Pump I / Pump V / KPH / MPH / Accel
1.8.5	Ind 2	Off / Trac I / Trac V / Pump I / Pump V / KPH / MPH / **Accel** / Steer
1.8.6	Fault mags	Off / **On**

(8) Pump controller personalities(controller adjustments)

Cal. ref.	Parameter adjusted	Logic type	Min adjust (all units)	Max.adjust 650A unit	Step size (all units)	*Actual value 1	*Actual value 2	***Actual value 3**
2.1.1	Current limit	P	50 A	650 A	10 A	650A	400A	**400A**
2.1.2	Ramp up delay	P	0.1 S	5.0 S	1.0 S	1.0 S	1.0 S	**0.1 S**
2.1.3	Ramp down delay	P	0.1 S	0.5 S	0.1 S	0.1 S	0.1 S	**0.1 S**
2.1.4	Creep speed	P	0%	25%	1.0%	3%	0%	**5%**
2.1.5	Pump speed 1	P	0%(0=inhibit)	100%	1.0%	100%	100%	**0%**
2.1.6	Pump compensation 1	P	1%(0 disables)	200%	1.0%	200%	100%	**50%**
2.1.7	Pump speed 2	P	0%(0=inhibit)	100%	1.0%	0%	0%	**68%**
2.1.8	Pump compensation 2	P	1%(0 disables)	200%	1.0%	0%	0%	**80%**
2.1.9	Pump speed 3	P	0%	100%	1.0%	70%	100%	**100%**
2.1.10	Pump compensation 3	P	1%(0 disables)	200%	1.0%	150%	150%	**200%**
2.1.11	Pump speed 4	P	0%	100%	1.0%	70%	50%	**60%**
2.1.12	Pump compensation 4	P	1%(0 disables)	200%	1.0%	150%	100%	**100%**
2.1.13	Pump Speed 5	P	0%	100%	1.0%	100%	100%	**80%**
2.1.14	Speed 5(Priority/additive)	P	Priority	Additive	-	Priority	Priority	**Priority**
2.1.15	Pump speed 6	P	0%	100%	1.0%	100%	0 %	**100%**
2.1.16	Speed 6(priority/additive)	P	Priority	Additive	-	Priority	Priority	**Priority**
2.1.17	Pump speed 6	P	0%	100%	1.0%	0%	0%	**0%**
2.1.18	Speed 6(priority/additive)	P	Priority	Additive	-	Priority	Priority	**Priority**
2.1.19	Power steer speed	P	0%	100%	10%	8%	9%	**0%**
2.1.20	Power steer compensation	P	1%(0 disables)	200%	10%	80%	80%	**0%**
2.1.21	Power steer ramp up delay	P	0.1 S	5.0 S	0.1 S	0.1 S	0.1 S	**0.1 S**
2.1.22	Power steer ramp down delay	P	0.1 S	0.5 S	0.1 S	0.1 S	0.1 S	**0.1 S**
2.1.23	Power steer delay	P	0 S	60 S	1 S	2.0 S	2 S	**2 S**
2.1.24	Seat switch delay	P	0 S	5 S	0.1 S	2.0 S	0.0 S	**2.0 S**
2.1.25	Accelerator zero level	P	0.0 V	5.0 V	0.02 V	4.30 V	4.30 V	**0.10 V**
2.1.26	Accelerator full level	P	0.0 V	5.0 V	0.02 V	2.30 V	2.90 V	**3.40 V**
2.1.27	Accelerator 2 zero level	P	0.0 V	5.0 V	0.02 V	3.00 V	0.0 V	**3.30 V**
2.1.28	Accelerator 2 full level	P	0.0 V	5.0 V	0.02 V	4.50 V	2.66 V	**0.74 V**
2.1.29	Low voltage init	P	14.5 V	48V for 24-48V units		20V/30.0 V	20V/30.3 V	**24V/36.0**
2.1.30	Low voltage cutback	P	14.5 V	48V for 24-48V units		16V/18.0 V	16V/18.0 V	**V**
2.1.31	High voltage init	P	14.5 V	75V for 24-48V units		65.0 V	65.0 V	**16V/18.0**
2.1.32	High voltage cutback	P	14.5 V	75V for 24-48V units		70.0 V	70.0 V	**V**
2.1.33	Battery protection	P	14.5 V	48V for 24-48V units		15.0 V	14.5 V	**65.0 V**
2.1.34	Protection delay	P	0.1 S	2.5S	0.1S	0.5 S	0.5 S	**70.0 V**

* Actual value 1 : HBF20/25/30/32-7, HBF20/25/30C-7

Actual value 2 : HBF15/18T-5

Actual value 3 : HBR14/15/18-7, HBR20/25-7

(9) Pump controller status information

Cal. ref.	Parameter displayed	Logic type	Min setting	Max setting	Step size	Default
2.2.1	Battery voltage	P	0V	127V	0.5V	+
2.2.2	Pump motor voltage	P	0V	127V	1V	
2.2.3	Pump motor current	P	0A	1200A	6 A	+
2.2.4	Pump mosfet voltage	P	0V	127V	0.5V	
2.2.5	Pump controller temp.	P	-30° C	+225° C	1° C	+-
2.2.6	Key switch hours count	P	0Hrs	65279.9Hrs	0.1Hrs	
2.2.7	Pump pulsing hours count	P	0Hrs	65279.9Hrs	0.1Hrs	
-	Service log reset	P	Press + Followed by - to reset service log			

※ Log info shows where the + and - keys can be used to access the service max and min data.

(10) Pump Controller Test Information

Cal. ref.	Input displayed	Logic type	Min display (all units)	Max display (all units)	Step size (all units)
2.3.1	Accelerator 1% range	P	0%	100%	1%
2.3.2	Accelerator 1 voltage range	P	0.0V	5.0V	0.1V
2.3.3	Accelerator 2% range	P	0%	100%	1%
2.3.4	Accelerator 2 voltage range	P	0.0V	5.0V	0.1V
2.3.5	Pump switch 3	P	Open	Closed	-
2.3.6	Pump switch 4	P	Open	Closed	-
2.3.7	Pump switch 5	P	Open	Closed	-
2.3.8	Pump switch 6	P	Open	Closed	-
2.3.9	Pump switch 7	P	Open	Closed	-
2.3.10	Pump steer trigger	P	Open	Closed	-
2.3.15	Software version/revision	P	000.00	999.99	-
2.3.16	Controller serial number	P	00000000	99999999	-

(11) Pump BDI(as traction (4))

(12) Pump fault log(as traction (5))

(13) Pump setup menu enables / disables features

① Setup

Cal. ref	Feature	Logic type	Actual value
2.6.1	Mode	P	**CAN bus mode**
2.6.2	Accelerator type	P	**Linear**
2.6.3	Accelerator 2	P	**Economy**
2.6.4	BDI	P	**On**
2.6.5	Fault log	P	**On**
2.6.6	Service log	P	**On**
2.6.7	Seat and pump	P	**Off**
2.6.8	Pin 5	P	**P.Switch 6**
2.6.9	Pin 6	P	**P.Switch 7**
2.6.10	Pin 7	P	**Motor Temp**
2.6.11	Power steer active sense	P	**Closed**

※ **Changes only take effect after a key-switch recycle.**

② Display

Cal. ref.	Feature	Actual value
2.7.1	Main hours	Key
2.7.2	Status	Off
2.7.3	Contrast	35
2.7.4	Ind 1	Off
2.7.5	Ind 2	Off
2.7.6	Fault mags	Off

(14) Traction and Pump adjustment descriptions

Adjustment	Logic type	Description (T=Affects traction, P=Affects pump)
Current limit	L, M, H, P	Maximum allowable motor current.
Acceleration delay	L, M, H, P	Time taken to ramp up from 0 to 100% on.
Current Ramp delay	L, M, H	Time taken to ramp up current in plugging and drive.
Deceleration delay	L, M, H, P	Time taken to ramp down from 100% to 0% on.
Creep speed	L, M, H, P	Minimum applied % on when drive first selected. only PS 1 on pump
Dir. brake current(plug)	L, M, H	Maximum Plug braking current during direction switch change.
Plug turn current(plug)	L, M, H	Current at which braking ends and drive starts. (Fixed percentage only)
Neut. brake current(plug)	L, M, H	Maximum plug braking current in neutral.
Plugging threshold(plug)	L, M, H	Plug to drive threshold. Higher numbers mean earlier plug exit.
Plug drop current(plug)	L, M, H	Current at which neutral braking ends. (Fixed percentage only)
Footbrake current(plug)	L, M, H	Maximum plug braking current in neutral when F. brake switch active.
Dir. Brake current(reg)	L, M, H	Maximum regen braking current during direction switch change.
Neut. brake current(reg)	L, M, H	Maximum regen braking current in neutral.
Footbrake current(reg)	L, M, H	Maximum regen braking current in neutral when F. brake switch active.
Regen delay(reg)	L, M, H	Used to minimize delays for unsuccessful regen attempts at low speeds. Higher numbers give regen at lower speeds. 0 forces plugging only.
Maximum speed	L, M, H	Maximum allowable % on.
Cutback speeds 1, 2 & 3	L, M, H	Maximum allowable % on when cutback switches active.
Accel. delay 1, 2 & 3	L, M, H	Independently adjustable acceleration delays during speed cutbacks.
Inch speed	L, M, H	Maximum allowable % on during inching operation.
Burst inch delay	L, M, H	Timer to allow inching for a set period only.
Bypass over current	M, H	Maximum allowable current in bypass before contactor opens.
Bypass delay	M, H	Time for bypass contactor to close after 100% on reached.
F.W.pull in current	M, H	F.Weak, contactor allowed to pull in at currents<pull in level.
F.W drop out current	M, H	F.Weak, contactor will drop out at currents>drop out level.
Power steer delay	L, M, H	Delay after power steer trigger removed until contactor opens.
Seat switch delay	L, M, H, P	Delay after seat switch opens until pulsing is inhibited.
Zero levels	L, M, H, P	Used to select minimum voltage input level for function. E.g. an accel zero level=0.5V means pulsing begins at 0.5V I/P.
Full levels	L, M, H, P	Used to select maximum voltage input level for function, E.g.an accel full level of 4.0V means 100% pulsing is reached at 4V I/P.
Speed limit	M, H	Used with external speed sensor to provide speed limit feature.
Low voltage init	L, M, H, P	Voltage at which controllers starts reducing the max available current limit to help reduce voltage drops.
Low voltage cutback	L, M, H, P	Voltage at which current limit is reduced to 0.
High voltage init	L, M, H, P	Voltage at which controller changes from regen braking to plug braking to help prevent high generated voltages damaging the battery or controller.

Adjustment	Logic type	Deseription (T=Affects traction, P=Affects pump)
High voltage cutback	L, M, H, P	Voltage at which contactors will open, to prevent high voltage damage.
Battery protection	L, M, H, P	Voltages below this level cause a battery low 7 flash fault.
Protection delay	L, M, H, P	Length of time the voltage can fall below the battery protection level for, before a fault is indicated. This helps prevent spikes tripping a low batt fault.
Pump speeds 1-7	P	Maximum allowable % on's when respective switch active.
Power steer speed	P	As above, but for power steer speed.
Pump comp. 1-4	P	Set-up compensation by adjusting the relevant pump speed to give the required minimum no load speed, then set the associated compensation adjustment to give the same speed under full load conditions
Power steer comp.	P	As above but for power steer speed compensation.
Power steer ramp up	P	Independent acceleration delay for power steer function.
Power steer ramp down	P	As above but for deceleration delay.
Speed 5, 6 & 7 Priority/additive	P	Lower numbers have priority over higher numbers. Additive is where the speed 5, 6 or 7 is added to lower numbered switches.
Electric brake delay	L, M, H	Used to specify a variable time delay between the power steer trigger becoming inactive and the electric brake contactor opening (brake on).

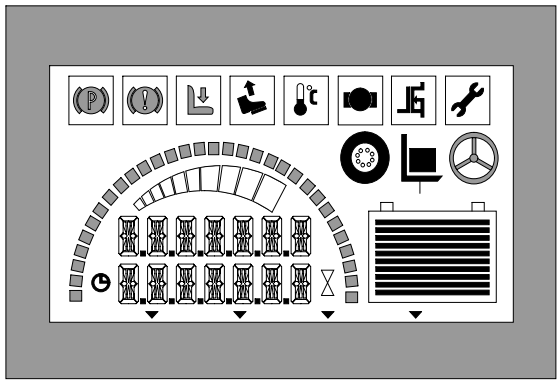
8) DIAGNOSTICS

Traction and pump fault messages and LED status/number of flashes.

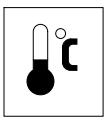
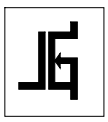
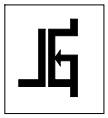
	Calibrator message	Standard display	Full Feature display	LED	Description and how to clear	Check
0	OK(lowest priority)	-	-	on	Traction operational and OK.	No action required.
1	Testing...	Run Tests	-	on	Only displayed briefly at power up.	No action required.
2	BDI cutout	BDI Cut	BDI CUT OUT	7F	BDI enabled and cut-out action initiated.	Battery charged.
3	Thermal cutback	Over Temp.	TRAC HOT	8F	Traction heatsink above 75° C. Allow controller to cool.	Heatsinking, mounting, Sur faces clean, fan req.
4	Speed probe	Speed Probe	SPEED PROBE	6F	Speed limit feature enabled & wire off.	Probe connections.
5	Accel fault	Accel fault	ACCEL FAULT	6F	Accel. pedal pressed at power up, or wire off. Recycle FS1 or direction.	Accel wiring. Accel zero & full Personalities.
6	Contactor o/c	Cont o/c	CONTACT FAULT	4F	Contactor has bad contact or didn't close, motor o/c. Recycle FS1 & Dir.	Coil wiring, power wiring, motor o/c.
7	Contactor s/c	Cont s/c	CONTACT FAULT	4F	Contactor didn't open or is welded. Recycle FS1 and direction switch.	Welded tips, particles in tips, wiring.
8	Sequence fault	Seq. Fault	SEQ FAULT	2F	Direction or FS1 switch at power up. Recycle direction FSI or both.	Dir and FS1 in neutral and dir/FS1 wiring.
9	2 Dir fault	2 Dir Fault	2 DIR FAULT	2F	Two directions selected together. Recycle both directions and FS1.	Direction switch wiring.
10	SRO fault	SRO Fault	SRO FAULT	2F	Dir. switch selected > 2 seconds after FS1. Recycle FS1 and Dir.	Dir first then FS1, FS1 and dir switch wiring.
11	Seat fault	Seat Fault	SEAT FAULT	2F	Drive selected and no seat sw. Recycle dir and FS1 switch.	Seat switch, closed, seat wiring.
12	Inch Fault	Inch Fault	INCH FAULT	2F	Inch switch at power up, both inch switches selected or inching attempted with seat switch or Dir/FS1 selected. Recycle inch switches.	Inch switch in neutral at power up, only 1 selected. Seat/Dir/ FS1 switches open.
13	Battery low	Bat. Low	BATTERY LOW	7F	Battery < Low battery personality. Recycle FS1 or direction switch.	Correct batt voltage, discharged battery.
14	Battery high	Bat. High	BATTERY HIGH	7F	Battery > High battery personality. Recycle FS1 or direction switch.	Correct battery voltage. Loose or missing B^+ to controller.
15	Pers error	Pers Error	PERS ERROR	1F	Personalities out of range at power up.	Reset personalities out of range(shown as...)
16	CRC error	CRC Error	CRC ERROR	1F	One or more personalities have been corrupted.	Check all personalities then recycle keyswitch.
17	Coil S/C	Coil S/C	COIL FAIL	9F	A contactor coil S/C or miswired Recycle key switch	Coil S/C, drive connected directly to B+ ve, wiring.
18	MOSFET S/C	FET S/C	MOSFET FAIL	3F	Bypass contactor S/C or MOSFET S/C Recycle FS1 or Direction	A/P/B power wiring. MOSFETs S/C

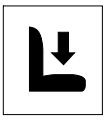
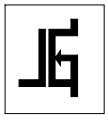
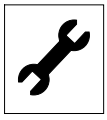
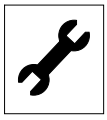
(1) Diagnostic/status text messages

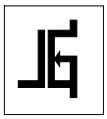
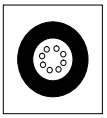
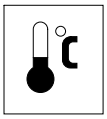
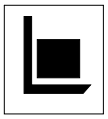
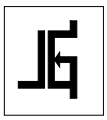
The controller can transmit text messages for diagnostic and status indication. On the standard display these appear over the status area, and on the full-feature display, they also overwrite the hours counter until the fault condition has cleared. This feature can be disabled via personality as described on the previous page. Some meassages may be displayed with one or more symbols. The following table shows the fault message and symbols displayed for each fault condition.



BR147OM283

No.	Message	Symbols displayed	Fault description
0	-	-	Traction operational and OK.
1	-	-	Only displayed briefly at power up.
2	BDI CUT OUT	-	BDI enabled and cut-out action initiated.
3	TRAC HOT	 & 	Traction heatsink above 75˚C. Allow controller to cool.
4	PUMP HOT	 & 	Pump heatsink above 75˚C. Allow controller to cool.
5	SPEED PROBE		Speed limit feature enabled & wire off.
6	ACCEL FAULT		Accelerator wire off. Recycle FS1 and direction.
7	ACCEL FAULT		Acclerator pedal pressed at power up, or wire off. Recycle FS1 and direction.

No.	Message	Symbols displayed	Fault description
8	CONTACT FAULT		Contactor has bad contact or didn't close, motor o/c. Recycle FS1 & Dir.
9	CONTACT FAULT		Contactor didn't open or is welded. Recycle FS1 and direction switch.
10	SEQ FAULT		Direction or FS1 switch at power up. Recycle Direction FS1 or both.
11	2 DIR FAULT		Two directions selected together. Recycle both directions and FS1.
12	SRO FAULT		Dir, switch selected > 2 seconds after FS1. Recycle FS1 and Dir.
13	SEAT FAULT		Drive selected and no seat sw. Recycle Dir and FS1 switch.
14	INCH FAULT		Inch switch at power up, both inch switches selected or inching attempted with seat switch or Dir/FS1 selected. Recycle inch switches.
15	BATTERY LOW	-	Battery < Low battery personality. Recycle FS1 or Direction switch.
16	BATTERY HIGH	-	Battery > High battery personality. Reycle FS1 or direction switch.
17	PERS ERROR	 & 	Personalities out of range at power up.
18	CRC ERROR	 & 	One or more personalities have been corrupted.
19	COIL FAIL		A contactor coil S/C or miswired. Recycle keyswitch.

No.	Message	Symbols displayed	Fault description
20	MOSFET FAIL	 & 	Bypass contactor S/C or MOSFET S/C Recycle FS1 or direction.
21	-	 & 	Traction motor too hot.
22	-	 & 	Pump motor too hot.
23	FAIL	 & 	If any of these messages is displayed then the controller has failed one of its internal power up checks.

9) SERVICE AND FAULT LOGS(All logics)

The service and fault logs have been incorporated to allow end users and service personnel to inspect and note the controller's performance and fault history. Utilising the controller's existing status measurements and diagnostics capabilities, information(such as the maximum temperature the controller has operated at or the number and type of faults that have been detected) can be stored in non-volatile memory and presented at a later date. Both the service and fault logs can be selected/deselected via the set-up menu on the calibrator, and when selected can be cleared at any time to start recording new data.

(1) Service log

Service information is available in the traction and pump status menus, where holding down the '+' key shows the maximum value of the current item, and holding down the '-' key shows the minimum value. The following items are logged :

- Maximum battery voltage
- Maximum motor current
- Maximum controller temperature and minimum controller temperature.

To clear the log, access the "service log + to reset log" message at the end of the status menu, and follow the prompts. The service log can be enabled in the setup menu.

(2) Fault log

The fault log is available at location 1.5 on the calibrator. Faults are grouped together by "LED flash fault", the types of flash fault and whether each is logged is shown below.

Generally faults that can occur during normal operation e.g. a2 flash driver procedure error or an 8 flash thermal cutback indication, are not logged.

- LED off faults Logged(Internal controller power up check faults)
- 1 flash faults Logged(Personality/CRC faults)
- 2 flash faults Not Logged(Driver procedure/sequence/wiring type faults)
- 3 flash faults Logged(MOSFET/bypass wiring type faults)
- 4 flash faults Logged(Contactor O/C or S/C or wiring type faults)
- 5 flash faults Not Logged(Not used)

· 6 flash faults Not Logged(Potentiometer wire off type faults)
· 7 flash faults Logged(Battery low or high faults)
· 8 flash faults Not Logged(Thermal cutback faults)
· 9 flash faults Logged(Contactor coil S/C type faults)

Each of the above logged categories contains the total number of faults of this type, the key hours count of the most recent fault and a text description of the fault. An example of how the fault log information is presented is shown below :

This display shows that 12 4-flash faults have occurred and been logged, the most recent at 12345.6 key hours and it was a contactor o/c fault.

12*04F 12345.6hr Contactor o/c

Once into the fault log menu, the left and right arrows are used to view any faults stored and at the end of the list a "Fault lot + to reset log" message is shown, where the fault log can be reset in a similar way to the service log. The fault log can be enabled and disabled in the setup menu.

10) CONTROLLER OPERATION AND FEATURE DESCRIPTIONS

(1) Traction operation

Applicable to all traction logics unless otherwise specified.

① Start up sequence

At keyswitch on, the direction and FS1 switches must be in the neutral condition simultaneously at least once before drive can be selected. This is a safety feature to help prevent unexpected movement immediately after power up.

② SRO(Static return to off)

This feature is optional in the setup menu and when specified, forces the following sequences of switch inputs to be followed before drive is allowed :
Keyswitch-Direction-FS1 or Keyswitch-FS1-Direction(within 2 seconds of FS1). Any other sequence will not allow drive. Drive will be inhibited if FS1 is active for more than 2 seconds with no direction selected. In this case the FS1 will need to be recycled.

③ Seat switch

If the seat switch is opened and the seat switch timer has timed out during drive the controller will stop pulsing and a seat fault will be indicated. Before drive can be restarted the seat switch must be closed, and FS1 and the direction switch must be recycled through neutral. Note the start sequence for drive requires that the seat switch is closed and both the direction and FS1 switches are in the neutral position simultaneously before drive can be initiated. The time period is programmed by means of the calibrator(seat switch delay). As a setup menu option the seat switch can also inhibit pump operation if required.

④ Handbrake switch(Not available on low i/o logic)

An input is provided for the connection of a handbrake switch, which if operated will disable traction pulsing but leave the drive related contactors in position to effect a minimum roll back hill start when drive is selected and the handbrake is released.

⑤ **Deceleration delay**

This is an adjustable delay to ramp down the pulsing from 100% on to 0% on, and can be used to limit the inherent truck lurch when acceleration is interrupted. When neutral is selected, contactors are only opened when the % on has ramped down to 0.

⑥ **Creep**

The creep speed is adjustable and is used to select a minimum pulsing level as soon as drive is requested, to minimize delays and dead-bands. The motor voltage is rapidly ramped to the creep level(equivalent to a 100ms acceleration delay).

⑦ **Cutback speeds**

There are 2 cutback switch inputs as standard. An additional cutback 3 function can be configured in the setup menu. Each one has an associated personality to adjust the maximum % on when the switch is active. In addition each cutback has an independently adjustable acceleration delay associated with it to further enhance low speed manoeuvrability. When both switches are active together, the lower speed is selected together with the slowest acceleration delay. The cutback speed inputs are usually normally closed so that a wire off type fault or bad connection initiates a lower speed.

When the BDI feature is enabled and the cut-out level is reached the speed 2 cutback is automatically initiated.

A maximum speed adjustment is also available to limit the maximum applied % on. (If the setting is less than 95% then bypass and field weakening are disabled).

⑧ **Bypass(Not available on low i/o logic)**

The bypass contactor is used to short out the main MOSFET switching device to increase speed and efficiency at high speeds and to allow higher motor currents than the controller's maximum current limit, to climb ramps laden or to escape from ruts or pot holes.

Bypass can be initiated in 2 ways :

Current-limit bypass : The accelerator is fully depressed and the controller has been in current limit for longer than 2 seconds. In order to prevent a sudden lurch of the truck the contactor will not be energised if the motor voltage during current limit is less than 20% of battery voltage. This mode of operation can be disabled via the setup menu.

High-speed bypass : If the accelerator is fully depressed and the controller has been pulsing at maximum % on for 1.5 seconds and the bypass delay personality has timed out. The bypass delay timer is a feature that can be used to allow the truck to obtain full speed, before contactor closure.

The bypass contactor will be de-energized if the accelerator demand is reduced below 86%, or if the motor current exceeds the bypass over-current dropout level, adjustable by the calibrator. To allow for initial overshoots the over-current test is disabled for the first 2 seconds of bypass. Although the software attempts to minimize arcing when the contactor opens, some arcing is inevitable under certain load conditions. After an over-current drop out, the bypass function will be inhibited until neutral is recycled to prevent repeated opening and closing of the tips under heavy current conditions. Bypass can be disabled by setting the over-current drop out to 0 A. also bypass will be disabled if either of the 2 speed cutback switches are enabled and the settings are adjusted below 95% or the maximum speed setting is less than 95%. Applying the footbrake switch or economy 0% will also prevent bypass closure.

⑨ **Power steer, traction controller**

A contactor drive is available to control a separate power steer motor. An adjustable delay allows the motor to operate for a set time, after the power steer trigger or power steer demand has been removed. SEVCON's standard trigger, i.e. when the contactor is closed, is when either FS1 or the footbrake switch is closed, or the traction unit is pulsing. It is an either or situation, so any one of these 3 inputs is sufficient to trigger the power steer.

This standard trigger is designed to give power steer whenever the truck is moving, but not to have a situation where the power steer could be on continuously, i.e. on a direction switch where the truck could be left with a direction selected and the keyswitch left on. If FS1 or the footbrake is applied then the vehicle is either about to move or is moving, and the traction pulsing is used if the truck was neutral braking(pulsing) down a long ramp, it is conceivable that neither of the 2 switches would be closed. On a tow-tractor, power steer is disabled during inching.

An independent input pin also exists to trigger power steer operation. This is normally used in conjunction with a steer on demand system where an output is generated when the steering wheel is turned. This gives power steer on demand and is more efficient since typically no steering delay, or only a short delay is needed.

The independent trigger only, or other trigger combinations can be configured if necessary in the setup menu.

Some vehicles derive the power steering assistance from the main pump hydraulic motor, instead of having a separate steer motor. In this situation the trigger is fed to the pump controller and runs the pump at the speed set by the P. S. speed personality.

Independent ramp up and ramp down delays are provided when power steer assistance is derived from the main pump controller, to help tune steering responsiveness without affecting the main pump operation.

⑩ **Regen braking**

Regen provides vehicle braking by controlling the motor as a generator and returning the generated energy back to the battery. Regen braking reduces motor heat dissipation compared with plug braking. Regenerative braking can be initiated in 3 ways, each with an independently adjustable braking level, as follows :

a) A direction switch change will initiate regen braking at a level set by the direction brake current level. Braking effort is proportional to the accelerator position, with a minimum accelerator pedal position giving 50% of the set brake level increasing to 100% for a fully depressed pedal. The proportionality range allows the driver to modify the braking effort without allowing freewheeling. The proportionality feature is optional and can be configured in the setup menu to give fixed braking at the set personality level.

b) Closure of the foot-brake switch in neutral, will initiate regen braking at the footbrake personality level. An input is provided to allow braking effort to be proportional to the footbrake position if a potentiometer is fitted. Setting a 0 into the personality disables braking on the footbrake switch.

c) When neutral is selected, regen is initiated at the neutral brake current level. Setting a 0 into the personality disables neutral braking and allows freewheeling. Neutral braking will only be attempted if the % on in the previous direction exceeded 20% above the set creep level. This helps minimise unnecessary delays and contactor operations.

Regen braking is not possible at low speeds depending on the motor characteristics. To help minimize delays attempting to regen, a regen time adjustment is offered which can be set so that regen is only attempted for a short period of time, which is sufficient to initiate regen at medium to high speeds but not to cause unnecessarily long delays at very slow speeds where regen is not possible. If the regen time setting is increased then regen can be initiated at lower speeds.
Setting the regen time to 0 disables regen and forces plug braking only.

If regen is not possible due to low vehicle speed, the following action will be taken :

- For direction braking, plugging will be used to slow, then reveres the vehicle.
- For neutral or footbrake braking, the vehicle will freewheel.

The switching frequency in regen is high frequency and silent.

⑪ **Plug braking**

Plug braking is achieved by controlling the rotating motor armature as a generator and dissipating most of the energy in the motor and the plug diode.
For plugging-only controllers, the conditions for initiating braking are identical to those for regen controllers : On a direction change, footbrake switch and in neutral. Plugging also operates on regen controllers if the truck has been travelling to slowly to initiate regen direction braking.
The switching frequency in the plug braking mode is 6kHz.

⑫ **Anti-rollback**

This is a standard SEVCON feature and is used to help prevent roll back conditions on ramps. If the driver reselects the previous direction after a neutral condition, braking is not attempted, and full drive power is available to restart on a hill.

⑬ **Analogue Inputs**

The accelerator/analogue inputs are flexible in the range of signal sources they can accommodate and can be adjusted to minimize dead-bands and mechanical tolerances. Each analogue inputs has 2 adjustments associated with it, that allow the input voltage range to be determined.
For the traction accelerator, for example, the 2 adjustments are called the “Accelerator zero level” and the “Accelerator full level”. If these were set to 0.20V and 4.80V then 0% pulsing would start at 0.20V at the input, increasing to 100% pulsing at 4.80V. For accelerators with decreasing voltage outputs, the zero adjustment might be set to 3.5V and the full adjustment to 0.0V.
The calibrator test menu shows the instantaneous voltage reading, and the equivalent % “push” for each input, and to allow easy set-up, pressing the “down” key on the calibrator from either of these test displays, allows a direct jump to the zero voltage and full voltage personality settings.

※ **Note that a 6 flash fault will occur if the full and zero levels are set within 0.50V of each other.**

⑭ Traction accelerator

When drive is elected and the accelerator is first pressed, pulsing will commence at the creep speed setting increasing towards the maximum % on.

If the accelerator is depressed at power up, pulsing will be inhibited and a 6 flash fault will be indicated, until the pedal is released. In case of a wire off type fault, pulsing will be limited to the creep setting and a 6 flash fault will also be given.

Various accelerator characteristics i. e. relationship between accelerator push and the applied motor voltage, can be selected via the setup menu.

There are 4 options : Linear, curve, 2* slope and crawl. Set to linear for a straight line accelerator characteristic, curved for more low speed manoeuvrability, 2* slope for a balance between linear and curved, and crawl for a very shallow low speed manoeuvrability curve. See graph 2 for actual characteristics.

⑮ Footbrake switch

This input is available to allow a switch to be fitted to the footbrake pedal for constant braking. Note that footbrake operation drops out both bypass and field weakening.

□ Digital switch inputs

The digital inputs on the controller can be configured as active low inputs, where the switches are wired to B-ve. Active high inputs, connecting to B+ve, are not available. The SEVCON standard is active low, and is recommended for its low impedance input stage and immunity to moisture related problems.

A further configuration allows each input to be specified as normally open or normally closed.

Most switches are normally open, with the exception of the 2 speed cutback switch inputs which are normally closed, so that a wire off type fault, or bad connection initiates the cutback speed, other than a higher speed. On compensated pump systems the power steer input can be conveniently configured as normally closed.

□ Contactors

The pump logic has no contactor drives. The low I/O logic has 3 outputs for driving contactors, the medium I/O has 5 outputs and the high I/O has 10. On medium and high I/O logics it is also possible to reconfigure an output, as an external LED or lamp driver to allow dashboard indication of the controller's integral LED.

The controller can diagnose open circuit (o/c) and short circuit (s/c) problems with certain contactors, as described in the diagnostic section. Generally, following a request to open a contactor, the controller will report a 4 flash fault and a calibrator message if a successful operation was not detected after approximately 500ms. To help prevent against minor tip contaminants causing spurious diagnostic trips when closing a contactor, if a closure is not detected after 500ms, pulsing up to a maximum of 25% is allowed. This is designed to pass a controlled amount of current to try and break through any contaminant present to allow uninterrupted drive. If a closure isn't detected on reaching 25%, then the contactor drive is removed and a 4 flash fault is indicated.

An optional line contactor, not controlled from the controller, can be connected between the B+ terminal of the controller and battery positive. A diode should be fitted in series with the line contactor coil to prevent large currents flowing through the battery connectors and into the internal capacitors when the controller is first connected to the battery. After the keyswitch has been switched, and once the capacitors have charged up (via internal resistance) the line contactor will be energised. An internal diode fitted in the keyswitch line will prevent any contactor energising if the polarity of the battery voltage is reversed.

On pump controllers the line contactor also gives a mechanical break.
Under normal operating conditions contractors will operate without arcing.
However, under certain fault conditions, contractors may arc when opening. The bypass contactor may also arc during bypass over-current drop out conditions.

□ Contactor chopping

This feature allows 24V contactors to be used at all battery voltages 24V-80V, by continuously monitoring the battery voltage and chopping the contactor output pins accordingly, to present an average voltage suitable for 24V coils. Chopping is selectable by the calibrator. All the contactor drives will be either chopped or not chopped. It is not possible to select individual drives to chop.
Care must be taken to ensure that chopping is always selected if 24V contractors are being used on battery voltages higher than 24V. In applications > 24 volts contractors must be fitted with blow out magnets.
Chopping can reduce the overall dissipation in the coils and allows only one set of contactors to be stacked for all battery voltages.
Chopping frequency approx. = 650Hz (Slightly audible at higher battery voltages).
Typical contactor coil voltage during chopping = 16 volts.
Typical contactor coil voltage during energisation = 24 volts for 1 second.
There are 3 contactor chopping options available via the setup menu : Off, On and 24V.
The off setting is used for nominal battery voltage coils, and the on setting is for 24V coils on higher voltage vehicles. Setting to 24V provides chopping for 24V coils and lamps without the drop the 16V after 1s.

□ Fail-safe

The controller's safety system includes a microprocessor watchdog which can detect software failure, and a hardward fail-safe system which can prevent dangerous runaway conditions in the event of certain hardware failures.
Every time the controller is powered-up, the software checks that the fail-safe circuit is able to switch off the MOSFETs and open the contactors.

□ Speed limit(Not available on low i/o logic)

A traction speed limit in kPH can be set via personality 1.1.33 (0 kPH disables the feature). As the speed of the vehicle approaches the limit, the maximum motor voltage is reduced. If the speed limit is exceeded by more than 2kPH (when the vehicle is travelling down-hill for example) electrical braking will be used until the speed of the vehicle falls to below the limit. Speed limit braking may operate in normal drive (as described above), to increase existing braking torque if the vehicle over-speeds, or if the vehicle is rolling in neutral.
The actual limit speed of the vehicle is typically $\pm$2kPH of the personality setting, depending on motor loading. When the feature is enabled, a probe "wire-off" feature will limit the motor voltage if the probe is disconnected.
Calibration of the feature is made via the set menu items "full speed" (1.6.23) and "probe frequency" (1.6.24). Full speed should be set to the maximum speed of the vehicle, unloaded on level ground. The probe frequency setting should be the output frequency of the sensor at that speed.
The recommended sensor is an active low (i.e. NPN) inductive proximity switch. The output is connected to the customer connector, pin 9. A $^{+}$12V supply on the customer connector pin 12 can be used for most types of sensor. The negative supply of the sensor should be connected to the controller's B- terminal. Contact SEVCON for further recommendations if required.

(2) Pump operation

① Pump Operation

There is no start-up sequence, so pulsing will be initiated after a small delay at power-up if one or more of the pump switches is selected. There are adjustable ramp up and ramp down delays. A pump contactor can be specified as an option. There are facilities for prioritising pump speeds, for having different pump speeds added together and for having speed compensation for different load conditions.

② Pump speeds and Priorities

Each of the 5 pump switch inputs has its own speed setting. The pump speeds are prioritsed in numerical order so that speed 1 has priority over all other speeds and speed 2 has priorits over speeds 3 to 5, etc. Example : -If speed 1 is set to 10%, speed 2 to 20% and speed 3 to 30% then selecting speeds 1 and 3 will give 10% and selecting speeds 2 and 3 will give 20%.

③ Additive speeds

Pump switches 5 and 6 can be adjusted to have an “Additive” speed. In this mode, the switch is excluded from the priority system ; instead its speed is added to the prioritised pump speed to the give increased power required to handle simultaneous pump operations.

Example : -If speed 2 is set to 40%, speed 5 is set to 25% and speed 6 is set to 10%, then selecting all three switches will give a demand of 75%, and selection 2 and 6 alone will give a demand of 50%

④ Pump accelerator inputs

The pump accelerator demands are associated with speeds 1 & 2. The pump will operate at the creep speed setting when the accelerator is at minimum demand and change linearly to speed 1 or 2 as the accelerator is increased to the maximum demand. The pump pot accelerator input can be connected and adjusted as per the previously described traction accelerator input.

⑤ EPS(Electric power steering) system

The power steering motor operates only as the start switch is ON position.

Withe the operation of steering wheel, the torque sensor detects the force and then transmits signals to EPS controller. The controller inspects the signals to decide the direction of rotation, velocity and force and supplies the current needed. EPS Motor rotates and its torque increases by reduction gear. Rotation force of reduction gear is transformed to linear force by actuator in order to steer the axle smoothly.

⑥ Pump speed compensation

Some trucks utilise the main hydraulic pump motor to provide power steering assistance, instead of a separate power steer motor. This feature provides speed compensation so that the pump motor always provides steering assistance, whilet allowing the motor to slow down when assistance isn’t required to minimise noise and improve efficiency. Pump speeds 1-4 and the power steer speed can be compensated if required.

The compensation is a staight line characteristic set up using 2 personalites. The set up procedure may require some repetition to give optimum performance of low load(low noise) and full compensated load. The low load speed is normally set up to run the pump motor at its lowest permissible lubrication speed to keep audible noise to an absolute minimum.

The calibrator’s base speed sets up the low load speed and the compensation factor sets the amount of boost when the controller detects a current increase due to the pump motor load increasing. The controller monitors the motor current and changes the motor voltage to ensure that the motor remains on this compensated speed line.

Set up Procedure-Set both the base speed and the compensation factor to 0. Activate the pump switch associated with the speed to be compensated. Ensure that the motor has its minimum load. Increase the base speed until the correct operation speed at minimum load is achieved. Increase the load associated with this pump speed to its maximum. Increase the compensated speed until varying the load has little or no effect on the speed.

Example-Power steer compensation where the main pump motor provides the hydraulic steering assistance. Set the power steer personality base speed and compensation factor to 0. Activate the power steer trigger input and increase the power steer base speed until the pump motor is running at its desired low speed. Operate the steering. Very little assistance will be given if the pump is going slow. Increase the power steer compensation setting until the required amount of assistance is given when the steering is operated. The set-up is an iterative process so it may be necessary to change the base speed again and repeat the procedure to obtain optimum results.

(3) General operation

① Operating frequency

The drive frequency of both the traction and pump power frames is 16kHz, for silent operation.
For traction regen-braking the frequency is also 16kHz, whilst plug braking is 6kHz.

② Temperature monitoring

If the temperature of either power frame exceed 75°C its maximum available current will be reduced. Note, however, that if the set current limit is less than the maximum available current limit actual cutback will occur at progressively higher temperatures than 75°C. The thermal cutback ensures that the maximum heatsink temperature is limited to 95°C.
When cutback occurs the diagnostic LED will flash 8 times.

③ Safe operating area(SOA)

The controller's current may be limited at high and/or low duty cycles depending on its current and voltage specification. This is to reduce the thermal stress on the power components in order to increase long term reliability.
The "Safe Operating Area" is a characteristic of the MOSFETs and Freewheel Diode which make up the power-frame. The MOSFET SOA restricts current at high duty cycles on all configurations, and the Diode SOA tends to restrict the current at lower duty cycles on lower voltage applications.
For most applications SOA will have little or no effect on the operation of the controller. Its effect is more significant in protecting the controller against adverse loads such as damaged motors and static test rigs.

④ Under-voltage and over-voltage protection

In order to prevent a sudden loss in power, the controller will begin to linearly ramp down the current limit, once the average battery voltage falls below a pre-set under-voltage start level. The current will be ramped down to 0 and a 7 flash fault indicated if the averaged battery voltage falls below the under-voltage cutout level.
To protect the controller from over-voltage caused by prolonged regen braking will be terminated and plug braking initiated when the average battery voltage reaches the over-voltage start level.
If the voltage exceeds the over-voltage cutout level in braking then all contactors will open and freewheeling will occur, requiring the vehicle's mechanical brakes to be used.
Under any other circumstances if the battery voltage exceeds the over-voltage cutout level, all pulsing is stopped and a 7-flash fault is indicated. This protects against incorrect battery connection.

Nominal battery voltage	Under-voltage cutout	Under-voltage start	Over-voltage start	Over-voltage cutout
48V	29V	36V	65.0V	70.0V

⑤ **Diagnostic LED**

This is mounted between the connectors on the front of the controller. It serves as a simple diagnostic tool as explained below :

Constant illumination	-No fault, normal condition
LED extinguished	-Internal controller fault
1 flash	-Personality out of range
2 flashes	-Illegal start condition
3 flashes	-MOSFET short Circuit
4 flashes	-Contactor fault or Motor Open-Circuit
5 flashes	-Not used
6 flashes	-Accelerator or Speed Probe wire off fault
7 flashes	-Low or High battery voltage or BDI cut-out operating
8 flashes	-Over temperature
9 flashes	-Contactor coil s/c

Further explanation of the LED flashes are displayed on the calibrator fault message section.

⑥ **Fault Clearance**

Any fault indication will be cleared by re-initiating the start sequence after the cause of the fault has been removed.

⑦ **Software Version and Revision indication**

For identification purposes and to assist in queries, the Software version and revision, and the controller serial number are indicated in the calibrator test Menu.

⑧ **Dashboard Displays**

SEVCON's existing CAN based standard and full feature displays are compatible with Powerpak controllers.

⑨ **Setup Menu**

A setup menu has been added to the calibrator that allows various features to be enabled and disabled. See 7) page 7-32 for more information.

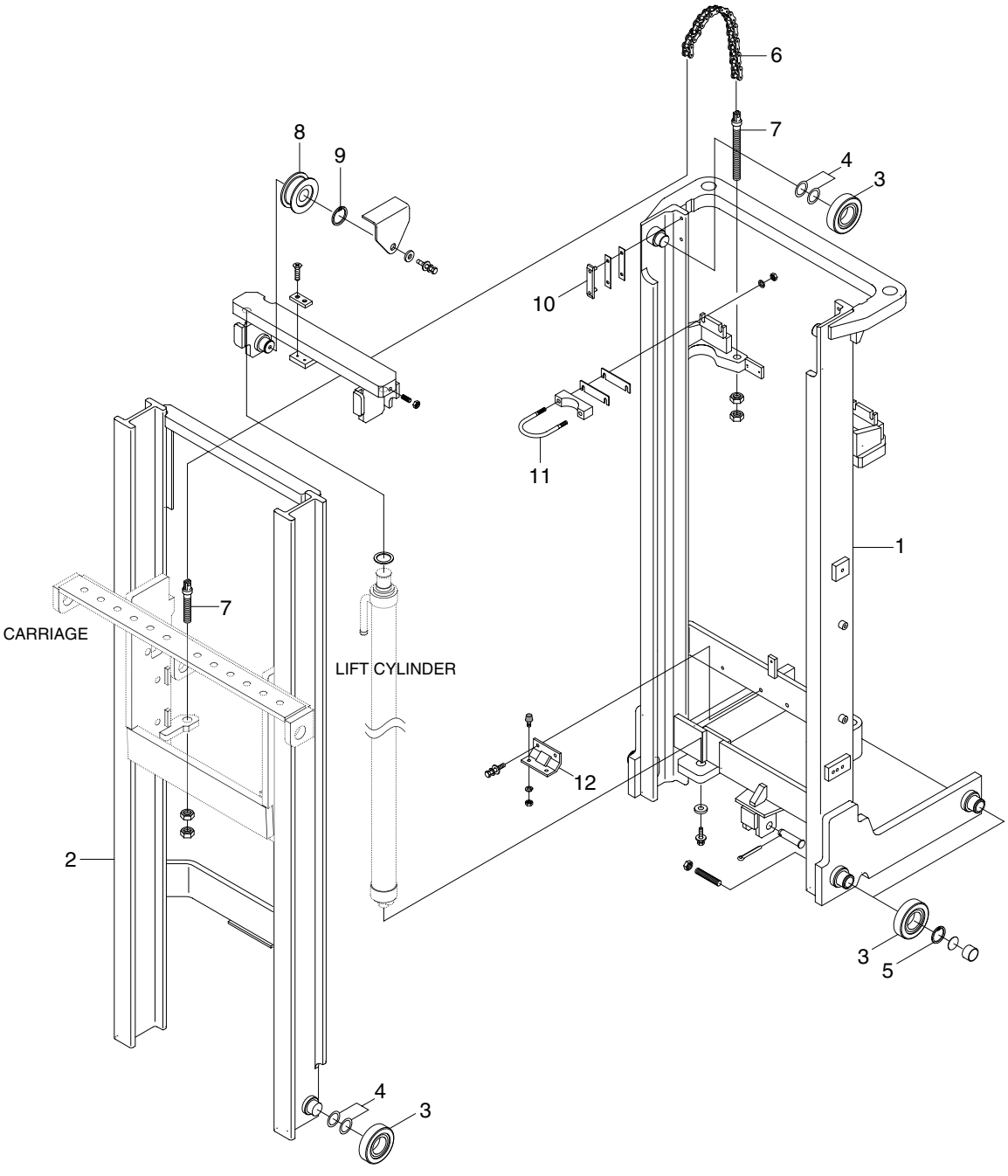
Note. Once a change has been made to the setup menu, the key switch must be recycled for the change to be operational.

SECTION 8 MAST

GROUP 1 STRUCTURE

1. 2 STAGE MAST(V MAST)

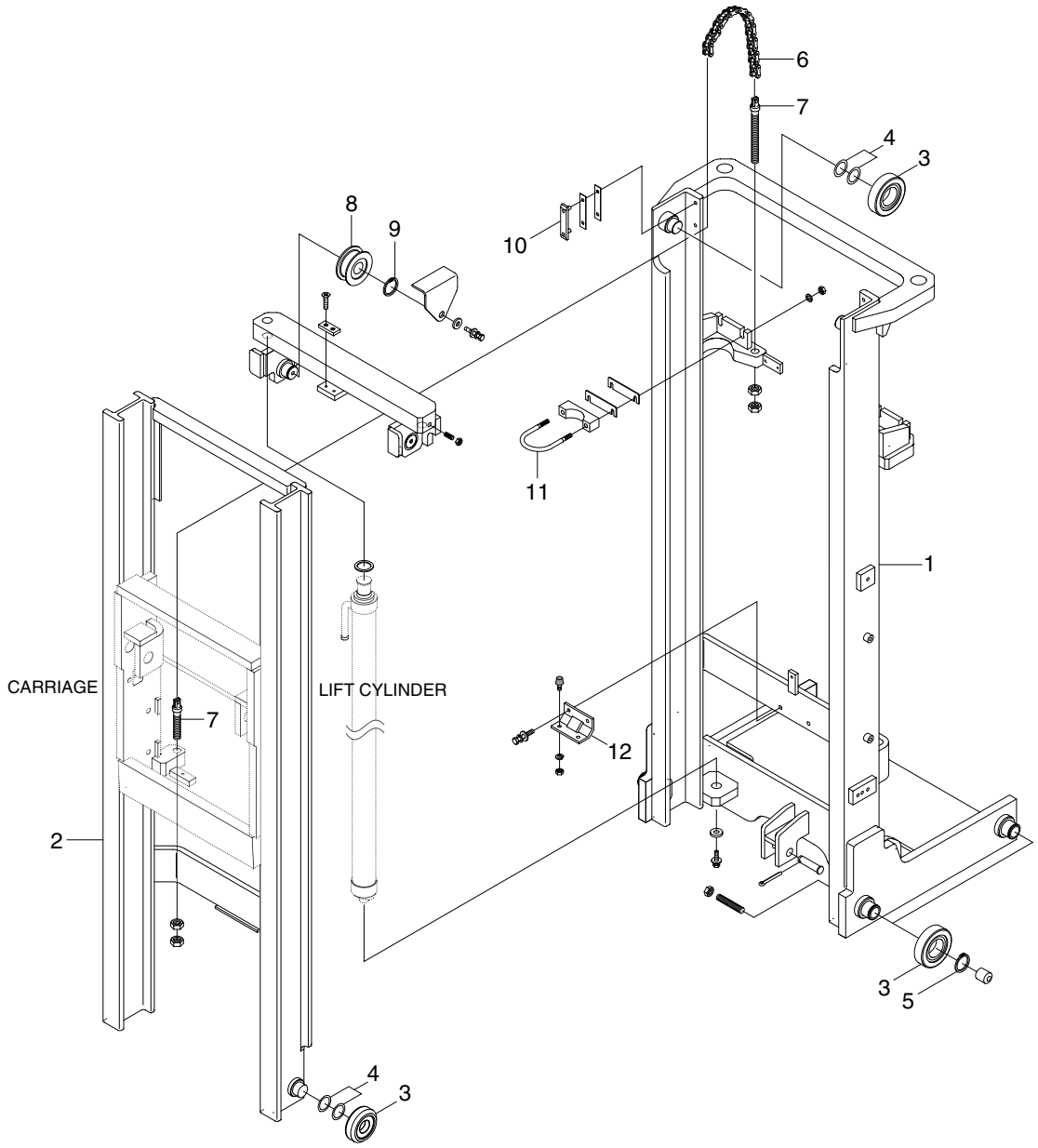
1) HBR14/15/18-7



BR147MS01

1	Outer mast	5	Retaining ring	9	Retaining ring
2	Inner mast	6	Lift chain	10	Back up liner
3	Roller	7	Anchor bolt	11	U-bolt
4	Shim(0.5, 1.0t)	8	Chain sheave	12	Inner support

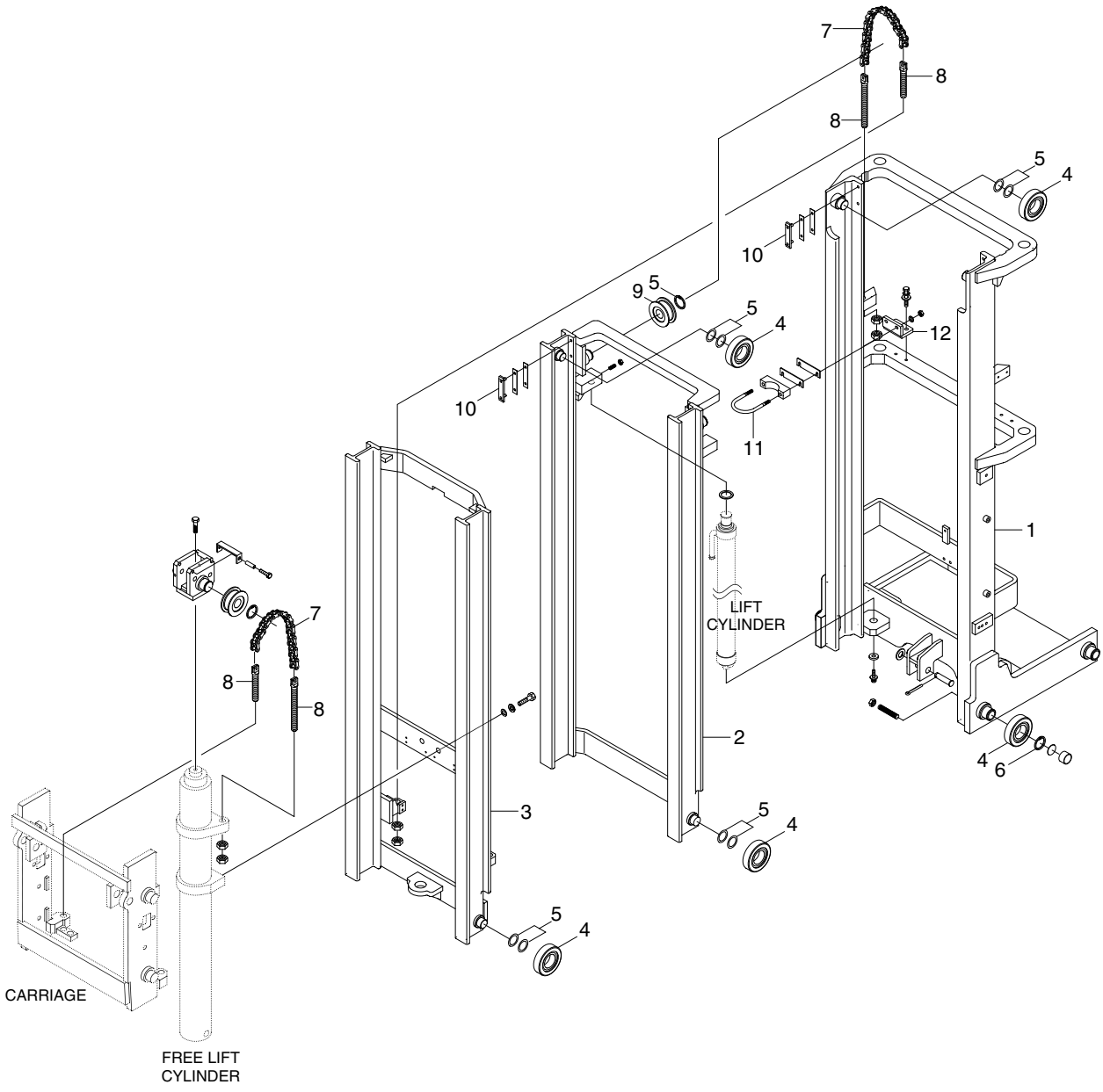
2) HBR20/25-7



BR147MS02

1	Outer mast	5	Retaining ring	9	Retaining ring
2	Inner mast	6	Lift chain	10	Back up liner
3	Roller	7	Anchor bolt	11	U-bolt
4	Shim(0.5, 1.0t)	8	Chain sheave	12	Inner support

2. 3 STAGE MAST(TF MAST)

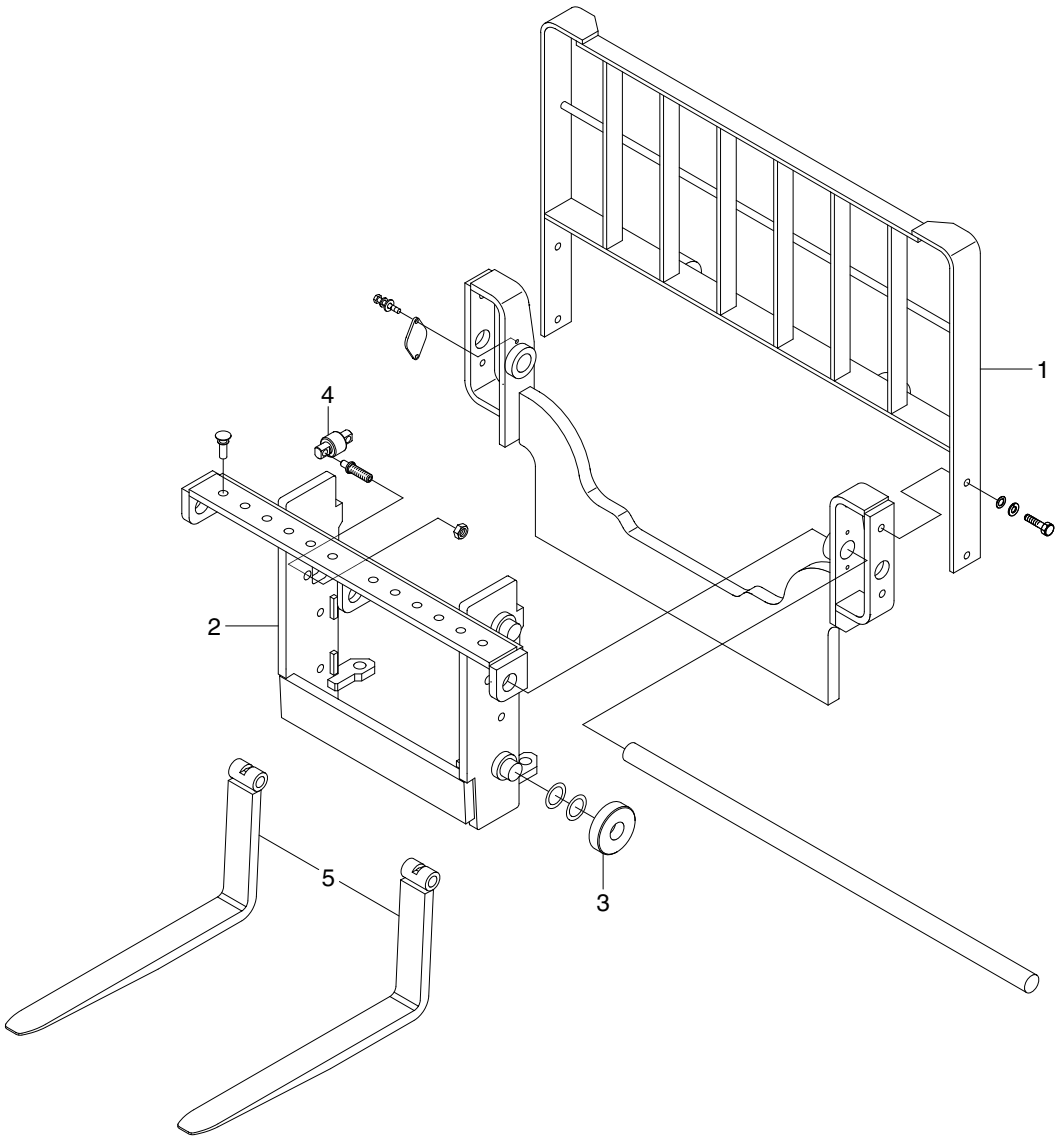


BR147MS03

1	Outer mast	5	Shim(0.5, 1.0t)	9	Chain sheave
2	Middle mast	6	Retaining ring	10	Back up liner
3	Inner mast	7	Lift chain	11	U-bolt
4	Roller	8	Anchor bolt	12	Inner support

3. CARRIAGE, BACKREST AND FORK

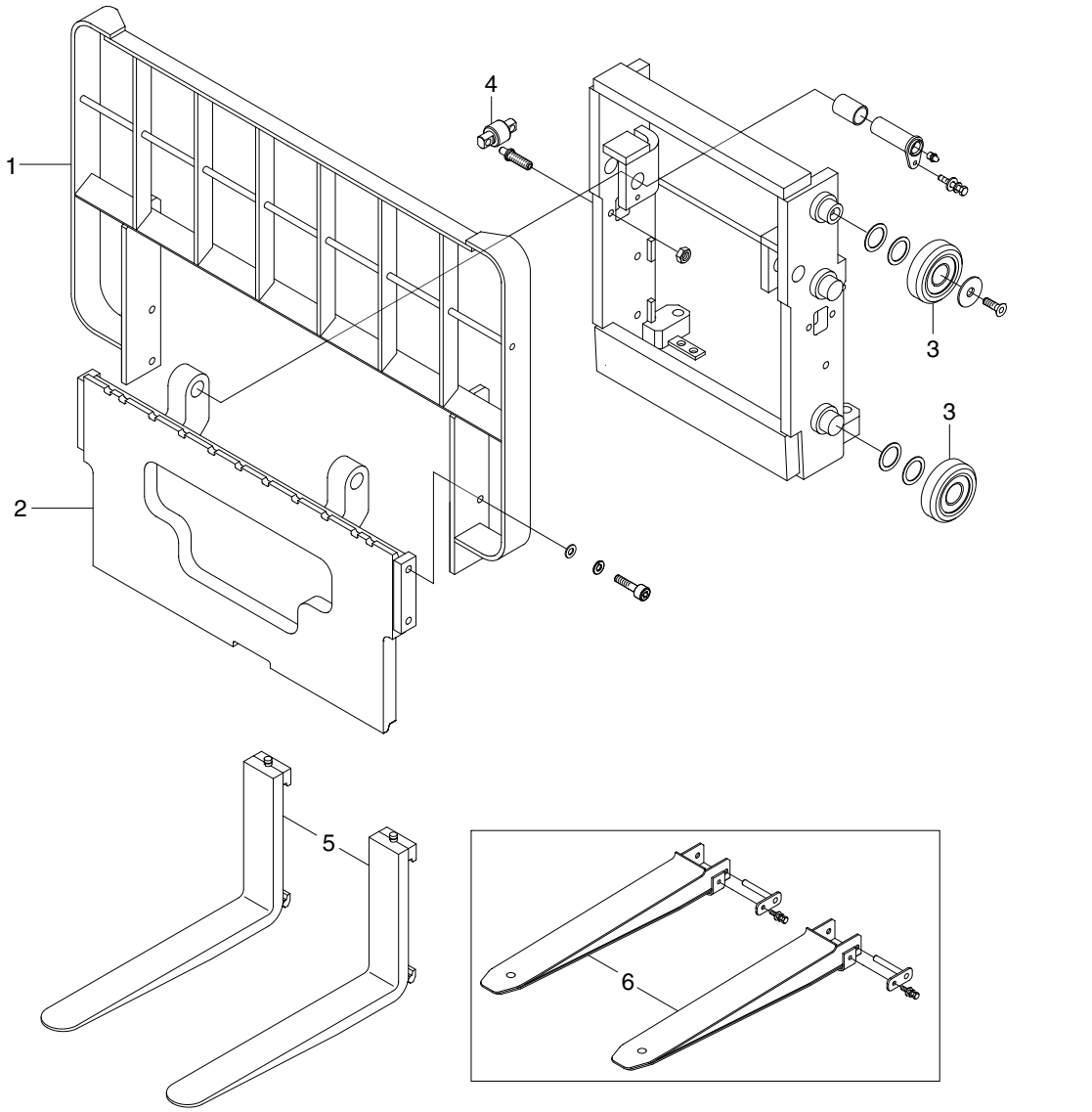
1) HBR14/15/18-7(SHAFT TYPE)



BR147MS04

1	Backrest	4	Side roller
2	Carriage	5	Fork assy
3	Load roller		

2) HBR20/25-7(HOOK TYPE)



BR147MS05

1	Backrest	4	Side roller
2	Carriage	5	Fork assy
3	Load roller	6	Extension fork

GROUP 2 OPERATIONAL CHECKS AND TROUBLESHOOTING

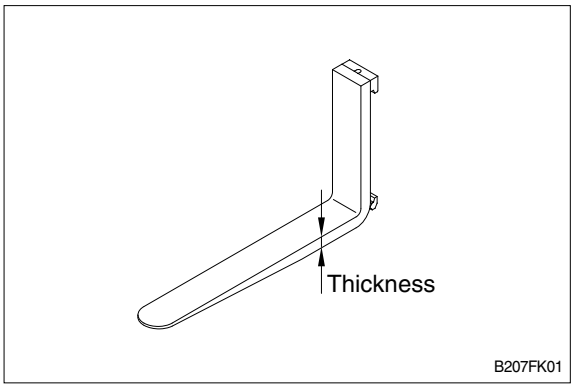
1. OPERATIONAL CHECKS

1) FORKS

(1) Measure thickness of root of forks and check that it is more than specified value.
EX : ℓ =900mm(35.4in)

mm(in)

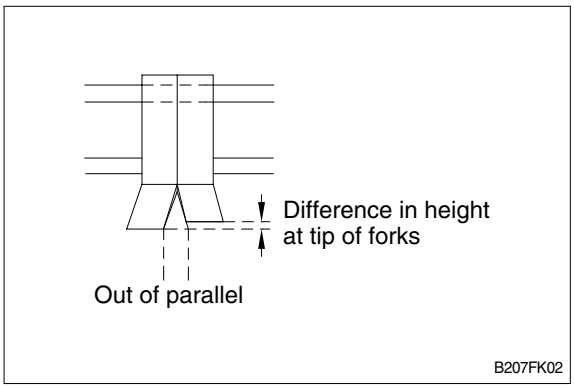
STD Fork assy	Applicable model	Standard	Limit
64FP-11030	HBR14/15/18-7	35(1.4)	31(1.2)
F173796-01	HBR20/25-7	45(1.8)	42(1.7)



(2) Set forks in middle and measure out of parallel and difference in height at the top of forks.

mm(in)

Difference in height	15(0.6)
Out-of-parallel	35(1.4)



(3) Most force is concentrated at root of fork and at hook, so use crack detection method to check cracks.

2. MAST

1) Check for cracks at mast stay, tilt cylinder bracket, guide bar, fork carriage and roller shaft weld. Check visually or use crack detection method. Repair any abnormality.
2) Set mast vertical, raise forks about 10cm from ground and check front-to-rear clearance and left-to-right clearance between inner mast and fork carriage, and between outer mast and inner mast. Use these figures to judge if there is any play at roller or rail.
   - Front-to-rear clearance : Within 2.0mm(0.08in)
   - Left-to-right clearance : Within 2.5mm (0.10in)
3) Check that there is an oil groove in bushing at mast support.
4) Set mast vertical, raise forks about 10cm from ground, and push center of lift chain with finger to check for difference in tension.
   If there is any difference in tension, adjust chain stopper bolt.
5) Check visually for abnormalities at thread of chain anchor bolt, and at contact surface between chain wheel and chain.
   Rotate chain wheel by hand and check for any play of bearing.

2. TROUBLESHOOTING

1) MAST

Problem	Cause	Remedy
Forks fail to lower.	· Deformed mast or carriage.	· Disassemble, repair or replace.
Fork fails to elevate	· Faulty hydraulic equipment.	· See troubleshooting hydraulic pump and cylinders in section 6, hydraulic system.
	· Deformed mast assembly.	· Disassemble mast and replace damag-ed parts or replace complete mast assembly.
Slow lifting speed and insufficient handling capacity.	· Faulty hydraulic equipment.	· See troubleshooting hydraulic pump and cylinders in section 6, hydraulic system.
	· Deformed mast assembly.	· Disassemble mast and replace damag-ed parts or replace complete mast assembly.
Mast fails to lift smoothly.	· Deformed masts or carriage.	· Disassembly, repair or replace.
	· Faulty hydraulic equipment.	· See Troubleshooting Hydraulic cylinders pump and control valve in section 6, hydraulic system.
	· Damaged load and side rollers.	· Replace.
	· Unequal chain tension between LH & RH sides.	· Adjust chains.
	· LH & RH mast inclination angles are unequal. (Mast assembly is twisted when tilted)	· Adjust tilt cylinder rods.
Abnormal noise is produced when mast is lifted and lower-ed.	· Broken load roller bearings.	· Replace.
	· Broken side roller bearings.	· Replace.
	· Deformed masts.	· Disassemble, repair or replace.
	· Bent lift cylinder rod.	· Replace.
	· Deformed carriage.	· Replace.
	· Broken sheave bearing.	· Replace.
Abnormal noise is produced during tilting operation.	· Insufficient lubrication of anchor pin, or worn bushing and pin.	· Lubricate or replace.
	· Bent tilt cylinder rod.	· Replace.

2) FORKS

Problem	Cause	Remedy
Abrasion	Long-time operations causes the fork to wear and reduces the thickness of the fork. Inspection for thickness is needed. ・Wear limit : Must be 90% of fork thickness	If the measured value is below the wear limit, replace fork.
Distortion	Forks are bent out of shape by a number of reasons such as overloading, glancing blows against walls and objects, and picking up load unevenly. ・Difference in fork tip height : 15㎜ ・Difference in fork tip width : 35㎜	If the measured value exceeds the allowance, replace fork.
Fatigue	Fatigue failure may result from the fatigue crack even though the stress to fork is below the static strength of the fork. Therefore, a daily inspection should be done. ・Crack on the fork heel. ・Crack on the fork weldments.	Repair fork by expert. In case of excessive distortion, replace fork.

GROUP 3 ADJUSTMENT

1. MAST LOAD ROLLER(V MAST)

1) INNER/OUTER MAST ROLLER CLEARANCE ADJUSTMENT

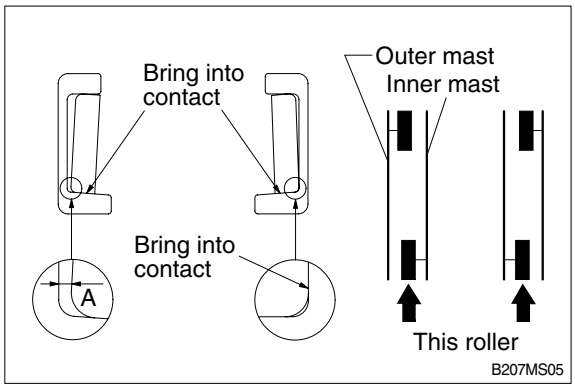
(1) Measure the clearance with the mast overlap at near 480mm.

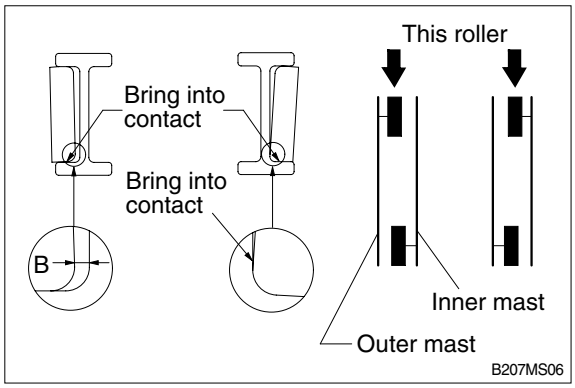
(2) Shift the inner mast to one side to bring the roller into contact with the outer mast, and adjust the clearance between the roller side face and mast at the closest position on the opposite side to the following value by inserting the inner/outer mast roller shim.

- Standard clearance A, B = 0~0.6mm
- Shim thickness 0.5, 1.0mm

(3) Distribute the shim thickness equally to the left and right roller. Refer to Mast load roller and back up liner, removal and Installation.

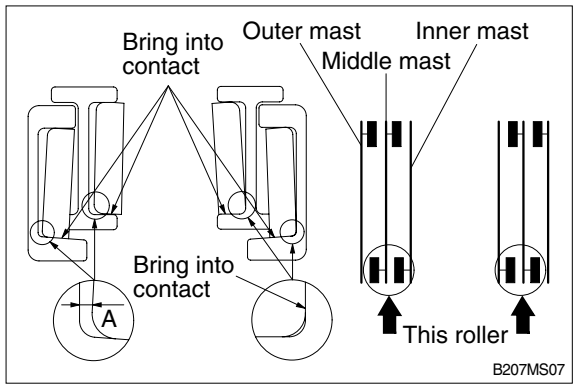
(4) After the adjustment, check that the inner mast moves smoothly in the outer mast.





2. MAST LOAD ROLLER(TF MAST)

1) INNER AND MIDDLE MAST ROLLER CLEARANCE ADJUSTMENT



(1) Measure the clearance with the mast overlap at near 480mm.

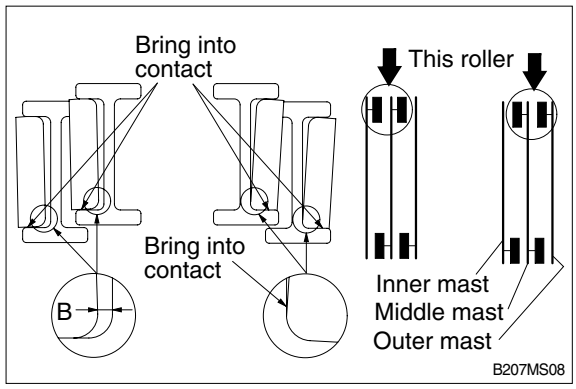
(2) Shift the inner mast to one side to bring the roller into contact with the outer mast and the middle mast, and adjust the clearance between the roller side face and mast at the closest position on the opposite side to the following value by inserting the inner and middle mast roller shim, respectively.

- Standard clearance A = 0~0.6mm
- Shim thickness 0.5, 1.0mm

(3) Distribute the shim thickness equally to the left and right roller. Refer to Mast load roller and back up liner, removal and Installation.

(4) After the adjustment, check that the inner mast moves smoothly in the middle mast, and the middle mast moves smoothly in the outer mast.

2) OUTER AND MIDDLE MAST UPPER ROLLER CLEARANCE ADJUSTMENT.



(1) Measure the clearance with the mast overlap at near 480mm.

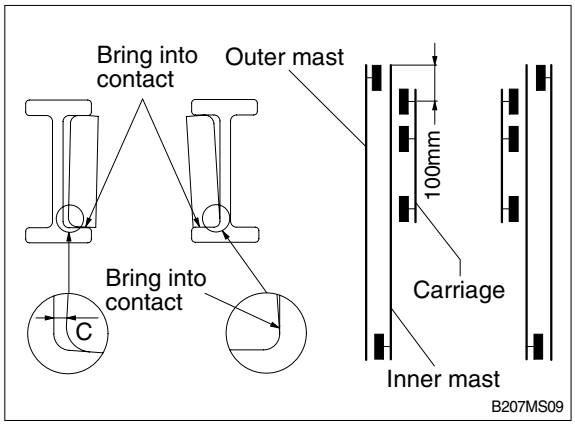
(2) Shift the inner mast to one side to bring the roller into contact with the outer mast and the middle mast, and adjust the clearance between the roller side face and mast at the closest position on the opposite side to the following value by inserting the outer and middle mast roller shim, respectively.

- Standard clearance B = 0~0.6mm
- Shim thickness 0.5, 1.0mm

(3) Distribute the shim thickness equally to the left and right roller. Refer to Mast load roller and back up liner, removal and Installation.

(4) After the adjustment, check that the inner mast moves smoothly in the middle mast, and the middle mast moves smoothly in the outer mast.

3) CARRIAGE LOAD ROLLER



(1) Measure the clearance when the center of the carriage upper roller is 100㎜ from the top of the inner mast.

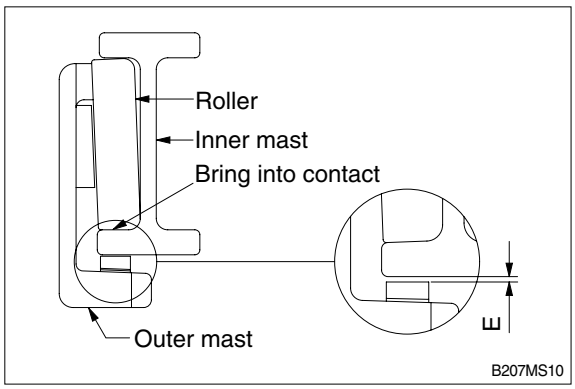
(2) Measure the clearance at upper, middle and lower rollers after loosen the adjust screws from the side rollers. Shift the carriage to one side to bring the roller into contact with the inner mast, and measure the clearance between the roller side face and mast at the closest position on the opposite side to the following value by inserting the carriage roller shim.

- Standard clearance C = 0~0.6㎜
- Shim thickness 0.5, 1.0㎜

(3) Distribute the shim thickness equally to the left and right roller. Refer to Carriage assembly.

(4) After the adjustment, the carriage should move smoothly along the overall mast length.

4) MAST BACK UP LINER



(1) Measure the clearance with the middle mast at the bottom position.

(2) With the middle mast in contact with the outer mast roller, adjust the clearance between the mast back up liner and middle mast to the following value by inserting the back up liner shim.

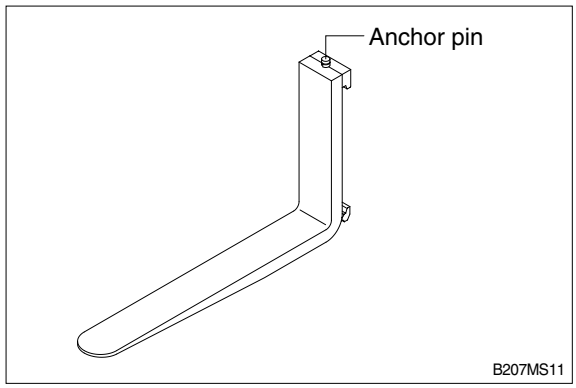
- Standard clearance E = 0.2 ~ 0.6㎜
- Shim thickness 0.5, 1.0㎜

(3) After the adjustment, the mast should move smoothly.

GROUP 4 REMOVAL AND INSTALLATION

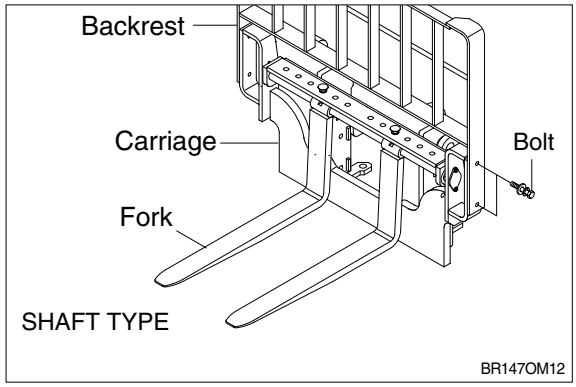
1. FORKS

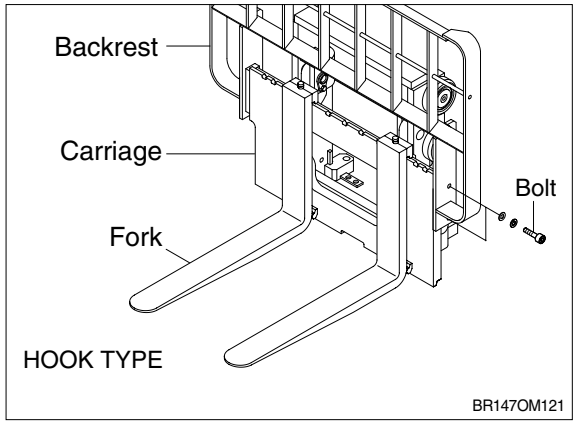
1) Lower the fork carriage until the forks are approximately 25mm(1inch) from the floor.
2) Release fork anchor pins and slide forks, one by one, toward the center of the carriage where a notch has been cut in the bottom plate for easy fork removal.
3) Remove the fork one by one. On larger forks it may be necessary to use a block of wood.
4) Reverse the above procedure to install load forks.



2. BACKREST

1) Remove bolts securing backrest to fork carriage. Lift backrest straight up and remove from carriage.
2) Position backrest on carriage and lower in place. Install and tighten bolts.





3. CARRIAGE ASSEMBLY

1) CARRIAGE

(1) With the mast vertical, raise the carriage high enough to place blocks under the load forks. This is done to create slack in the load chains when the carriage is lowered. Lower the carriage all the way down to the floor. Make sure the carriage is level, this will prevent any binding when the mast is raised.

(2) While supporting lift chains, remove the split pin and slide out chain anchor pins from the chain anchors of stationary upright.

(3) Pull the chains out of the sheaves and drape them over the front of the carriage.

(4) Slowly raise elevating upright until mast clears top of fork carriage. Move carriage to work area and lower mast.

⚠ **Make sure carriage remains on floor and does not bind while mast is being raised.**

(5) Inspect all parts for wear or damage. Replace all worn or damaged pars.

(6) Reverse the above steps to reinstall.

⚠ **Replace the split pin of chain anchor with new one.**

2) SIDE ROLLER

(1) Remove carriage as outlined in the carriage assembly and removal paragraph.

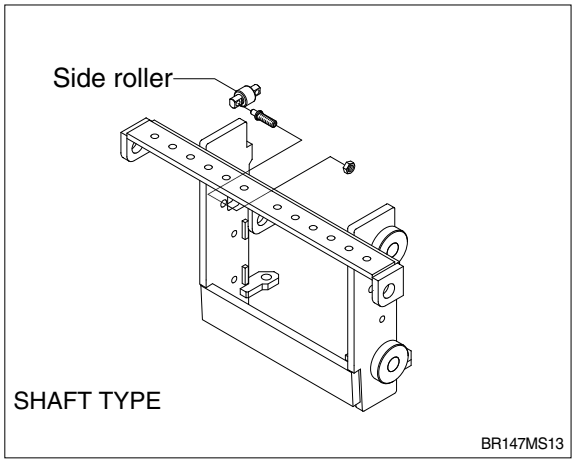
(2) Loosen and remove nuts, adjust screws and side rollers from carriage side pate.

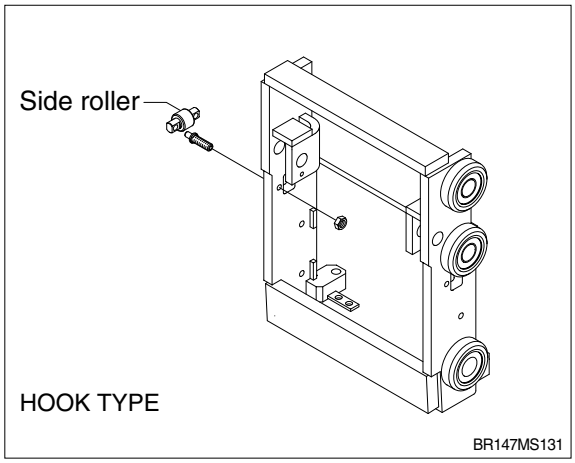
(3) Thoroughly clean, inspect and replace all worn or damaged parts.

(4) Reverse the above procedure to assembly.

※ **Adjustment**

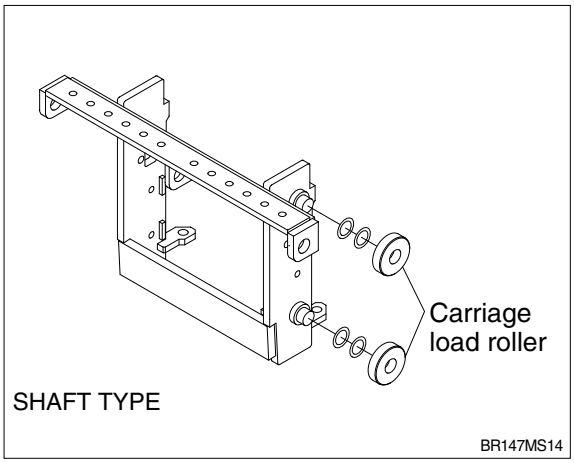
- Once carriage is properly installed, loosen nuts and adjust screws, (if not already done) allowing carriage to be centered in the inner mast.
- Adjust side roller by tightening screw until side roller just makes contact with mast. Back off approximately 1/10 turn on screw and tighten nut to lock screw in place.
- Run carriage up and down for the inner mast to be sure the carriage has free movement and does not stick. Also, make sure chains are properly adjusted. Refer to chain adjustment paragraph. Make adjustment when necessary and recheck operation of carriage.



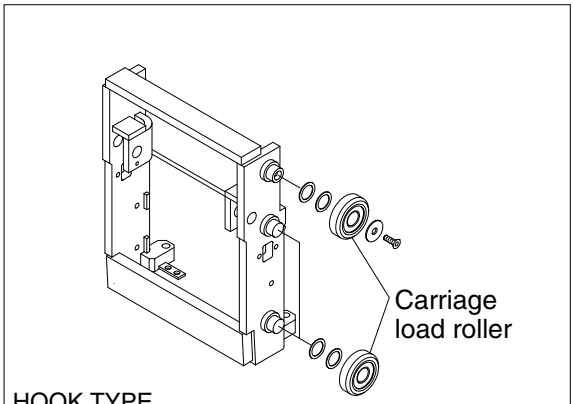


3) CARRIAGE LOAD ROLLER

(1) Remove carriage as outlined in the carriage assembly removal paragraph.
(2) Loosen and remove flat head bolts and plain washers from top load roller bracket.
(3) Using a pryer, remove load rollers from load roller bracket.
(4) Reverse the above procedure to assemble. Refer to MAST ROLLER ADJUSTMENT paragraph.



SHAFT TYPE
BR147MS14

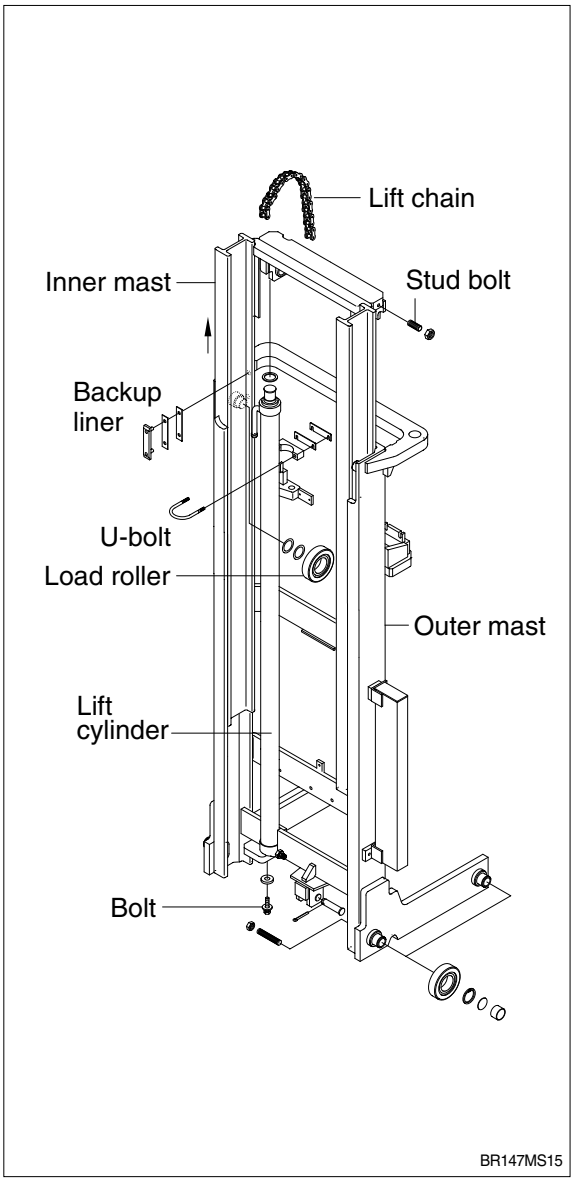


HOOK TYPE
BR147MS141

4) MAST LOAD ROLLER AND BACK UP LINER

(1) 2 stage mast(V mast)

① Remove the carriage assembly and move them to one side.
② Loosen and remove hexagon bolts and washers securing lift cylinders to inner mast.
③ Loosen and remove hexagon bolts and nuts securing lift cylinders to inner mast.
④ Attach chains or sling to the inner mast section at top crossmember. Using an overhead hoist, slowly raise the inner mast high enough to clear lift cylinder.
⑤ After lowering the lift cylinder rods, and disconnecting lift cylinder hose, tilt the lift cylinders LH and RH and them with ropes to the outer mast.
⑥ Using the overhead hoist, lower inner mast until top and bottom rollers and back up liners are exposed.
⑦ Using a pryer, remove load rollers from load roller bracket. Remove back up liners and shims.
⑧ Thoroughly clean, inspect and replace all worn or damaged parts.
⑨ Reverse the above procedure to assemble. Refer to MAST LOAD ROLLER ADJUSTMENT paragraph.



(2) 3 stage mast(TF mast)

① Remove the carriage assembly and move to one side.

② Loosen and remove hexagon bolt securing bottom cylinder from outer mast.

③ Loosen and remove bolts and special washers securing lift cylinders to middle mast.

④ Attach chains or sling to the inner and middle mast section at top crossmember. Using an overhead hoist, slowly raise the uprights high enough to clear lift cylinder.

⑤ After lowering the lift cylinder rods, and disconnecting lift cylinder hose, tilt the lift cylinders LH and RH and tie them with ropes to the outer mast.

⑥ Using the overhead hoist raise inner and middle masts. Place 4 inch block of wood under the free lift cylinder bracket of the inner mast then lower mast sections (this will create slack in the chains).

⑦ Remove retaining rings securing chain sheaves to sheave support brackets. While support chains, remove chain sheaves and let chains hang free. The upper outer and lower middle mast rollers and back up liners are now exposed.

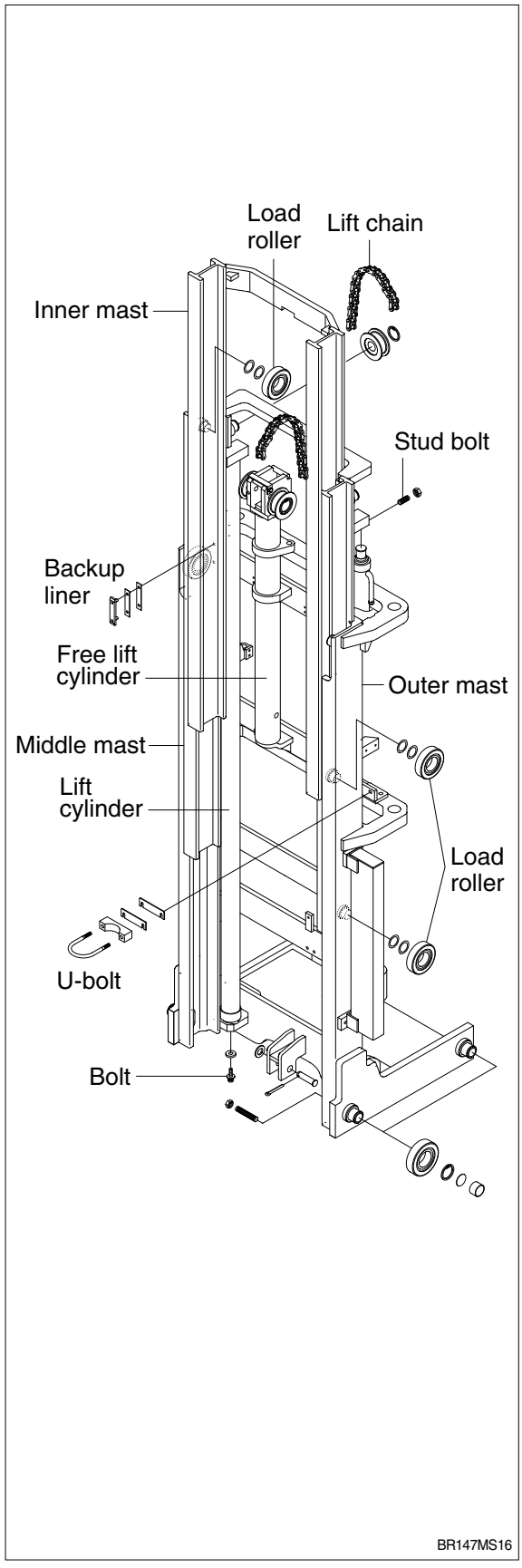
⑧ Using a pryer, remove load rollers from load bracket. Remove back up liners and shims.

⑨ Attach chains or sling to the middle mast section at top crossmember. Using an overhead hoist, slowly raise the middle mast until top and bottom rollers are exposed.

⑩ Using a player, remove load rollers from load roller bracket.

⑪ Thoroughly clean, inspect and replace all worn or damaged parts.

⑫ Reverse the above procedure to assemble. Refer to MAST LOAD ROLLER ADJUSTMENT paragraph.



5) ELEVATING MAST

(1) Inner mast (V mast)

① After completing all necessary steps for load rollers and back up liner removal use an overhead hoist and sling or chain around upper crossmember of the inner mast section.

② Lift inner mast upright straight up and out of outer mast section.

③ Replace and reverse above procedure to install. Make all necessary measurements and adjustments.

(2) Inner and middle mast(TF mast)

① After completing all necessary steps for load rollers and back up liner removal. Remove rear chains and sheave support if not already done.

② Disconnect free lift cylinder hose. Drain hose into a suitable pan or container and cap hose.

③ While supporting free lift cylinder assembly, remove bolts and washers securing cylinder to mast crossmember.

④ Place a sling around free lift cylinder and attach to an overhead hoist. Slowly raise and move cylinder to one side.

⑤ Attach chains or sling to the inner mast section at top crossmember. Using an overhead hoist slowly raise the upright straight up and out of middle mast section.

⑥ Attach chains or sling to the middle mast section at top crossmember. Using an overhead hoist slowly raise the upright straight up and out of outer mast section.

⑦ Replace upright and reverse above procedure to install. Make all necessary measurements and adjustments.

6) CHAIN

(1) Chain sheave(V mast)

① Place a sling around carriage and attach to an overhead hoist. Lift carriage high enough so that the tension on the chain over sheaves is relieved after the carriage is blocked. Position wooden blocks under the carriage and lower it.

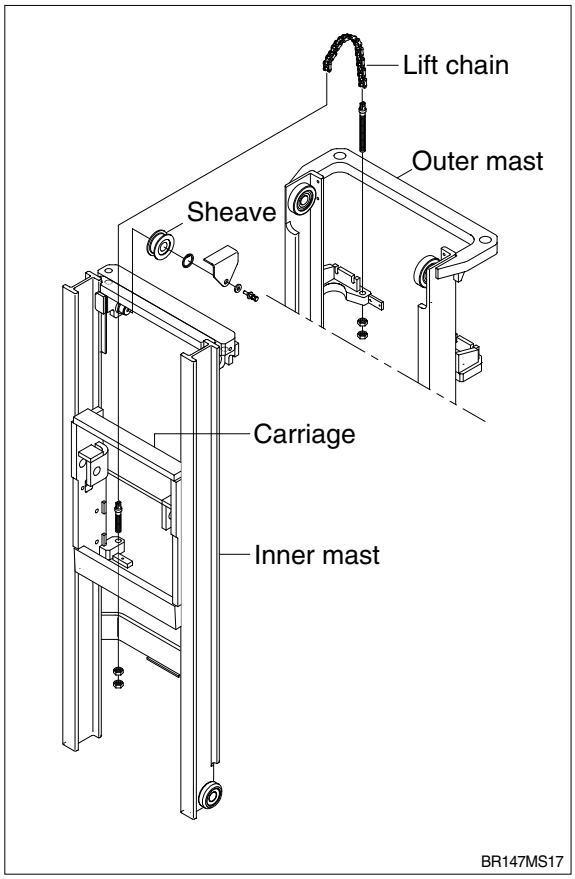
② Remove the split pin securing the chain anchor pins and discard. While supporting the chains, remove the chain anchor pins and drape the chains over the carriage.

③ Remove retaining ring securing sheaves to sheave support. Remove sheaves with bearings.

④ Remove bearining retaining ring from sheave and press bearings from sheaves.

⑤ Thoroughly clean, inspect and replace all worn or damaged parts.

⑥ Reverse the above to assemble and install. Use new split pins in chain anchor pins.



(2) Rear chain sheave(TF mast)

① Raise and securely block carriage and inner mast section.

② Remove the split pin securing the chain anchor pins and discard. While supporting the chains, remove the chain anchor pins from outer mast section.

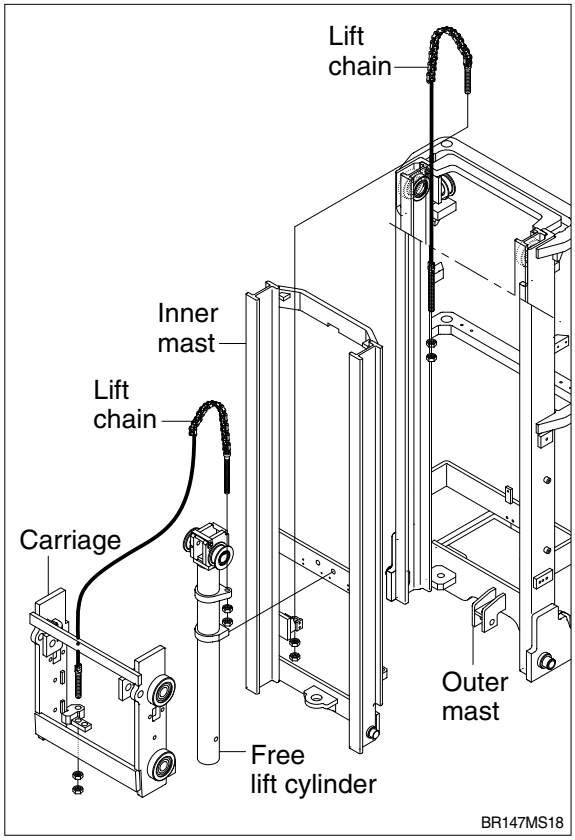
③ Remove chains.

④ Remove retaining ring securing chain sheaves to sheave support. Pry off sheaves with bearings.

⑤ Remove bearing retaining ring from sheave and press bearings from sheaves.

⑥ Thoroughly clean, inspect and replace all worn or damaged parts.

⑦ Reverse the above procedure to assemble and install. Use new split pins in chain anchor pins.



(3) Chain wheel bearing support(TF mast)

① Remove the carriage assembly and move to one side.
② After removing bolt to securing chain wheel bearing support assembly to free lift cylinder.
After a sling to the chain wheel bearing support assembly. Using an overhead hoist, lift support assembly straight up and off of free lift cylinder. Move assembly to work area.
③ Remove retaining ring securing chain wheel bearing to chain wheel bearing support.
④ Remove bearing retaining ring from chain wheel bearing and press bearings from chain wheel bearings.
⑤ Thoroughly clean, inspect and replace all worn or damaged parts.
⑥ Reverse the above procedure to install.

(4) Rear chain(TF mast)

① Remove the carriage assembly and move to one side. Refer to carriage removal and installation.
② Raise and securely block truck approximately 6 inches from the floor.
③ Using a sling or chain around inner mast section attached to an overhead hoist, slowly raise inner mast until there is enough slack in the chains to remove them. Block inner mast section.
④ Remove split pins and chain anchor pins securing chains to chain anchor(part of inner mast).
⑤ While supporting the chains, remove split and chain anchor pins securing chains to chain anchors attached to outer mast section.
⑥ Remove chains.
⑦ Reverse the above to assemble and install. Use new split pins in chain anchor pins. Refer to this section for Load chain lubrication and adjustment.

(5) Carriage chain

① Place a sling around carriage front plate and attach to an overhead hoist. Lift and secure carriage high enough so that split and chain anchor pins on carriage can be easily be removed. Remove chain anchor pins from carriage and drape chains out over carriage.
② Place a wooden block under the carriage and lower the carriage on the block.
③ While supporting the chains, remove split pins and chain anchor pins from chain anchors.
④ Remove chains and wash them with solvent. Refer to this section for Load chain inspection and maintenance.
⑤ Reverse the above procedure to assemble and install. Use new split pins in chain anchor pins. Refer to this section for Load chain lubrication and adjustment.

(6) Load chain inspection and maintenance

After every 200 hours of truck operation, lift chains should be inspected and lubricated inspect for the following chain conditions :

① Wear

As the chain flexes on and off the chain wheel bearings, the joints very gradually wear. The stretch a chain developes in service is due to material being worn off pin outer diameter and pitch hole inner diameter on the inside plate.

Chain wear can be measured using a wear scale or steel tape. When chains have elongated 2%, they should be discarded. When checking chain wear, be sure to measure a segment of chain that operates over a sheave. Do not repair chains by cutting our the worn section and splicing in a new piece. If part of the chain is worn, replace all the chains on the truck.

② **Rust and corrosion**

Chains used on lift trucks are highly stressed precision components. It is very important that the "as-manufactured" ultimate strength and fatigue strength be maintained throughout the chain service life. Corrosion will cause a major reduction in the load-carrying capacity of lift chain or roller chain because corrosion causes side plate cracking.

③ **Cracked plate**

The most common cause of plate cracking is fatigue failure. Fatigue is a penomenon that affects most metals and many plastics. After many repeated heavy loads, the plates may crack and the chains will eventually break. Fatigue cracks are almost always found through the pitch holes perpendicular to the pitch line. Contrast this failure mode to the random failures caused by stress-corrosion cracking. If cracks are present, replace all the chain on the truck. Noise in the chain indicates that the plate is on the verge of cracking and will be failed before long.

④ **Tight joints**

All joints in lift chain should flex freely. Tight joints resist flexure, increase internal friction, thus increasing chain tension required to lift a given load. Increased tension accelerates wear and fatigue problems.

Tight joints in lift chains can be caused by :

- Bent pins or plates.
- Rusty joints.
- Peened plate edges.

Oil rusty chains and replace chains with bent or peened components.

⑤ **Protruding or turned pins**

Heavily loaded chains operating with lube generate tremendous friction between pins and plates. In extreme cases, the frictional torque in the joint can actually turn pins in the press-fit outside plates. If chain is allowed to operate in this condition, the pins slowly work out of the chain causing chain failure. Turned pins can be quickly spotted because the flats on the V heads are no longer in line. Chains with turned or protruding pins should be replaced immediately. Do not attempt to repair the chain by driving pins back into the chain.

⑥ **Chain side wear**

A wear pattern on pin heads and outside plates indicates misalignment. This condition damages chain and sheaves as well as increasing internal friction in the chain system.

⑦ **Chain anchors and chain wheel bearings**

An inspection of the chain system includes a close examination of chain anchors and chain wheel bearings. Check chain anchors for wear, breakage and misalignment.

Anchors with worn or broken fingers should be replaced. Anchors should be adjusted to eliminate twisting or other misalignment in the chain. When chain is misaligned, load is not distributed uniformly between the plates. Prolonged operation will result in premature fatigue failure. Chain wheel bearings with badly worn flanges and outside diameter should be replaced. Heavy flange wear indicates chain misalignment.

⑧ **Chain wear scale**

The chain can be checked for wear or stretching with the use of a chain wear scale. Stretching of a chain is due to the elongation of the pitch holes and wearing of the pin O.D. The greatest amount of stretching occurs at the areas of the chain that flex over the sheaves most frequently. Check the chain at this point with a scale. The wear scale has instructions printed on the sides for use in determining chain stretch and are as follows :

- Determine pitch length of chain using 6 inch scale on one side of wear scale.
- If pitch is 1/2(12.7㎜), 3/4(19.05㎜), 1(25.4㎜), 1-1/2(38.1㎜), 2(50.8㎜), use side A of scale.
- If pitch is 5/8(15.875㎜), 1-1/4(31.75㎜) or 2(50.8㎜), use side B.
- Align point A or B to center of a pin and note position of the opposite A or B point.
- If other point also lines up with a pin, the chain is worn and should be replaced.

If any of the above conditions exists(cracked plates, turned pins, stretching etc), the chains should be replaced in pairs as a complete assembly. Order chains by part number to insure the correct chain length, pitch and material specifications.

(7) Load chain lubrication and adjustment

① **Lubrication**

The most important consideration in field maintenance of lift chains is lubrication. Hard working, heavily loaded chains cannot be expected to give satisfactory wear life without scheduled periodic re-lubrication. Like all bearing surfaces, the precision manufactured, hardened steel, joint-wearing surfaces require a film of oil between mating parts to prevent rapid wear. Oil must penetrate the chain joint to prevent wear. Applying oil to external surfaces will prevent rust, but oil must flow into the live bearing surfaces for maximum wear life. Frequency of re-lube will vary with operating conditions and environment, the best estimate of lube period is 200 hours. Trucks parked outdoors or trucks in extremely severe service, may require more frequent re-lube to maintain an oil film on all chain surface.

- Wipe off the old oil with a clean cloth and blow out the remaining dirt with compressed air.

⚠ **Wear eye protection.**

- With a clean brush, apply EP-140 extreme pressure lubricant or heavy motor oil(40W).

② **Replacement**

Replace chains as a pair. It will be virtually impossible to maintain uniform loading between the strands if a new chain is put into service opposite an old chain. The jonts in the old chain will be greater than that on the new chain, greatly complicating the problem of maintaining equal chain tension. The new chain will wear more slowly causing it to bear the major portion of the load resulting in premature wear and fatigue failure. Don't steam clean or decrease new chains.

The manufacturer's grease is effective in reducing wear and corrosion. If the original factory lube is dried out or wiped off, soak the new chain in heavy engine oil for at 1/2 hour prior to installing on truck. After the old chains have been stripped from the mast, very carefully inspect chain anchors and chain wheel bearing. Broken, cracked or worn anchor must be replaced using the new anchor pin and split pin. Do not paint newly replaced chain after it has been installed.

③ **Adjustment**

Chain adjustments are important for the following reasons :

- Equal loading of chain.
- Proper sequencing of mast.
- Prevent over-stretching of chains.
- Prevent chains from jumping off sheaves if they are too loose.

④ **Adjustment procedure**

- With mast in its fully collapsed and vertical position, lower the fork to the floor.
- Adjust the chain length by loosening or tightening nut on the chain anchor.
  After making adjustment on the mast, be sure to tighten the nut.