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 and operation.

SECTION 6 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.

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

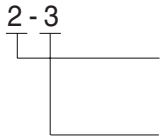
Distribution and updating

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 5 in 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, 55 mm = 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 55 mm.

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

(3) The original value (550 mm) 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 550 mm = 21.65 inches.

Millimeters to inches

1 mm = 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

1 mm = 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

Kilogram to Pound

1 kg = 2.2046 lb

	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

1 kgf · m = 7.233 lbf · 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

1 kgf / cm² = 14.2233 lbf / 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.

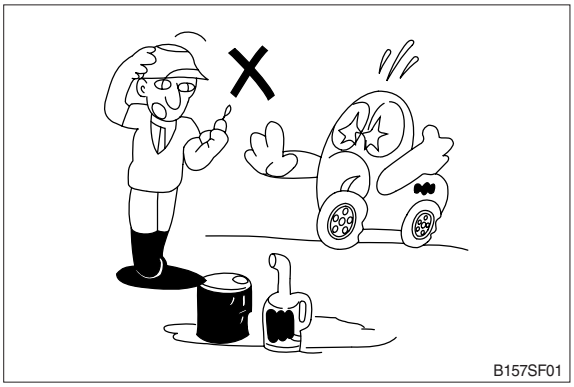
˚C		˚F	˚C		˚F	˚C		˚F	˚C		˚F
-40.4	-40	-40.0	-11.7	11	51.8	7.8	46	114.8	27.2	81	117.8
-37.2	-35	-31.0	-11.1	12	53.6	8.3	47	116.6	27.8	82	179.6
-34.4	-30	-22.0	-10.6	13	55.4	8.9	48	118.4	28.3	83	181.4
-31.7	-25	-13.0	-10.0	14	57.2	9.4	49	120.2	28.9	84	183.2
-28.9	-20	-4.0	-9.4	15	59.0	10.0	50	122.0	29.4	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

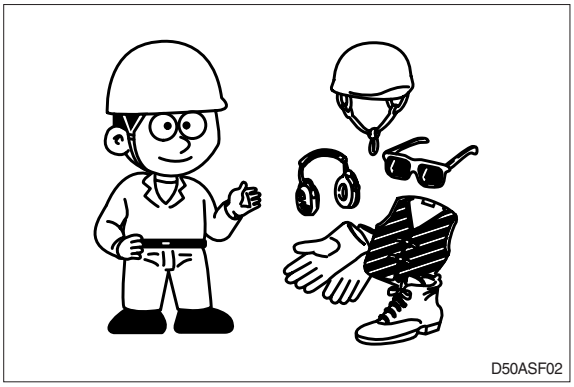
GROUP 1 SAFETY HINTS

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

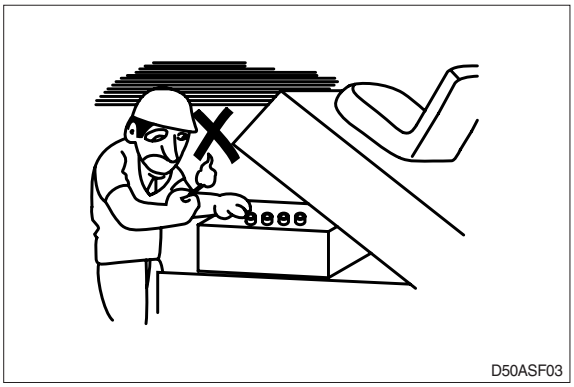
- Oil is a dangerous substance. Never handle oil, grease or oily clothes in places where there is any fire of flame.
  As preparation in case of fire, always know the location and directions for use of fire extinguishers and other fire fighting equipment.


B157SF01

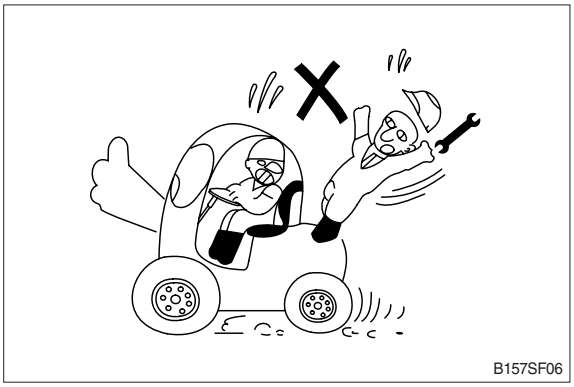
- Wear well-fitting helmet, safety shoes and working clothes. When drilling, grinding or hammering, always wear protective goggles.
  Always do up safety clothes properly so that they do not catch on protruding parts of machines. Do not wear oily clothes.
  When checking, always release battery plug.


D50ASF02

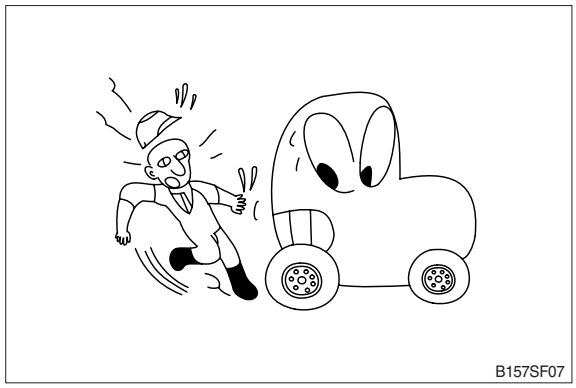
- Flames should never be used instead of lamps. Never use a naked flame to check leaks or the level of oil or electrolyte.


D50ASF03

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

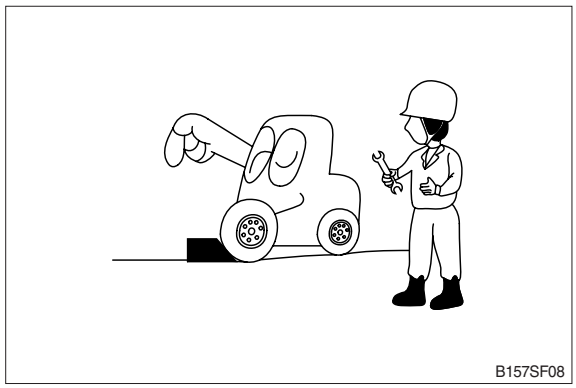

B157SF06

・ 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.

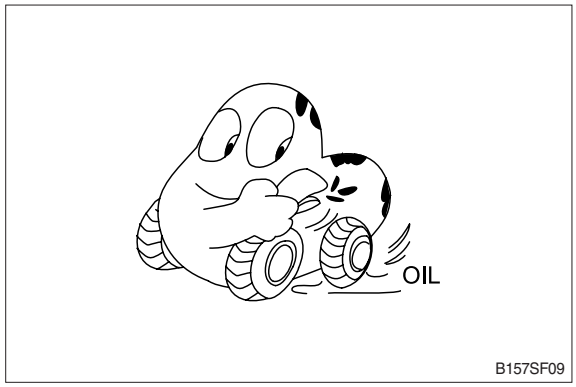

B157SF07

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.
Stop the engine.
Return each lever to NEUTRAL and apply the brake lock.

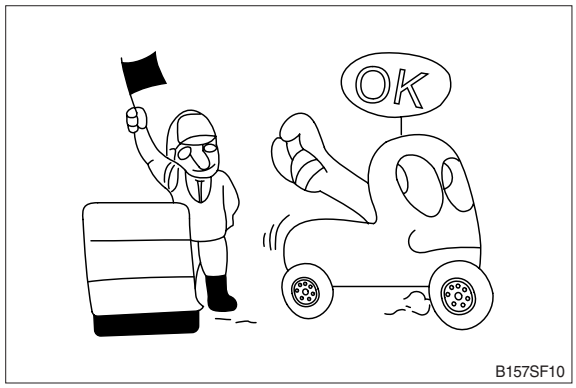

B157SF08

・ 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.



B157SF09

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



B157SF10

· 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.

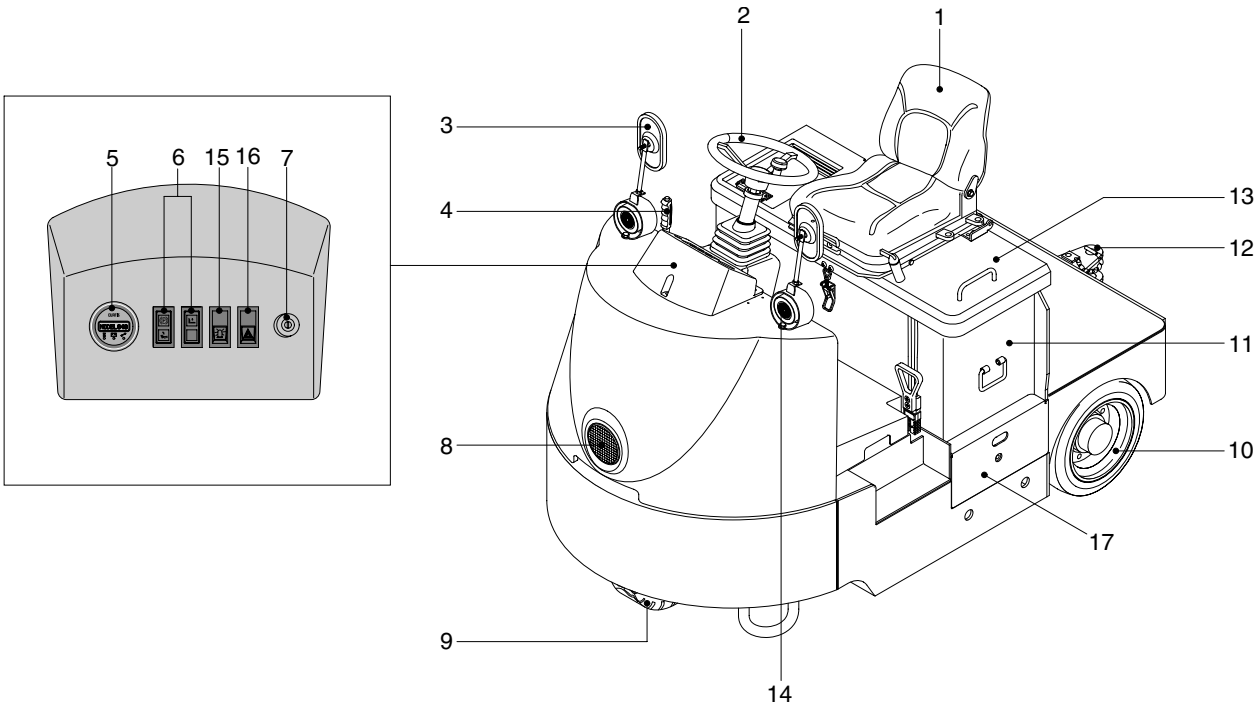

B157SF11

- 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 genuine parts for replacement.
- Always use the grades of grease and oil recommended by HYUNDAI.
  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



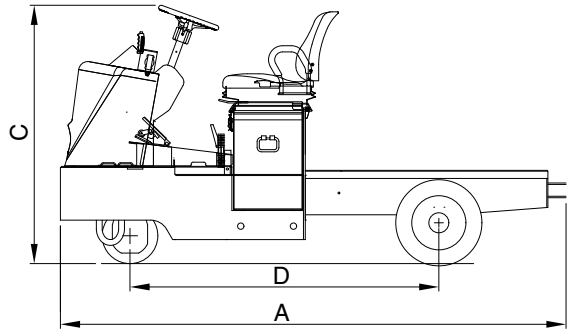
15PAGEN01

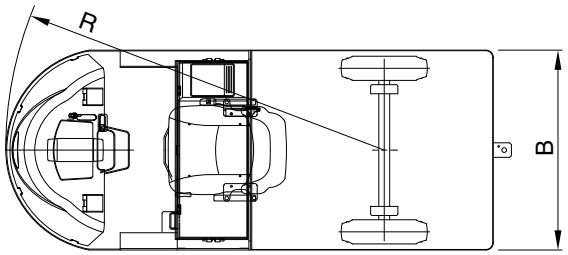
1	Seat	7	Start key switch	13	Battery cover
2	Steering wheel	8	Head lamp	14	Flasher lamp
3	Rear view mirror	9	Front wheel	15	Beacon switch
4	Parking brake lever	10	Rear wheel	16	Hazard switch
5	Display	11	Battery	17	Battery support
6	Warning lamps	12	Hook		

2. SPECIFICATIONS

1) DIMENSIONS

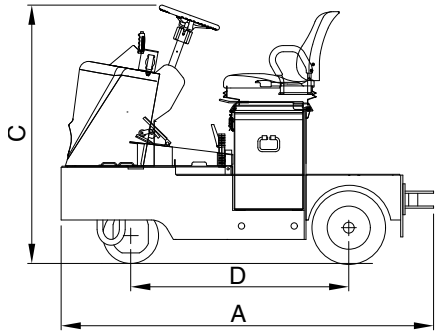
(1) 15PA-7

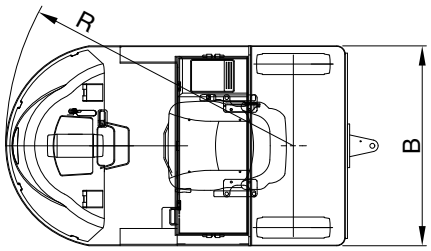




BP157SP01

(2) 40/60TA-7





BP157SP01

Item			Unit	15PA-7	40TA-7	60TA-7
Capacity			kg (lb)	1500 (3310)	4000 (8820)	6000 (13200)
Travel speed	Loaded		km/h (mph)	8 (5)	5.5 (3.4)	4.5 (2.8)
	Unloaded		km/h (mph)	10 (6.2)	11 (6.8)	←
Min. turning radius		R	mm (in)	2065 (6' 9")	1565 (5' 2")	←
Overall length		A	mm (in)	2798 (9' 2")	2050 (6' 9")	←
Overall width		B	mm (in)	1100 (3' 7")	1100 (3' 7")	←
Overall height		C	mm (in)	1430 (4' 8")	1430 (4' 8")	←
Wheel base		D	mm (in)	1700 (5' 7")	1200 (3' 11")	←
Weight (Unloaded)			kg (lb)	1225 (2701)	1260 (2778)	←
Drive motor			kW	5.0	←	←
Battery	Voltage		V	48	←	←
	Capacity		AH/5HR	280	←	←
Charger	Input		-	3 ø 220/380V	←	←
	Type		-	CC/CV	←	←
Control type			-	AC	←	←
Tire	FR		-	ø 305 × 127	←	←
	RR		-	5.00-8-8PR	4.00-8	←

3. SPECIFICATION FOR MAJOR COMPONENTS

(1) EPS actuator assy

Item	Unit	Specification
Rated voltage for motor	V	DC 48
Output torque	kgf · m	8.6
Gear ratio	-	31.13

(2) Drive controller

Item	Unit	Specification
Rated voltage	V	DC 48
Maximum current	A	Current limit 275
		2 Min rating 250
		Hour rating 120

(3) EPS controller

Item	Unit	Specification
Rated voltage	V	DC 48
Operating voltage	V	DC 28-80
Maximum current	A	±25
Operating temperature	˚C	-40 ~ 60

(4) Charger

Item	Unit	Specification
Type	-	IUIa
Battery capacity for charge	V-AH/hr	48-280~365/5
AC input	V	Triple phase 410
		Single phase 220
		Triple phase 220/380
		Triple phase 440
DC output	V	64±1
Charge time	hr	6±2
Connector	-	SB 350

(5) Traction motor

Item	Unit	Specification
Model	-	AMDF 6001
Type	-	AC
Rated voltage	Vac	ø 3, 28Vac
Rated output	kW	5.0
Insul. class	-	F

(6) Drive unit

Item	Unit	Specification
Max drive input	kW	5.0
Max wheel load	kg/lb	750/1653
Gear ratio	-	20.125
Weight without fluid	kg/lb	100/220.4

(7) Wheels

Item		Front	Rear
Type		Cushion, Urethane, Non-marking	Pneumatic (solid), Non-marking
Quantity		1	2
Wheel	15PA-7	305×127	5.00-8-8PR(5.00-8)
	40/60TA-7	305×127	4.00-8

(8) Steering

Item		Specification
Steering	Type	Electric power steering
	Steering angle	90° to both right and left angle, respectively

(9) Brake

Item		Specification
Type		Drum brake
Brake shoe	W×L×T	40×110×5 mm (1.6×4.3×0.2 in)
	Area	44 cm^2 (6.8 in^2)
Brake drum diameter	New	120 mm (4.7 in)
	Repair limit	117 mm (4.6 in)
Brake pedal play		10~15 mm (0.4~0.6 in)
Braking distance	Unloaded	Less than 5.0 m (197 in)
	Loaded	Less than 2.0 m (79 in)

(10) Parking brake

Item	Specification
Type	Ratchet
Parking lever stroke	68 mm
Parking cable stroke	16 mm

4. TIGHTENING TORQUE FOR MAJOR COMPONENTS

No.	Items		Size	kgf · m	lbf · ft
1	Electric system	EPS actuator assy	M10×1.5	3.9±0.2	28.1±1.5
2	Power train system	Drive unit & motor assy	M12×1.75	12.0±1.0	86.8±7.2
3		Rear axle mounting bolt	M14×2.0	20.0±2.0	144.7±14.4
4		Front wheel mounting nut	M16×1.5	20.0±1.5	144.7±10.8
5		Rear wheel mounting nut	M12×1.5	10.0±1.0	72.3±7.2
6	Others	Seat mounting bolt	M 8×1.25	2.5±0.5	18.1±3.6

5. TORQUE CHART

Use following table for unspecified torque.

1) BOLT AND NUT

(1) Coarse thread

Bolt size	8T		10T	
	kg · m	lb · ft	kg · m	lb · 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
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 × 2.5	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

(2) Fine thread

Bolt size	8T		10T	
	kg · m	lb · ft	kg · m	lb · 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

6. RECOMMENDED LUBRICANTS

Service point	Kind of fluid	Capacity ℓ (U.S. gal)	Ambient temperature °C (°F)						
			-20 (-4)	-10 (14)	0 (32)	10 (50)	20 (68)	30 (86)	40 (104)
Drive unit	Gear oil	1.6 (0.4)	SAE 80W-90/API GL-5						
EPS Actuator	Gear oil	0.175 (0.05)	SAE 80W-90/API GL-5						

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.**

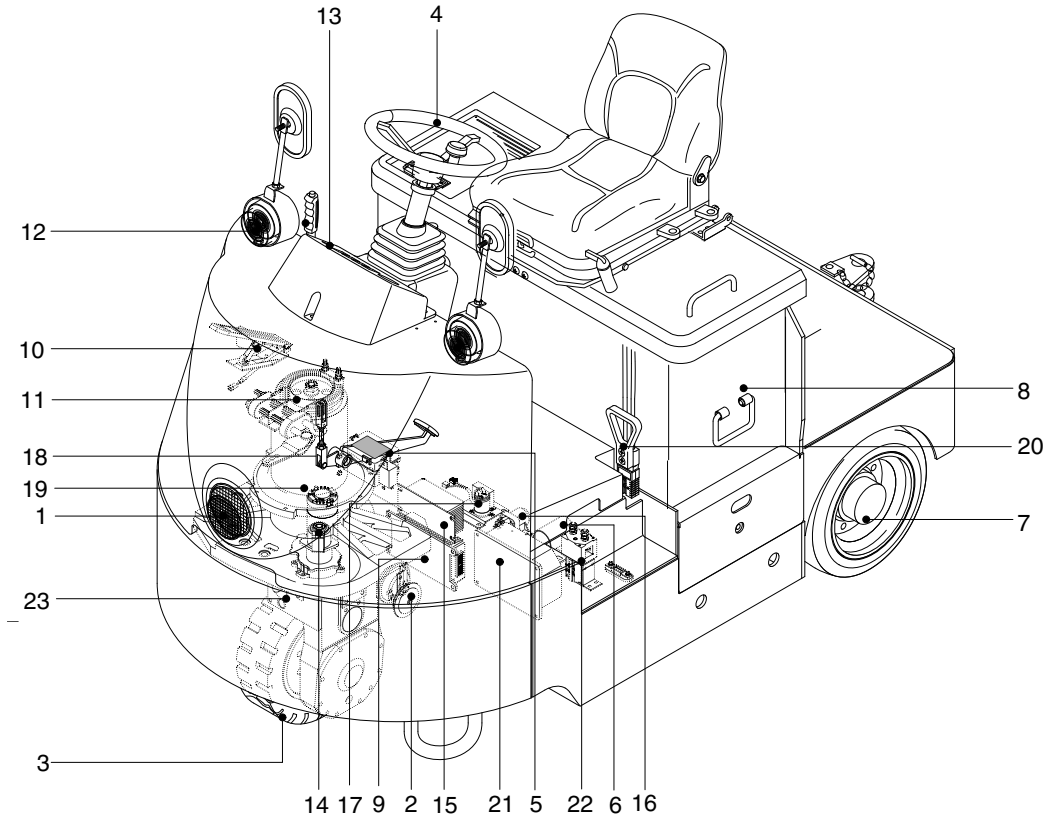
No.	Description	Period of replacement
1	Brake fluid	Every 1 year
2	Differential oil	Every 1 year
3	Gear oil	Every 1 year
4	Wheel bearing grease	Every 1 year

SECTION 2 REMOVAL & INSTALLATION OF UNIT

SECTION 2 REMOVAL & INSTALLATION OF UNIT

GROUP 1 STRUCTURE

Use the illustration below to locate components included in the PM procedures.



15PAOM113

1	Head lamp	9	EPS controller	17	EPS filter
2	Horn	10	Accelerator	18	Brake pedal
3	Front wheel	11	Brake system	19	Drive motor
4	Steering wheel	12	Flasher lamp	20	Battery connector
5	Fuse box	13	Display & warning lamp	21	Drive controller
6	Buzzer	14	EPS actuator	22	Contactor
7	Rear wheel	15	DC-DC converter	23	Drive unit
8	Battery	16	EPS contactor		

GROUP 2 REMOVAL AND INSTALLATION OF UNIT

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

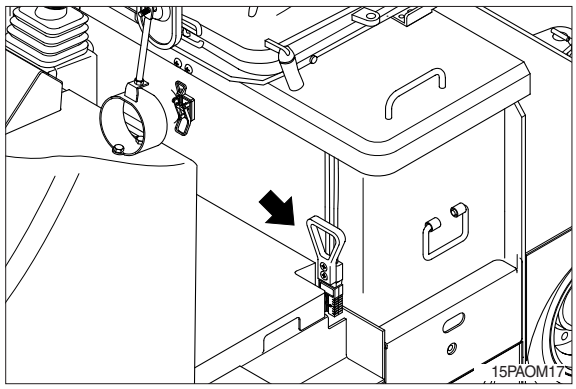
1. POWER TRAIN ASSEMBLY

1) REMOVAL

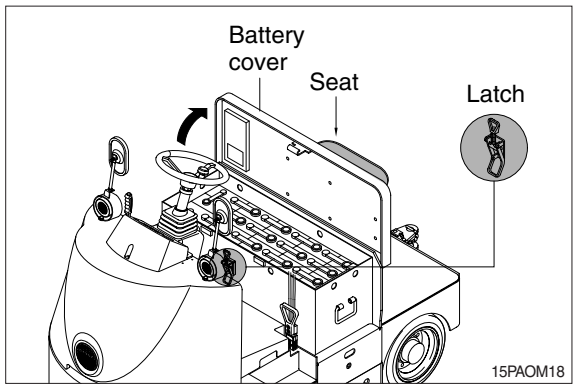
Battery → Front cover → Main cover → Brake cable → Wiring & piping → Drive unit

(1) Battery

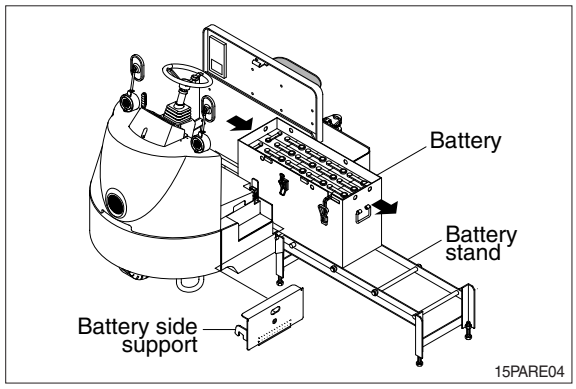
① Disconnect the battery cable.



② Open battery cover by unlocking latch.

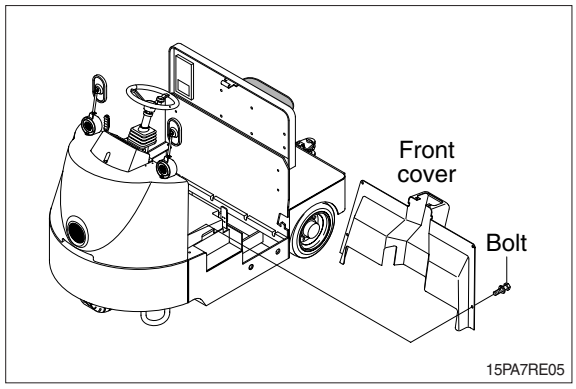


③ Release battery side support and then pull out the battery to stand.



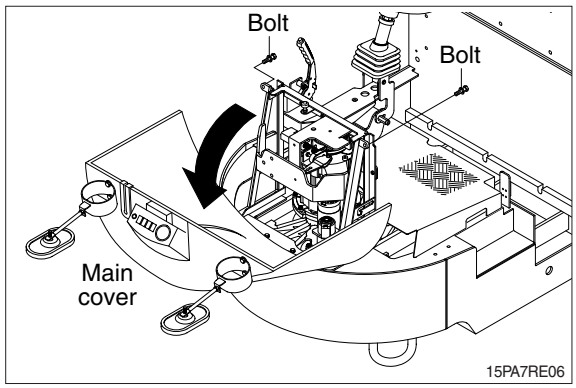
(2) Front cover

① Remove front cover by loosening the mounting bolts.

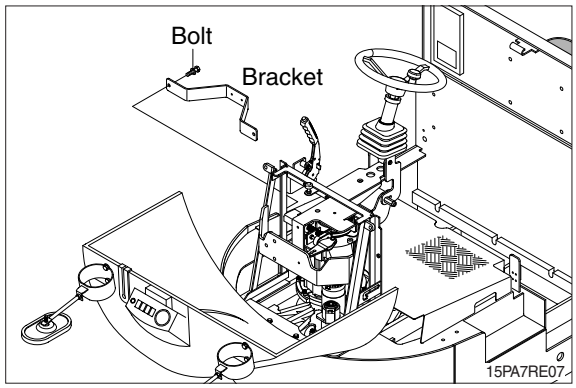


(3) Main cover

① Open main cover as shown in the figure.

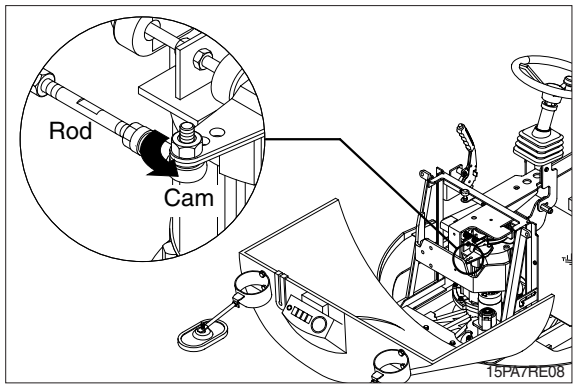


② Remove bracket fixing drive unit at cowl.



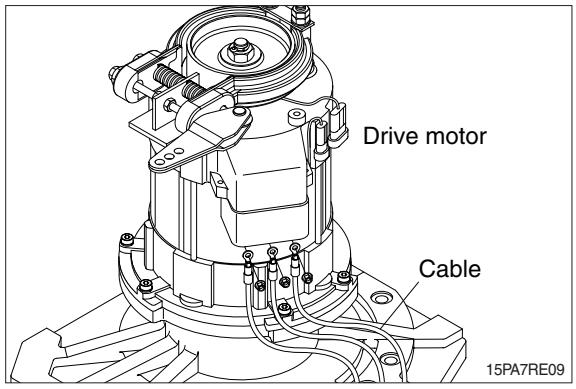
(4) Brake rod

① Disconnect brake rod from brake cam.

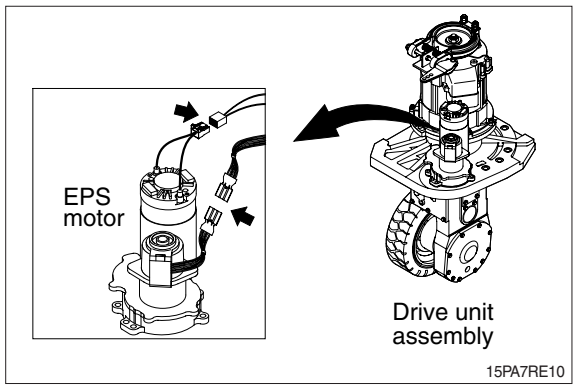


(5) Wiring

① Disconnect cable from drive motor and drive axle.

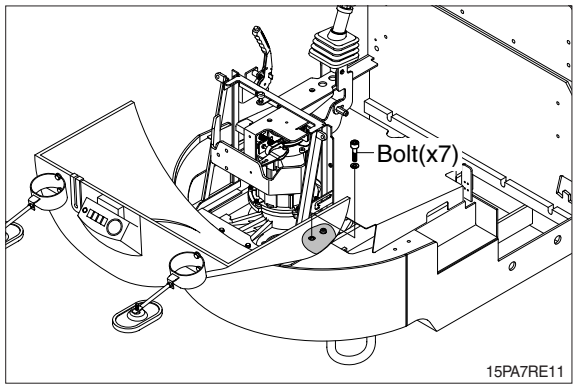


② Disconnect cable from EPS-actuator assy.

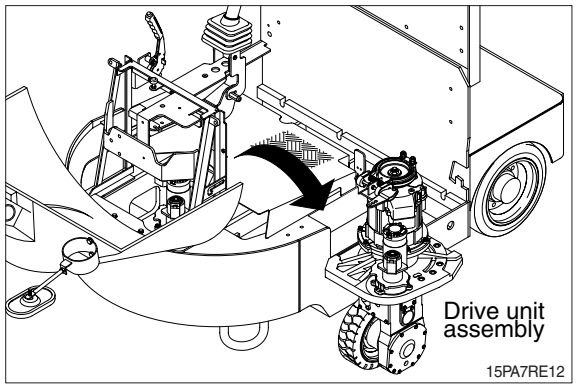


(6) Drive unit

① Loosen mounting bolts fixing drive unit assembly at frame.



② Lift up drive unit assembly carefully through the rear side space as show in the figure.

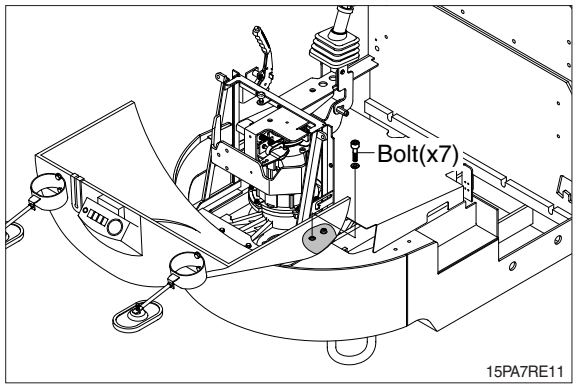


2) INSTALLATION

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

(1) Drive unit mounting bolts.

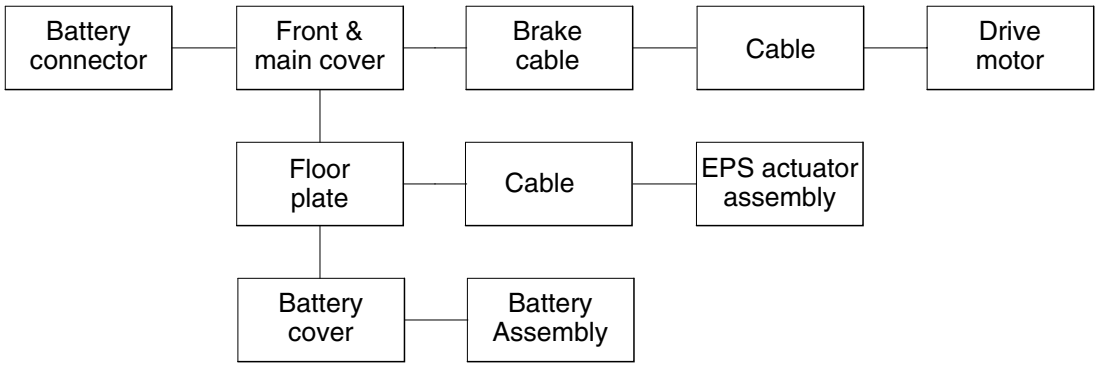
· Tightening torque : 11~13 kgf · m
(79.6~94.0 lbf · ft)



2. ELECTRICAL COMPONENTS

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

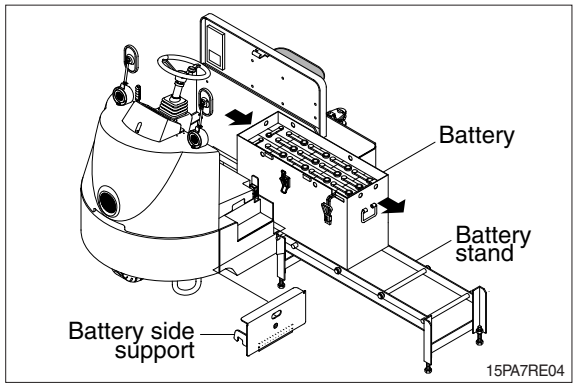
1) REMOVAL



15PA7RE001

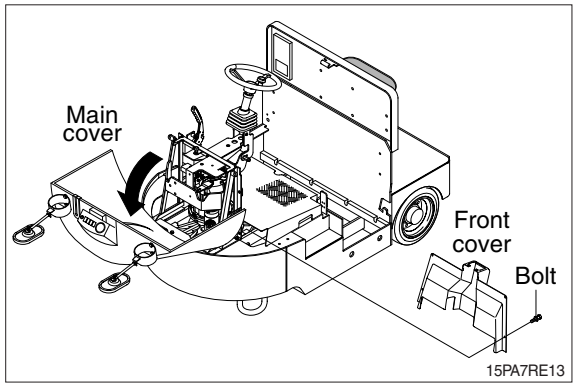
(1) Drive motor

① Disconnect the battery cable and then remove battery side support, pull out the battery to battery stand or carrier.



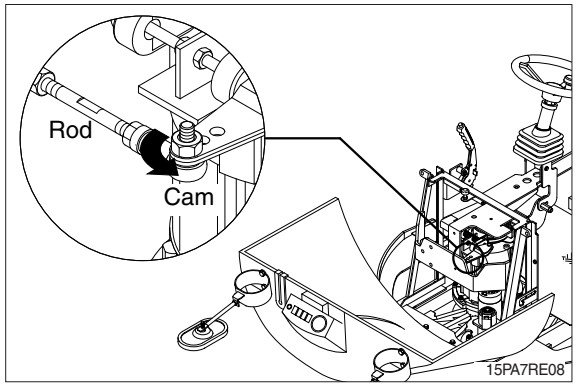
15PA7RE04

② Remove front cover and then open main cover.



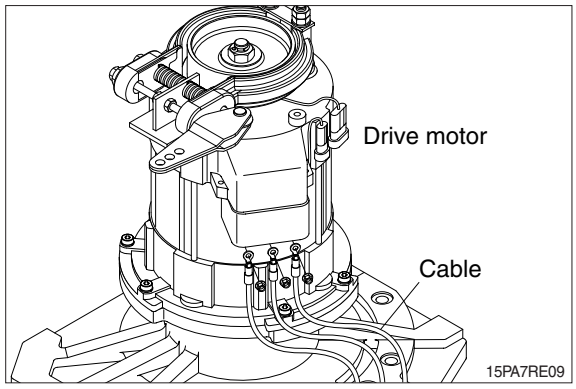
15PA7RE13

③ Disconnect brake rod from brake cam.

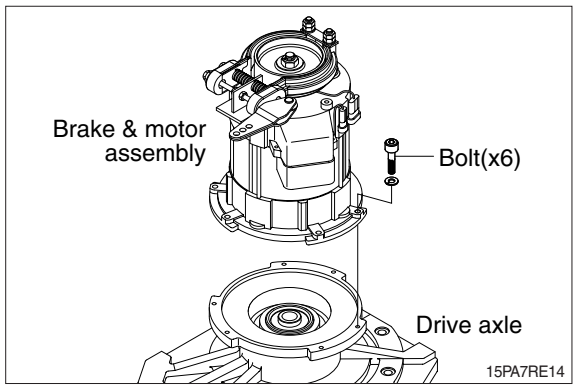


15PA7RE08

④ Disconnect cable from drive motor and drive axle.

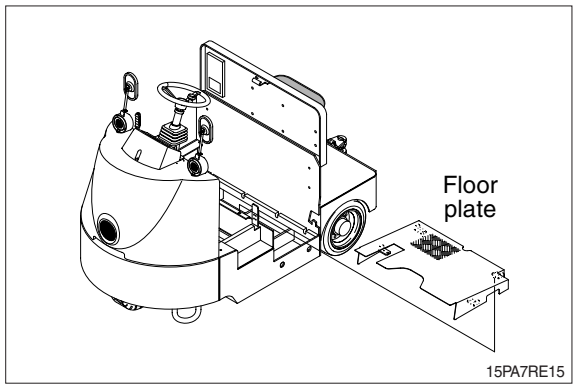


⑤ Remove drive motor and brake assembly by loosening the mounting bolts.

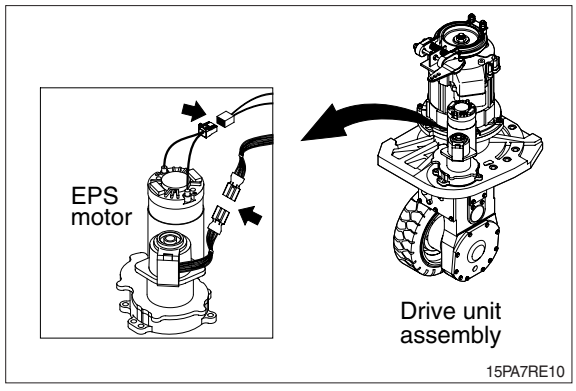


(2) EPS-actuator assembly

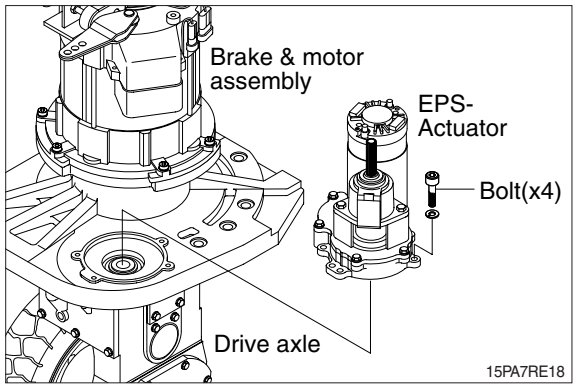
① Remove floor plate



② Disconnect cable from power EPS-actuator assy.

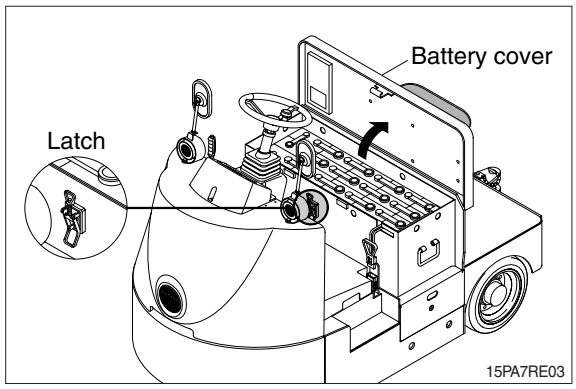


③ Remove EPS-actuator assy by loosening the mounting bolts.

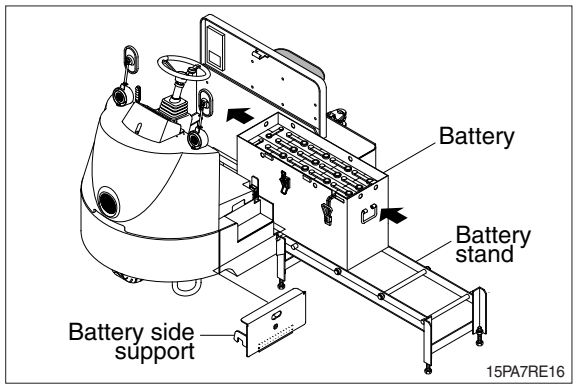


(3) Battery assembly

① Open battery cover by unlocking latch.



② Remove battery side support and then pull out the battery to stand.

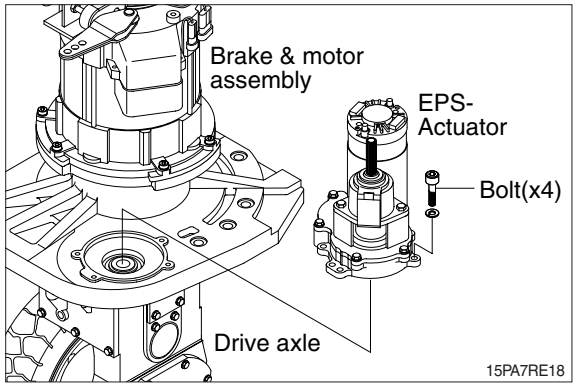


2) INSTALLATION

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

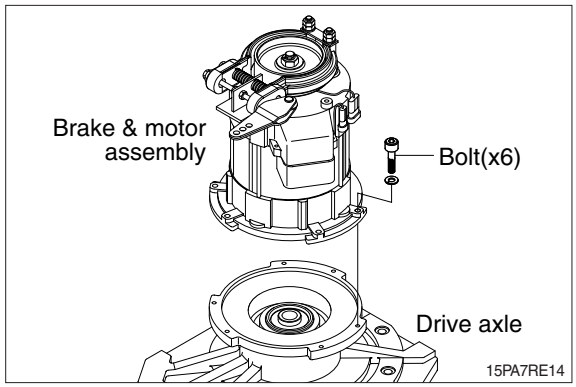
(1) EPS-actuator mounting bolts

· Tightening torque : 3.7~4.1 kgf · m
(26.8~29.6 lbf · ft)



(2) Drive motor mounting bolts

· Tightening torque : 3.7~4.1 kgf · m
(26.8~29.6 lbf · ft)

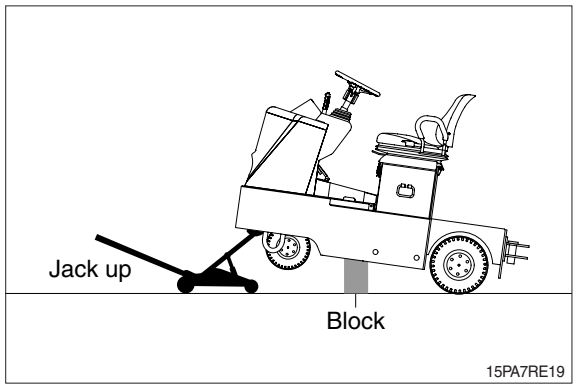


3. TIRE AND WHEEL ASSEMBLY

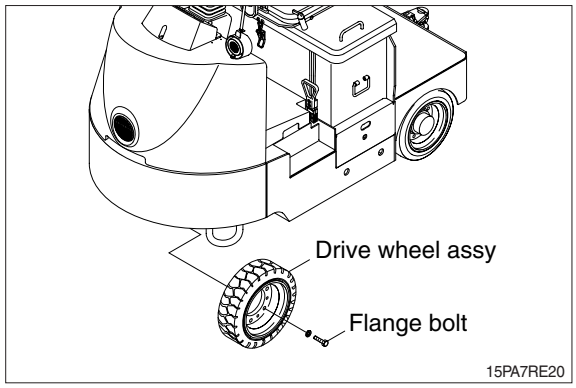
1) REMOVAL

(1) Drive tire and wheel assembly

① Jack up the front side of frame and put blocks under the lifted frame.

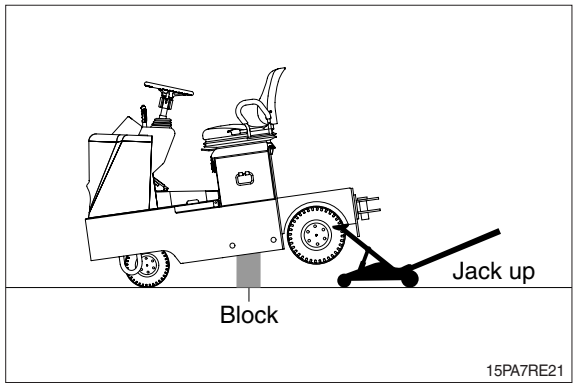


② Remove 6 flange bolts fixing the drive wheel and take off the drive wheel assembly.

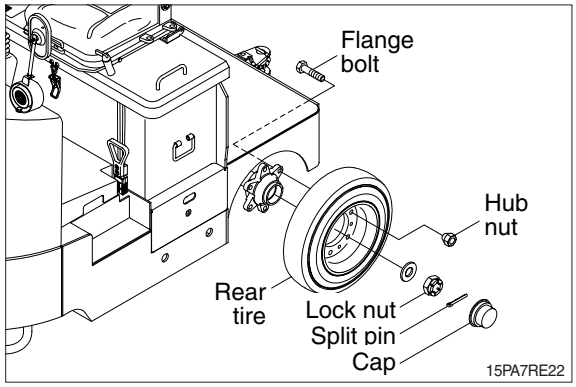


(2) Rear tire and wheel assembly

① Jack up the rear side of frame and put blocks under the lifted frame.



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

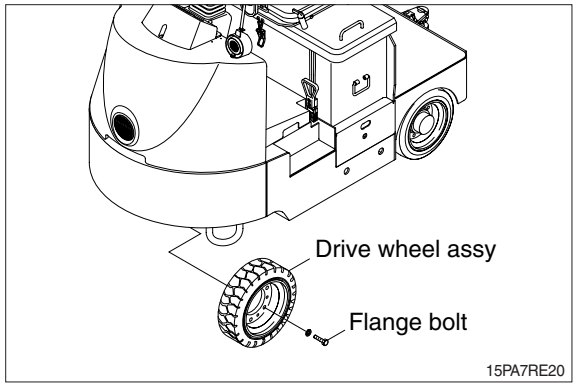


2) INSTALLATION

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

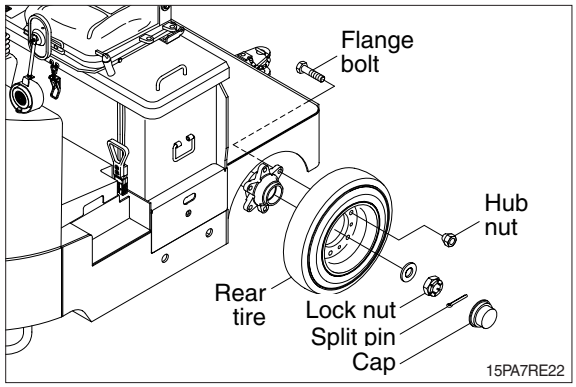
(1) Drive wheel flange bolts

· Tightening torque : 19~22 kgf · m
(137.4~159.1 lbf · ft)



(2) Rear wheel flange bolts

· Tightening torque : 9~11 kgf · m
(65.1~79.6 lbf · ft)

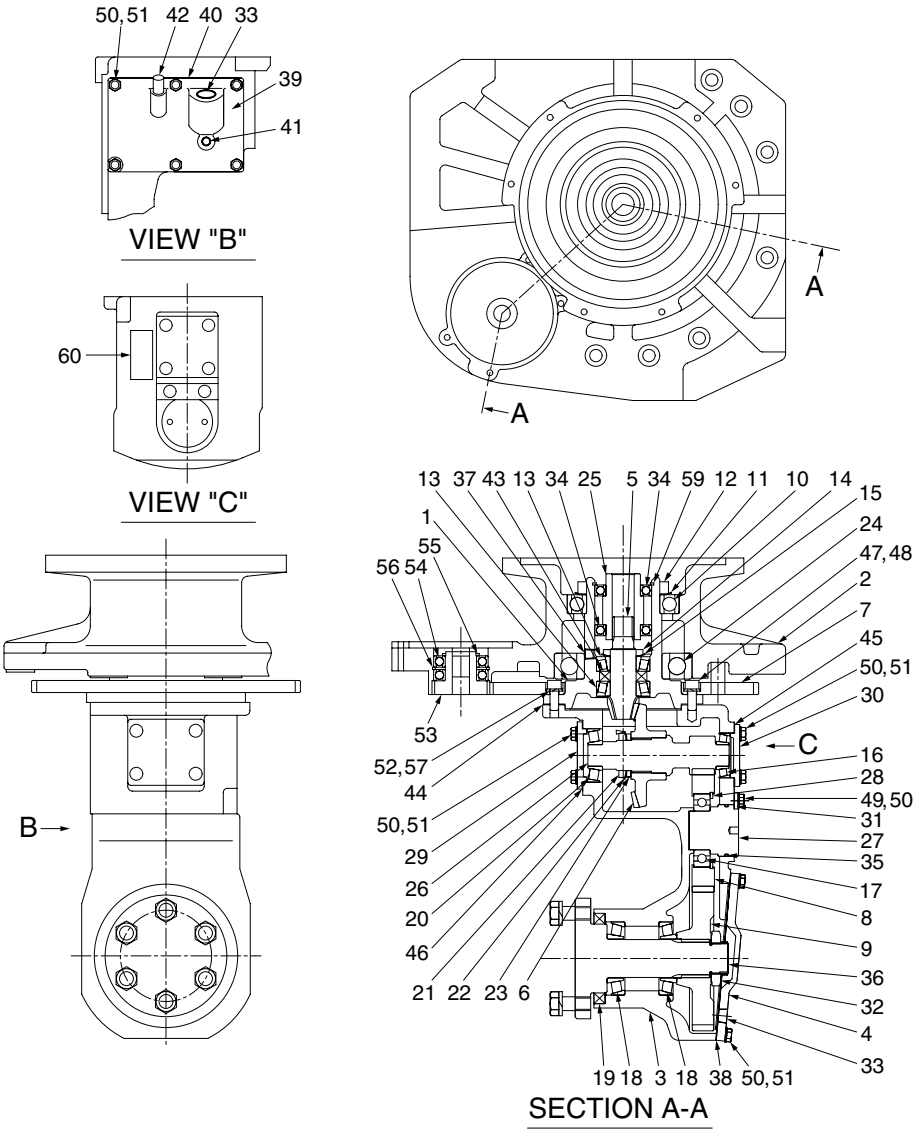


SECTION 3 POWER TRAIN SYSTEM

GROUP 1 STRUCTURE AND OPERATION

1. DRIVE AXLE UNIT

1) STRUCTURE



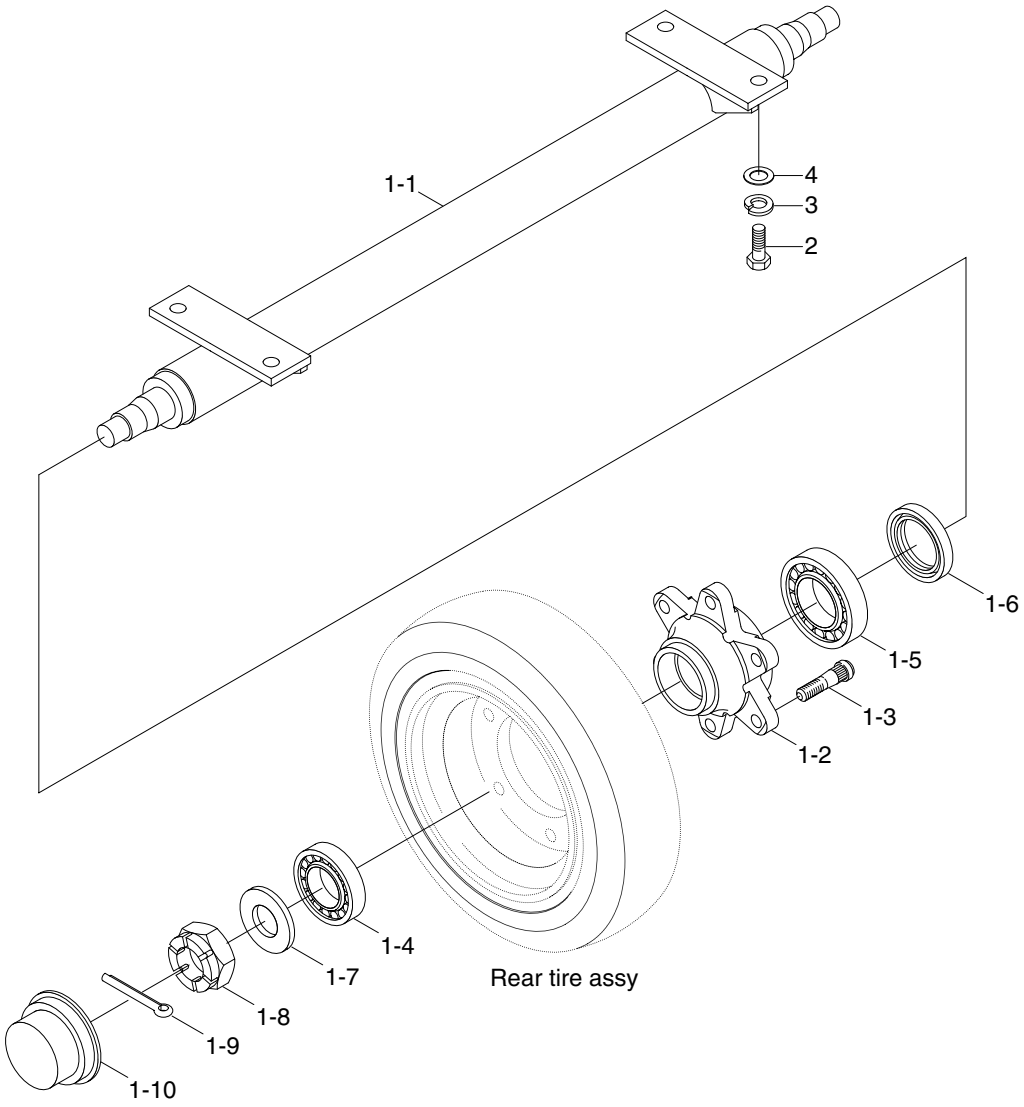
1	Gear case cover	16	Bearing	31	Lock plate	46	Shim
2	Bracket	17	Bearing	32	Drive shaft nut	47	Hexagon bolt
3	Gear case	18	Bearing	33	Taper plug	48	Washer
4	Dirve unit cover	19	Seal	34	Bearing	49	Hexagon bolt
5	Spiral bevel gear	20	Taper roller bearing	35	O-ring	50	Spring washer
6	Spiral bevel gear	21	Bearing nut	36	Drive wheel shaft	51	Hexagon bolt
7	Steering gear	22	Bearing washer	37	Taper plug	52	Hexagon bolt
8	Idle gear	23	Spacer	38	Drive unit gasket	53	Pinion
9	Gear	24	Bearing	39	Cover	54	Pinion gear
10	Bearing	25	Sleeve	40	Gasket	55	Snap ring
11	Bearing washer	26	Pinion shaft	41	Plug	56	Snap ring
12	Bearing nut	27	Idler gear shaft	42	Breather	57	Spring washer
13	Taper roller bearing	28	Snap ring	43	Oil seal	59	Snap ring
14	Bearing nut	29	Dirve unit cover	44	Shim	60	Name plate
15	Bearing washer	30	Dirve unit cover	45	Shim		

2) SPECIFICATION

Item	Unit	Specification
Max drive input	kW	5.0
Max wheel load	kg/lb	750
Gear ratio	-	20.125
Weight without fluid	kg/lb	100/220
Oil quantity	ℓ /U.S. · qt	1.6/1.7

2. REAR AXLE

1) STRUCTURE



BP157RA01

1-1	Rear axle	1-8	Low castle nut
1-2	Hub	1-9	Split pin
1-3	Hub bolt	1-10	Hub cap
1-4	Taper bearing	2	Hexagon bolt
1-5	Taper bearing	3	Spring washer
1-6	Oil seal	4	Plain washer
1-7	Plain washer		

GROUP 2 TROUBLESHOOTING

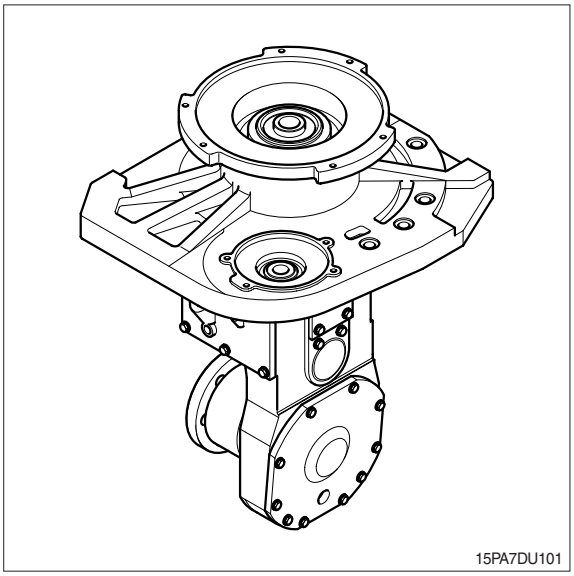
Problem	Probable cause	Remedy
Continuous metallic groan		
1) During acceleration	· Worn out gears. · Pinion and bevel gear meshed too deeply.	· Adjust back-lash or replace gears.
2) During travelling at uniform speed	· Lack of gear oil. · Worn out gears. · Loose or worn out bearing. · Loose bevel gear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

Problem	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 gear stage / input	· Too much oil in drive unit. · O-ring on cover defective. · Breather valve defective.	· Check oil level. · Install new O-ring. · Replace breather valve.
Beating noise at gear stage	· Teeth on input pinion and/or gear damaged by false installation.	· Check tooth flanks for damage and touch up damaged spots with oil rubber.
Ringing noise	· 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 enter-ed 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.

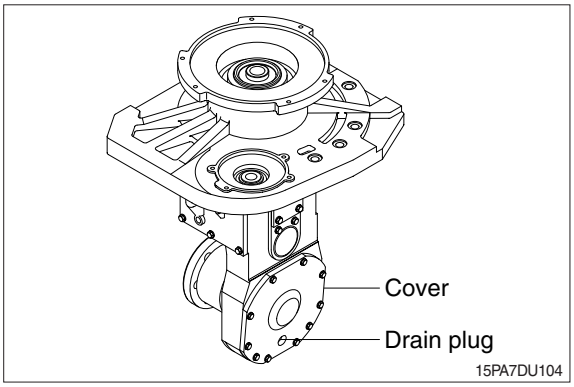
1) DISASSEMBLY

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

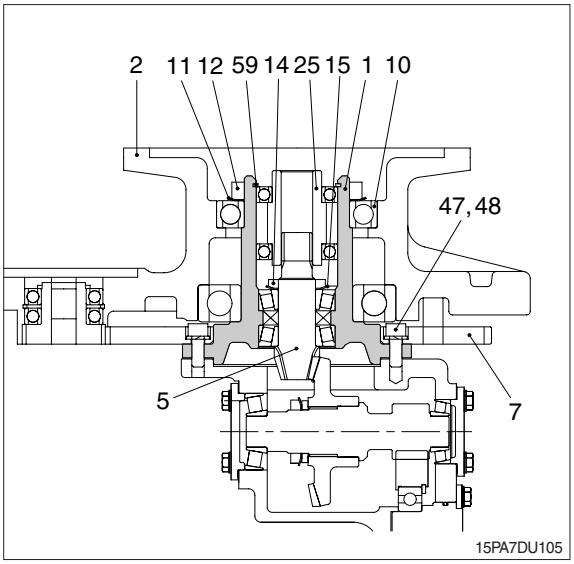
(1) Stabilize the drive unit assembly by using wooden block.



(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 bearing (10) from bracket.
(5) Remove bolts (47) and remove the steering gear (7).
(6) Remove bolts (10EA).
(7) Remove the cover (1) of gear case with spiral bevel pinion (5).
(8) Remove the snap ring (59).
(9) Remove bearing (34) and sleeve (25) from gear case cover (1).
(10) Remove bearing nut (14) by straightening the locking part of the bearing washer (15), and remove the spiral bevel pinion (5) from the cover (1) of gear case.



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

(12) 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).

(13) 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.

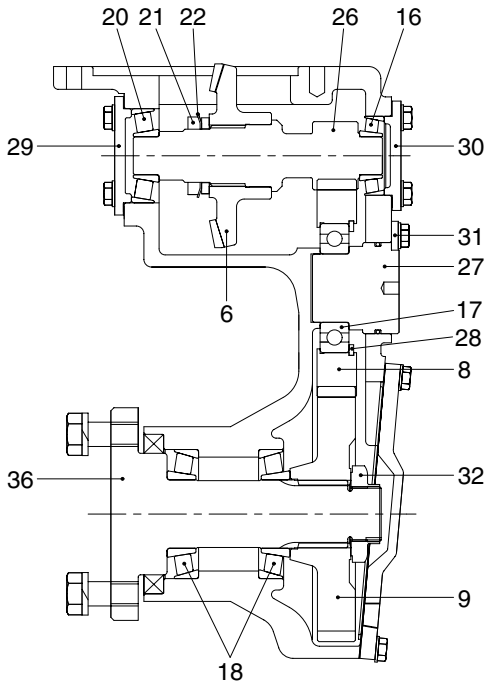
Remove the bearing (18) from drive shaft.

(14) 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).

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

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



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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

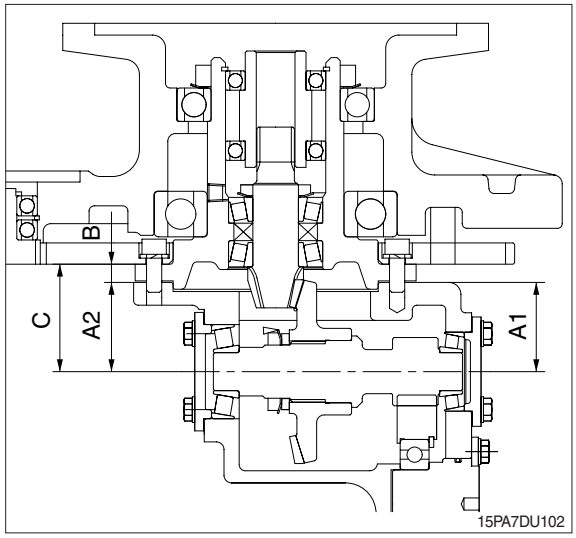
(1) Assemble the oil seal to the cover of gear case, assemble the bearing to spiral bevel pinion shaft. Assemble the spiral bevel pinion shaft bearing, washer and nut to the cover of gear case, and screw on the locking nut.
Tighten the locking nut while measuring starting torque required to start the bevel pinion turning.
Bevel pinion starting torque. 2.7~3.0 kgf · cm (0.2~0.22 lbf · 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 required to start the spur gear turning. Spur gear starting torque. 23.6~26.3 kgf · cm (1.7~1.9 lbf · 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

XKCJ-00043 ····· 0.10 mm
XKCJ-00044 ····· 0.20 mm
XKCJ-00045 ····· 0.30 mm
XKCJ-00043 ····· 0.50 mm



(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
XKCJ-00047	0.10 mm	XKCJ-00052	0.10 mm
XKCJ-00048	0.15 mm	XKCJ-00053	0.15 mm
XKCJ-00049	0.2 mm	XKCJ-00054	0.2 mm
XKCJ-00050	0.3 mm	XKCJ-00055	0.3 mm
XKCJ-00051	0.5 mm	XKCJ-00056	0.5 mm

(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 0.15~0.20 mm
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.

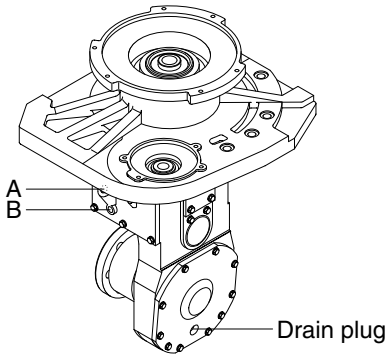
5) LUBRICATION PROCEDURES

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.



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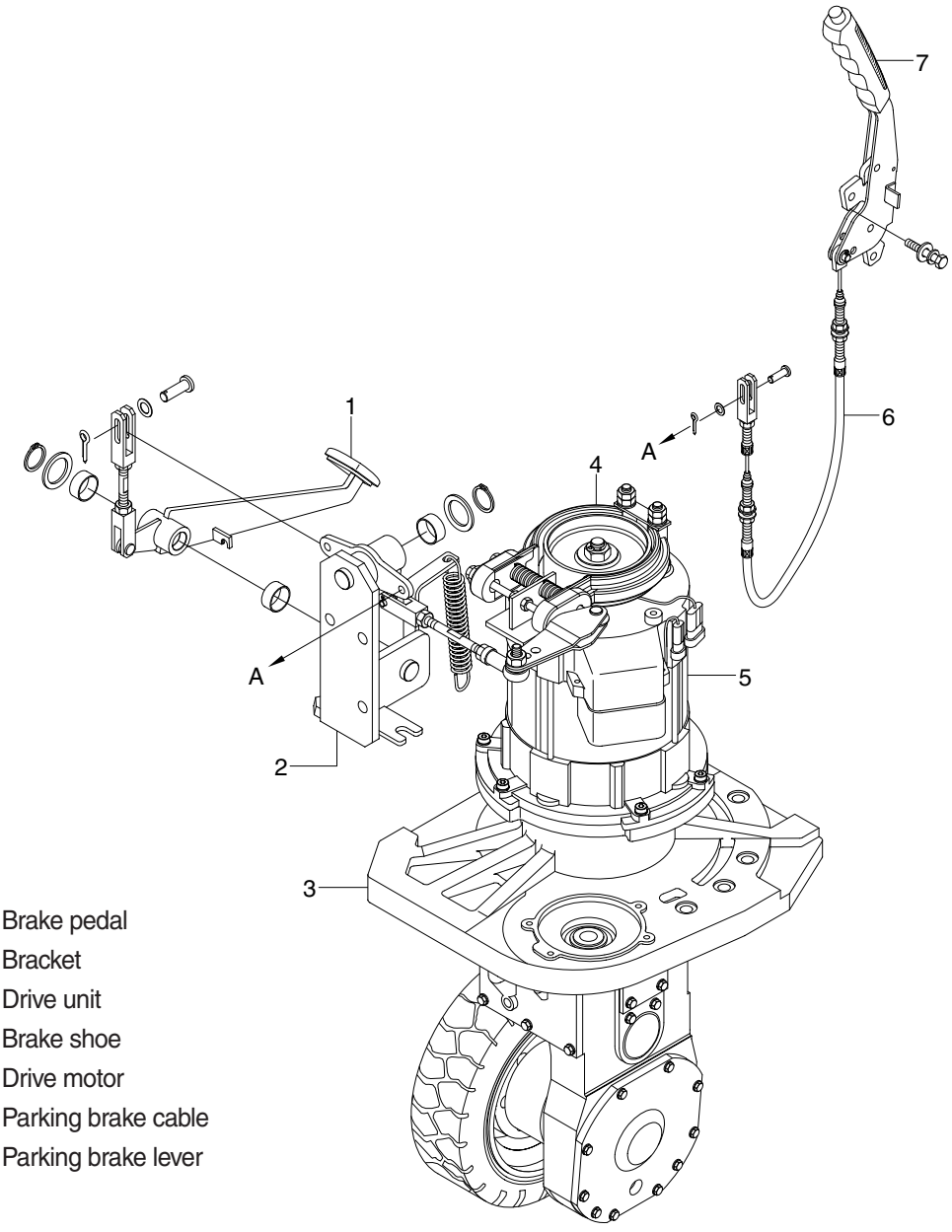
SECTION 4 BRAKE SYSTEM

GROUP 1 STRUCTURE AND FUNCTION

1. OUTLINE



1 Brake pedal
2 Bracket
3 Drive unit
4 Brake shoe
5 Drive motor
6 Parking brake cable
7 Parking brake lever

15PA7BS02

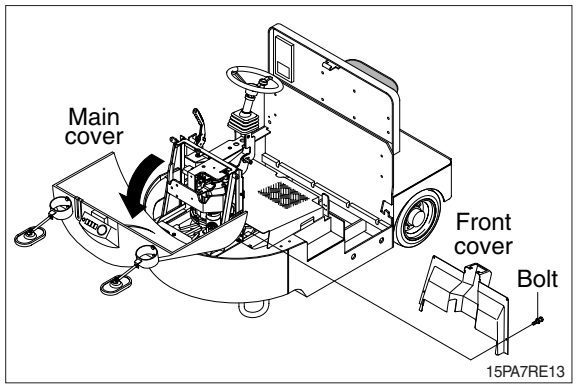
2. SPECIFICATION

Item		Specification
Type		Drum brake
Brake shoe	W × L × T	40 × 110 × 5 mm (1.6 × 4.3 × 0.2 in)
	Area	44 cm^2 (6.8 in^2)
Brake drum diameter	New	120 mm (4.7 in)
	Repair limit	117 mm (4.6 in)
Braking distance	Unloaded	Less than 5.0 m (197 in)
	Loaded	Less than 2.0 m (79 in)

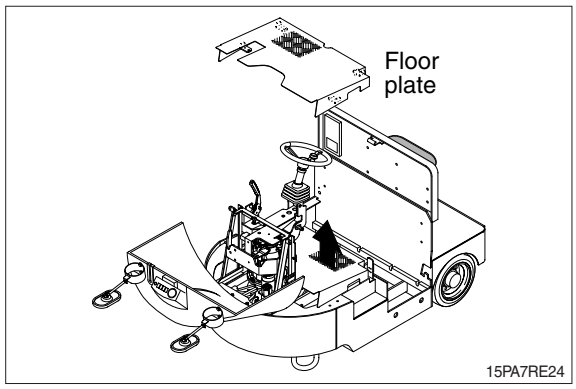
3. DISASSEMBLY AND ASSEMBLY

1) Disassembly

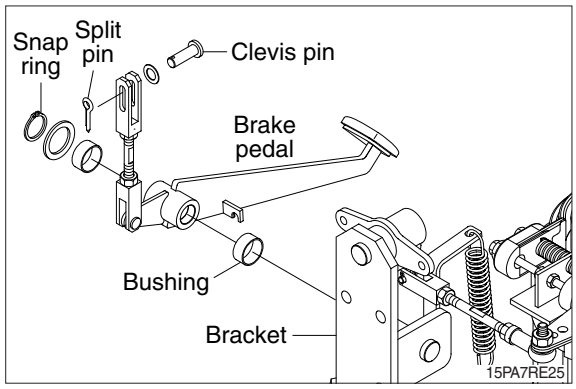
(1) Remove front cover and open main cover.



(2) Remove floor plate.



(3) Remove snap ring and split pin to disassemble pedal.

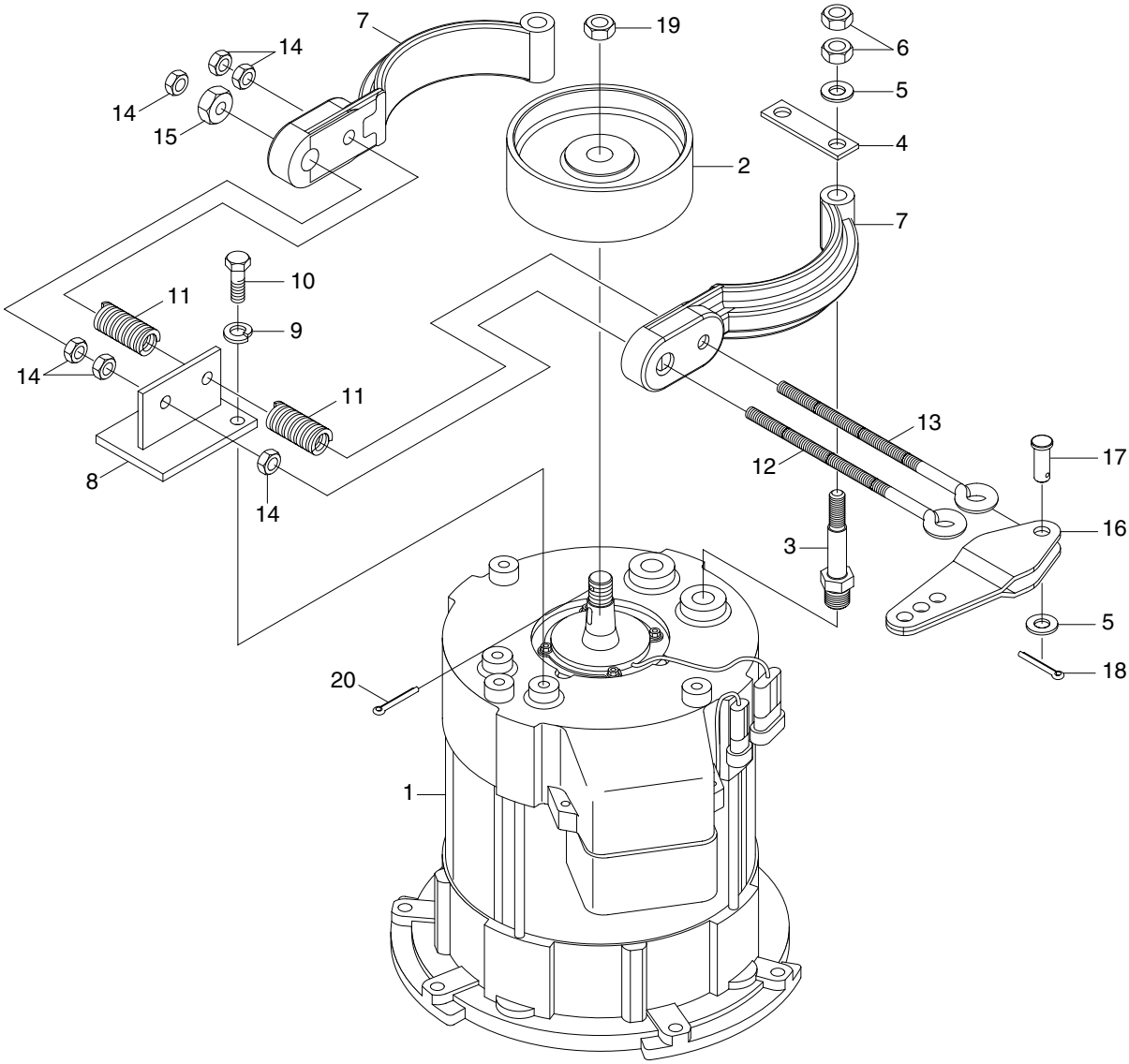


2) Assembly

Perform disassembly in reverse order.

4. BRAKE SYSTEM

1) STRUCTURE



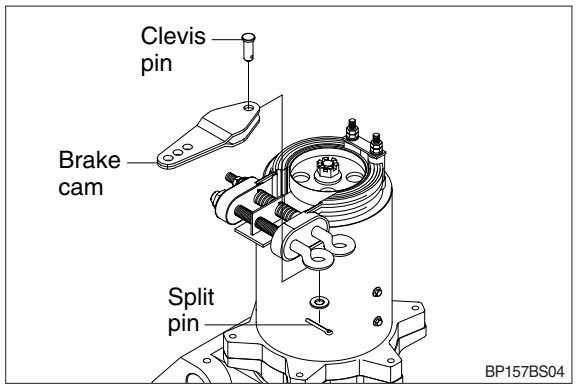
15PA7BS03

1	Traction motor	8	Bracket	15	Adjust nut
2	Brake drum	9	Spring washer	16	Brake cam
3	Brake shoe pin	10	Hexagon bolt	17	Clevis pin
4	Lock plate	11	Adjust spring	18	Split pin
5	Plain washer	12	Hexagon bolt	19	Low castle nut
6	Hexagon nut	13	Hexagon bolt	20	Split pin
7	Brake shoe lining	14	Hexagon nut		

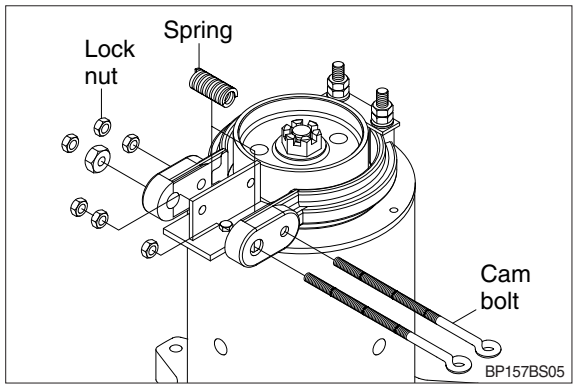
2) DISASSEMBLY AND ASSEMBLY

(1) Disassembly

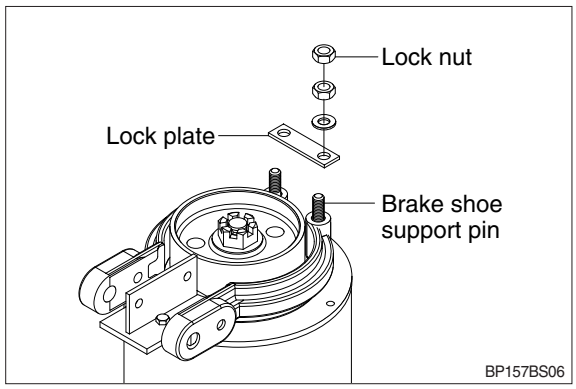
① Remove the brake cam carefully from bolt head.



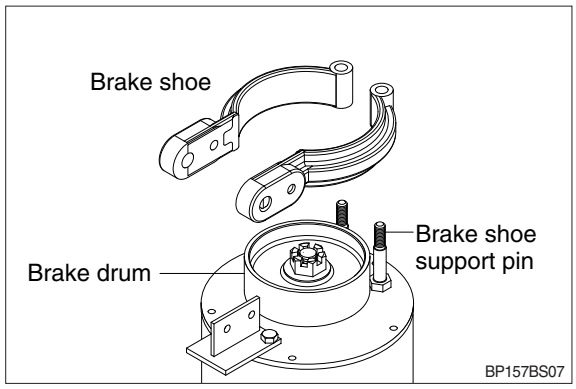
② Remove spring and cam bolts after removing lock nut.



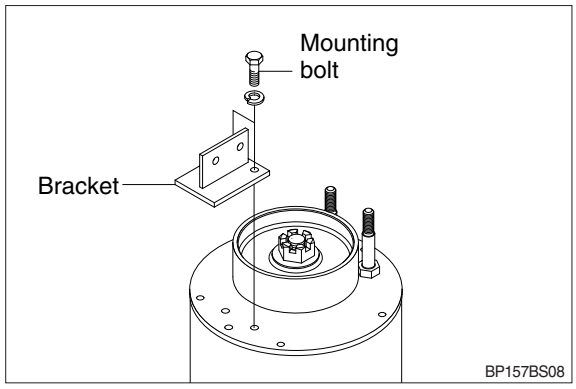
③ Remove lock nut of brake shoe support pin and take off lock plate.



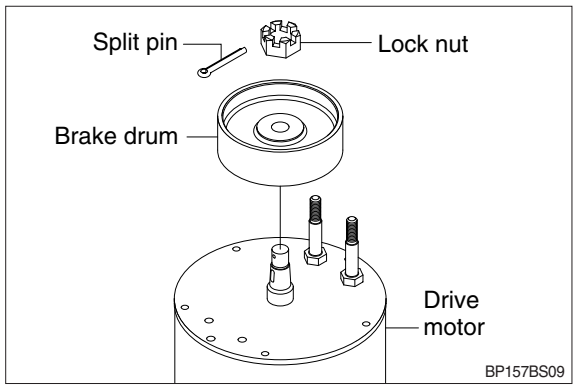
④ Take off brake shoe by lifting up straightly.



⑤ Remove bracket by loosening the mounting bolts.



⑥ Remove lock nut and then take off brake drum.

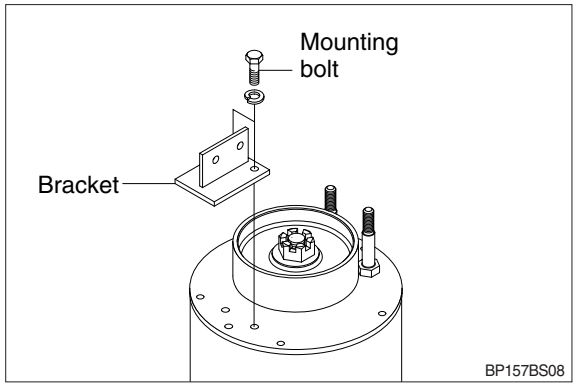


(2) Assembly

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

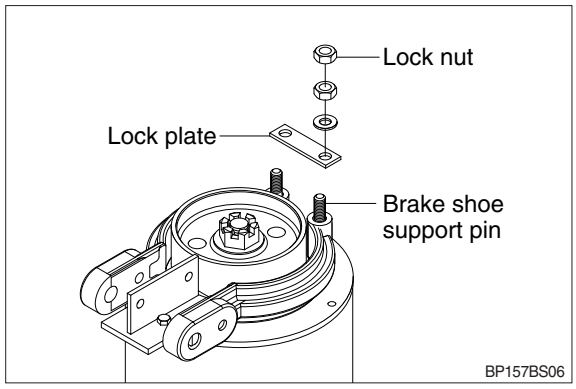
① Bracket mounting bolts.

· Tightening torque : 1.6~1.9 kgf · m
(11.6~13.7 lbf · ft)



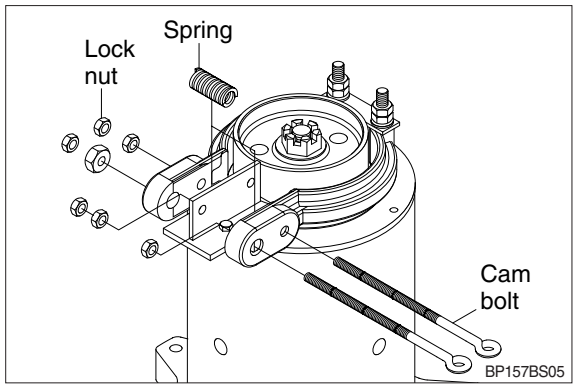
② Brake shoe support pin mounting.

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



③ Cam bolts lock nuts.

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



5. INSPECTION

1) Lining inspection

(1) Contact normally?
(2) Any damages?
(3) Any one sided contact?
(4) Service limit : 1.5 ㎜ (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 play of pedal is 30~35 mm (1.18~1.37 in).
(3) Check the pedal height is 130~131 mm (5.12~5.15 in).

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 mm (0.08 in).
(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 5 m (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	Probable 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.

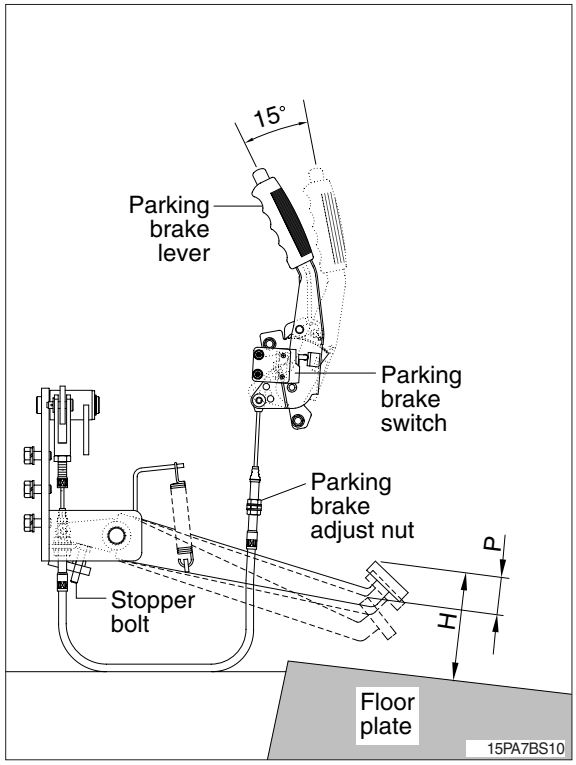
1. BRAKE PEDAL AND CABLE

1) Check the pedal height and adjust the stopper bolt if the height is too high or too low.
   - H : 130~131 mm (5.12~5.15 in)

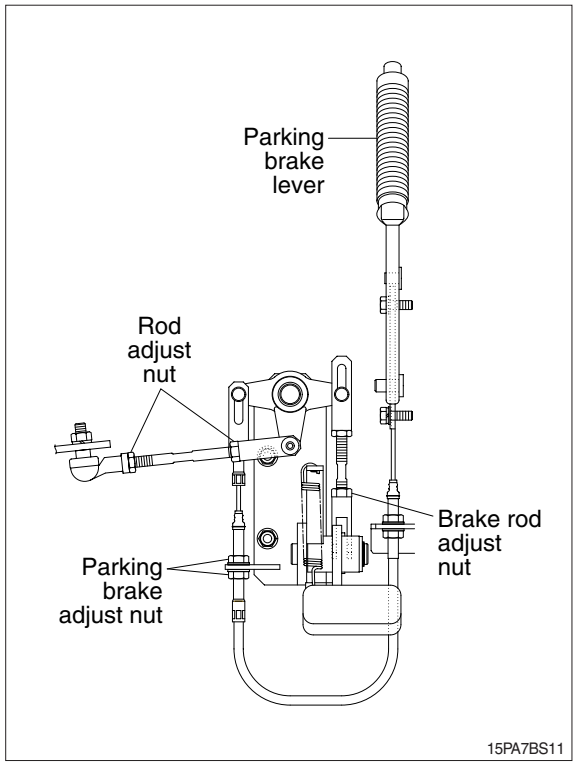
2) Adjust the pedal stroke
   - P : 30~35 mm (1.18~1.37 in)

※ There should be no play in the brake linkage.

3) Check the brake switch to be operating condition while the pedal is depressed.



4) To adjust brake linkage or plays, check out the adjust points as shown in the figure.

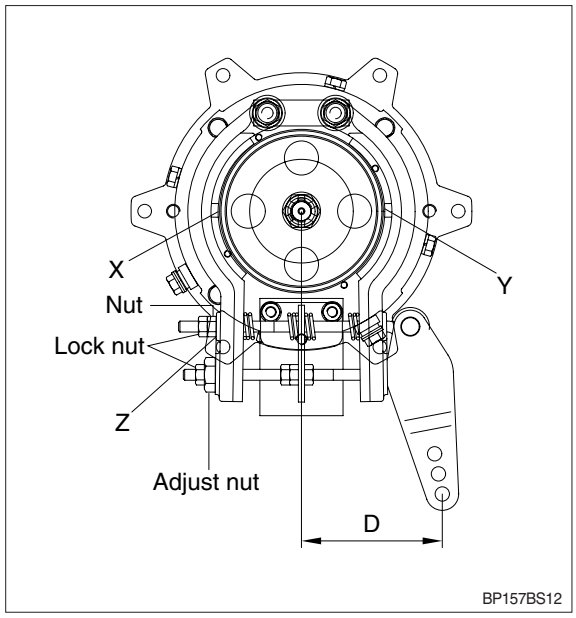


2. BRAKE SYSTEM

1) Check the gap between brake cam and adjusting bolt.
   · X, Y : 0.5~0.8 mm (0.02~0.03 in)
   If the gap is too wide or narrow adjust the adjust nut.

2) After adjusting the nut fasten lock nut as following torque.
   · Lock nut tightening torque
   2.3~2.8 kgf · m (16.6~20.3 lbf · ft)

3) Check the distance "D" is 99 mm (3.9 in).
   If the distance is far from above dimension, adjust the nut and the fasten lock nut.
   · Z : 0.5~1.0 mm (0.02~0.04 in)

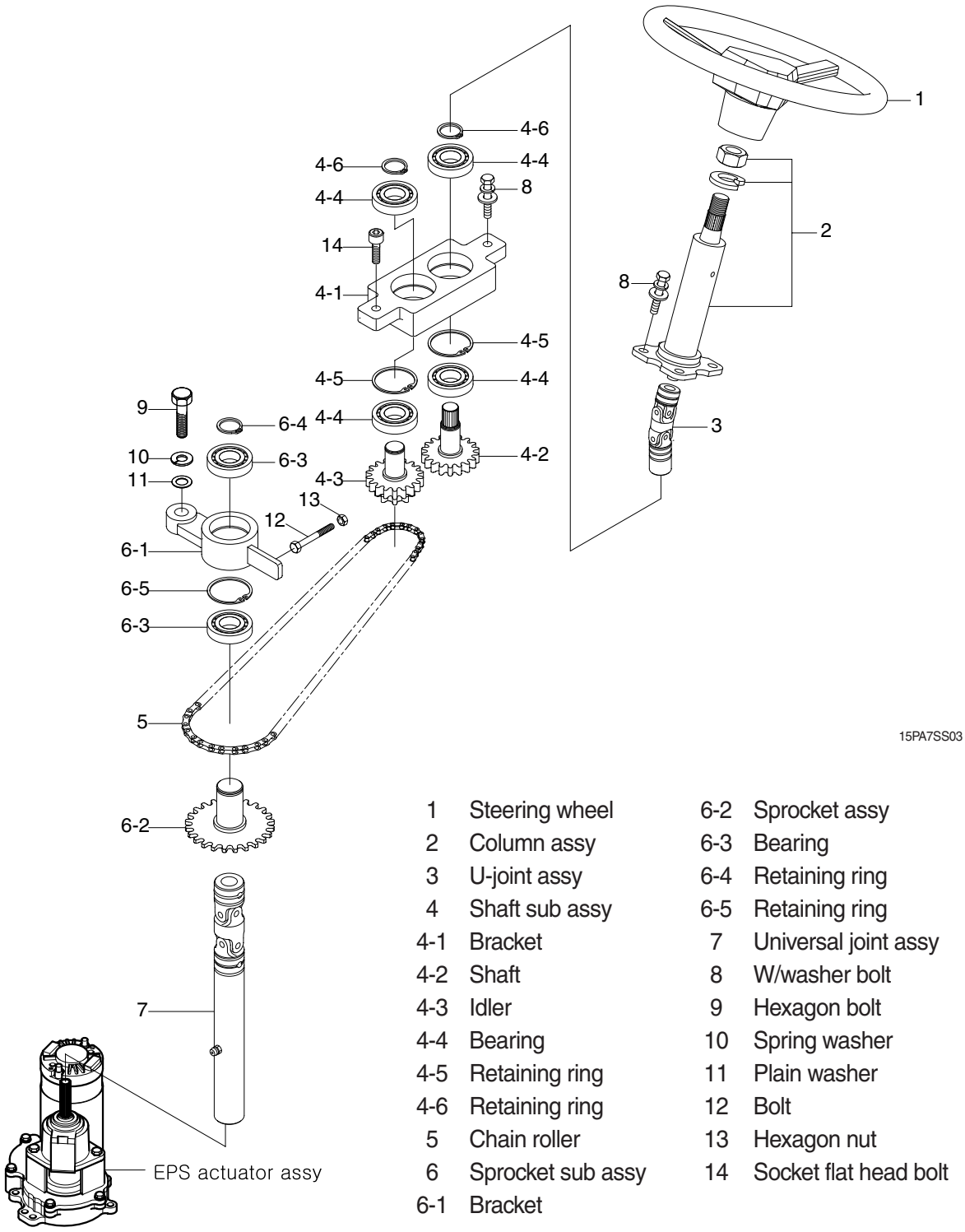


SECTION 5 STEERING SYSTEM

SECTION 5 STEERING SYSTEM

GROUP 1 STRUCTURE AND FUNCTION

1. OUTLINE



1	Steering wheel	6-2	Sprocket assy
2	Column assy	6-3	Bearing
3	U-joint assy	6-4	Retaining ring
4	Shaft sub assy	6-5	Retaining ring
4-1	Bracket	7	Universal joint assy
4-2	Shaft	8	W/washer bolt
4-3	Idler	9	Hexagon bolt
4-4	Bearing	10	Spring washer
4-5	Retaining ring	11	Plain washer
4-6	Retaining ring	12	Bolt
5	Chain roller	13	Hexagon nut
6	Sprocket sub assy	14	Socket flat head bolt
6-1	Bracket		

2. SPECIFICATIONS AND SERVICE STANDARD

Type		1st stage	Chain
		2st stage	Gear
Steering wheel diameter (mm)		ø 320	
Steering wheel free play (mm)		25~50	
Steering chain slack (mm)		3~5	
Steering angle	Right turn	90°	
	Left turn	90°	
Minimum turning radius (mm)	15PA	2065	
	40TA	1565	

3. TROUBLE SHOOTING

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

GROUP 2 DISASSEMBLY AND ASSEMBLY

1. TOOL

1) Standard tool

2) Universal puller

3) Vernier caliper

2. DISASSEMBLY

1) Remove the steering wheel (1) after loosening the hexagon nut (2) by using box spanner.

2) Loosen the hexagon bolts (8) and remove the column assy (2) together with U-joint assy (3).
   · Retightening bolts torque (8) : 5±1 kgf · m (36.15±7.25 lbf · ft)

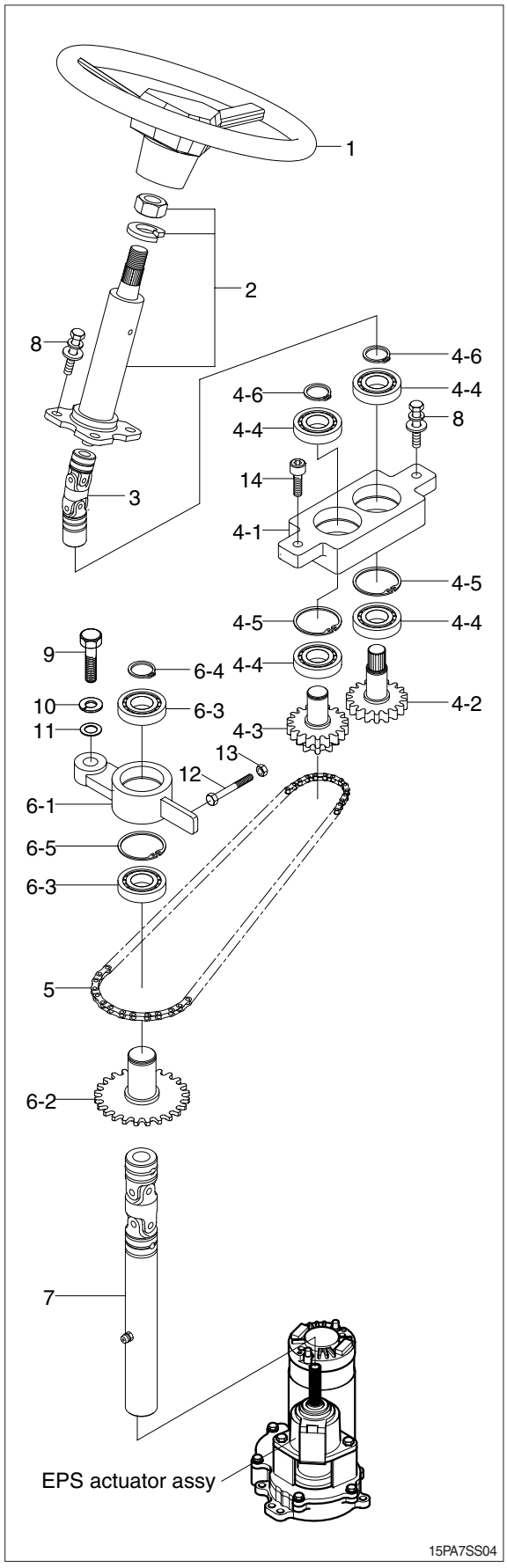
3) Loosen the bolts (8) and remove the shaft sub assy (4).

4) Dismantle the shaft (4-2), idler (4-3) and bearing (4-4) and bracket (4-1) after taking off retaining rings (4-6).
※ Check the bearings (4-4) and teeth of the shafts (4-2) and the replace it if necessary.

5) Remove the roller chain (5) from the sprocket shaft assy (6).
※ Check the roller chain (5) for damage or defects.

6) Sprocket sub assy (6) and universal joint assy (7).

7) After removing the retaining rings (6-4, 6-5), dismantle the sprocket (6-2), bearings (6-3) and bracket (6-1) from the sprocket sub assy (6).
※ Check the sprocket assy (6) and bearings (6-3) for damage or defects.



3. ASSEMBLY

Assembly is reverse order of the disassembly.

※ When assembling the steering linkage assembly, observe performing the following works.

1) After completion of assembly the steering linkage, keep sufficiently the chain tension by using chain tension adjusting bolt.

※ When taking the force with 5 ㎏ for the chain, keep the deflection within 10 ㎜.
Adjusting method.
Loosen the hexagon bolt (9) and adjusting chain tension by using bolt (12) and then tighten the hexagon bolt (9) and hexagon nut (13).

2) When assembling the universal joint assy (7) in the EPS actuator, observe that the inserting depth of the spline is 30 ㎜ at least.

3) Maximum turning of the steering wheel is 5.8±0.5 turns.

4) When assembling the U-joint assy (3) and universal joint assy (7), apply sufficiently grease.

4. INSPECTION

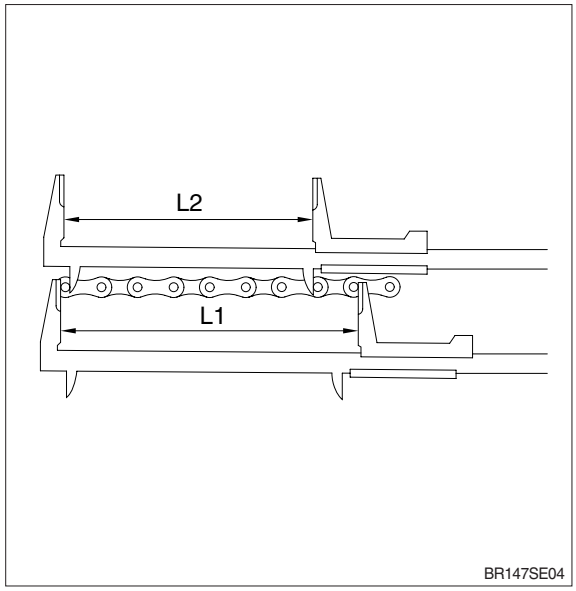
1) Inspect the steering chain for extension, cracks and damage and replace if defective.

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

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

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.



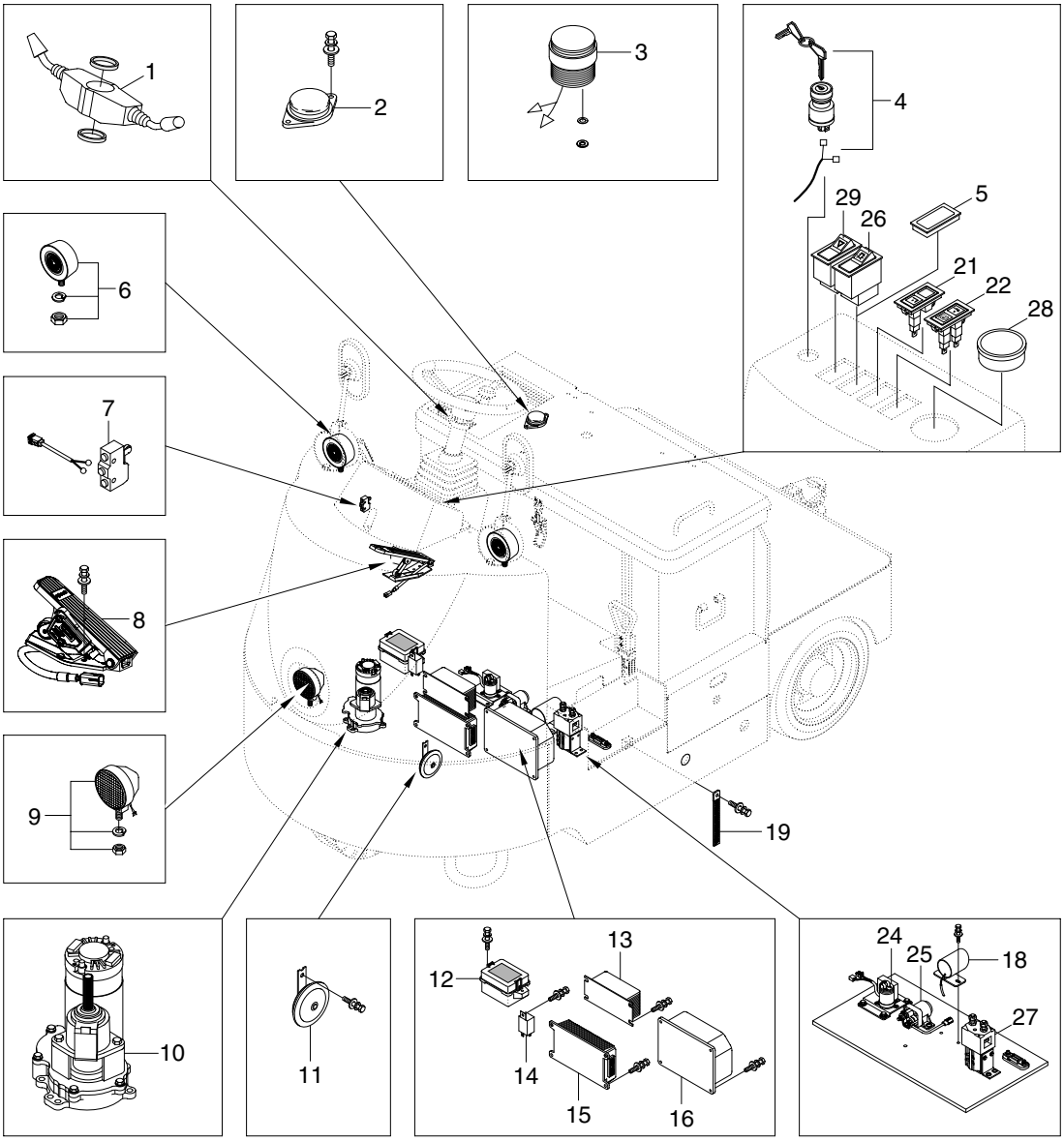
5. ADJUSTMENT

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

SECTION 6 ELECTRICAL SYSTEM

SECTION 6 ELECTRICAL SYSTEM

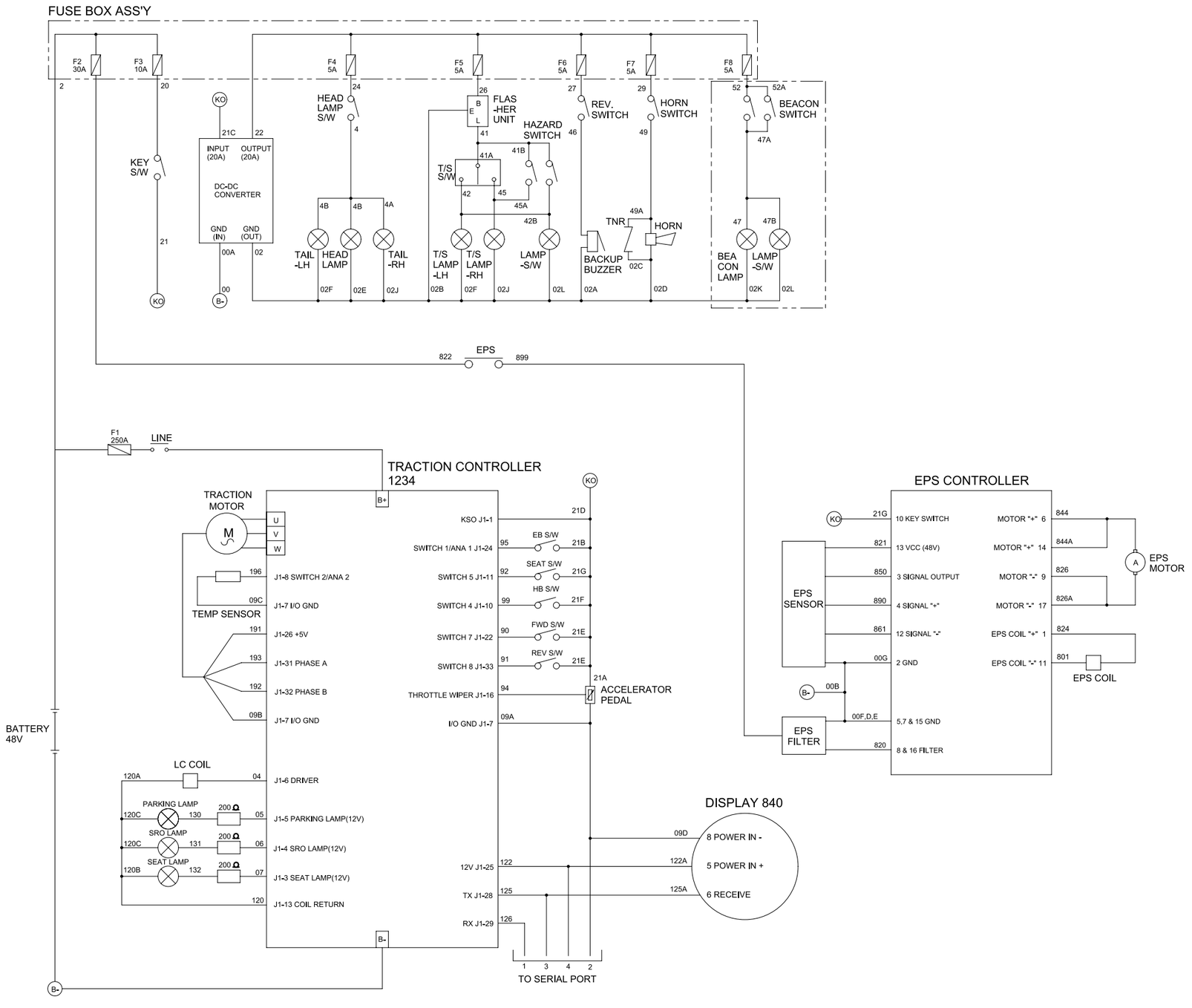
GROUP 1 COMPONENT LOCATION



15PA7EL01

1	Combination switch	10	EPS actuator	21	Warning lamp
2	Seat switch	11	Horn	22	Warning lamp
3	Beacon lamp	12	Fuse box	24	EPS filter
4	Key switch	13	DC-DC converter	25	EPS contactor
5	Cover	14	Flasher unit	26	Beacon switch
6	Turn signal lamp	15	EPS controller	27	Contactor
7	Parking brake switch	16	Controller-1234	28	Display
8	Accelerator	18	Back buzzer	29	Hazard switch
9	Head lamp	19	Static strap		

GROUP 2 ELECTRICAL CIRCUIT



15PA7EL02

GROUP 3 ELECTRIC COMPONENTS

1. FUNCTIONS OF BATTERY TRACTOR AND ELECTRIC COMPONENTS.

The major functions of battery troctor can be divided into DRIVING FUNCTION and LOADING & TRACTION FUNCTION.

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

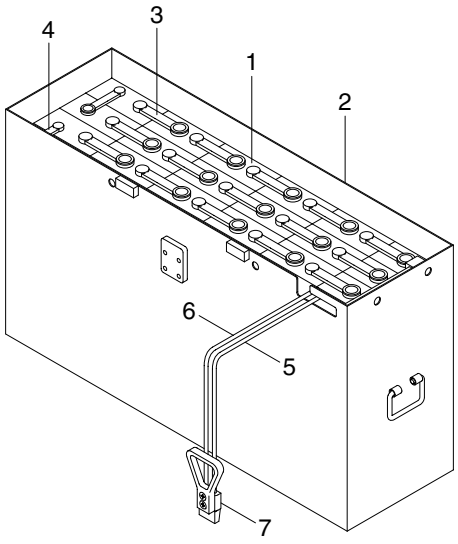
To drive the battery tractor, a DRIVING CONTROL SYSTEM and some electric components such as direction change lever (forward/reverse section switch) and accelerator are required to select the driving direction and to control the speed of driving motor.

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 and temperature sensors. The HYUNDAI battery tractor 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

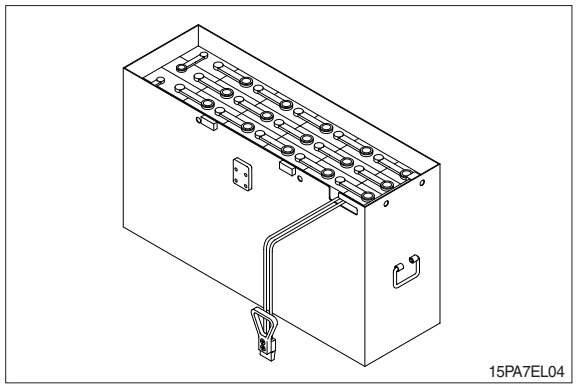


15PA7EL03

1	Cells	5	Negative leading cable
2	Steel box	6	Positive leading cable
3	Cell connector	7	Plug
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

Item	Unit	Specifications
Model	-	VCF 280
Rated voltage	V	48
Capacity	AH/hr	280/5
Electrolyte	-	WET
Dimension (W × D × H)	mm	965 × 380 × 550
Connector (CE spec)	-	SB350 (SBE320)
Weight	kg	470 ± 25

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˚C, 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˚C, before initial charge is fulfilled. The temperature of the cells and filling electrolyte should be between 15˚C and 30˚C. 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˚C, 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˚C) 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˚C, and the temperature during the charge should be maintained at no higher than 55˚C. (Under any unavoidable situations, it should never be above 55˚C). 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 ×1.0~1.5" at the start of charging, and at the final stage it is "5 hour rate current ×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

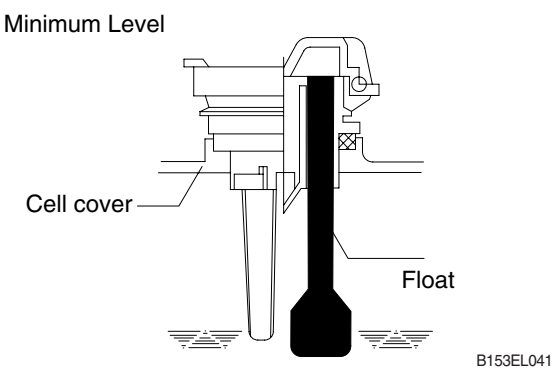
When large number of cells are used in a set of battery, the voltage and specific gravity of respective cells tend to become unequal, resulting in necessity of charging all the cells at an appropriate time in order to equalize them. This is called equalizing charge. Normally the equalizing charge should 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.

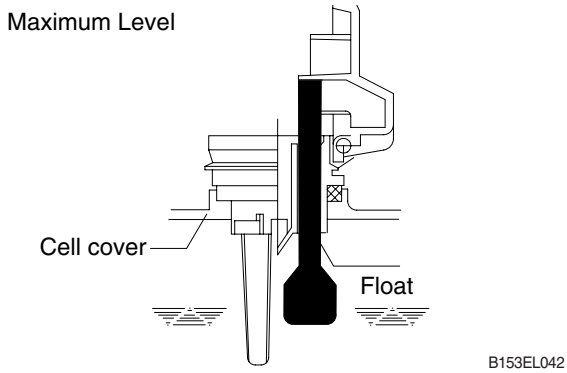
⑥ Water replenishment

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˚C, check the specific gravity once a month, and when lower than 20˚C, check it once every two months. If the measurements show values lower than 1.230 (20˚C), 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**

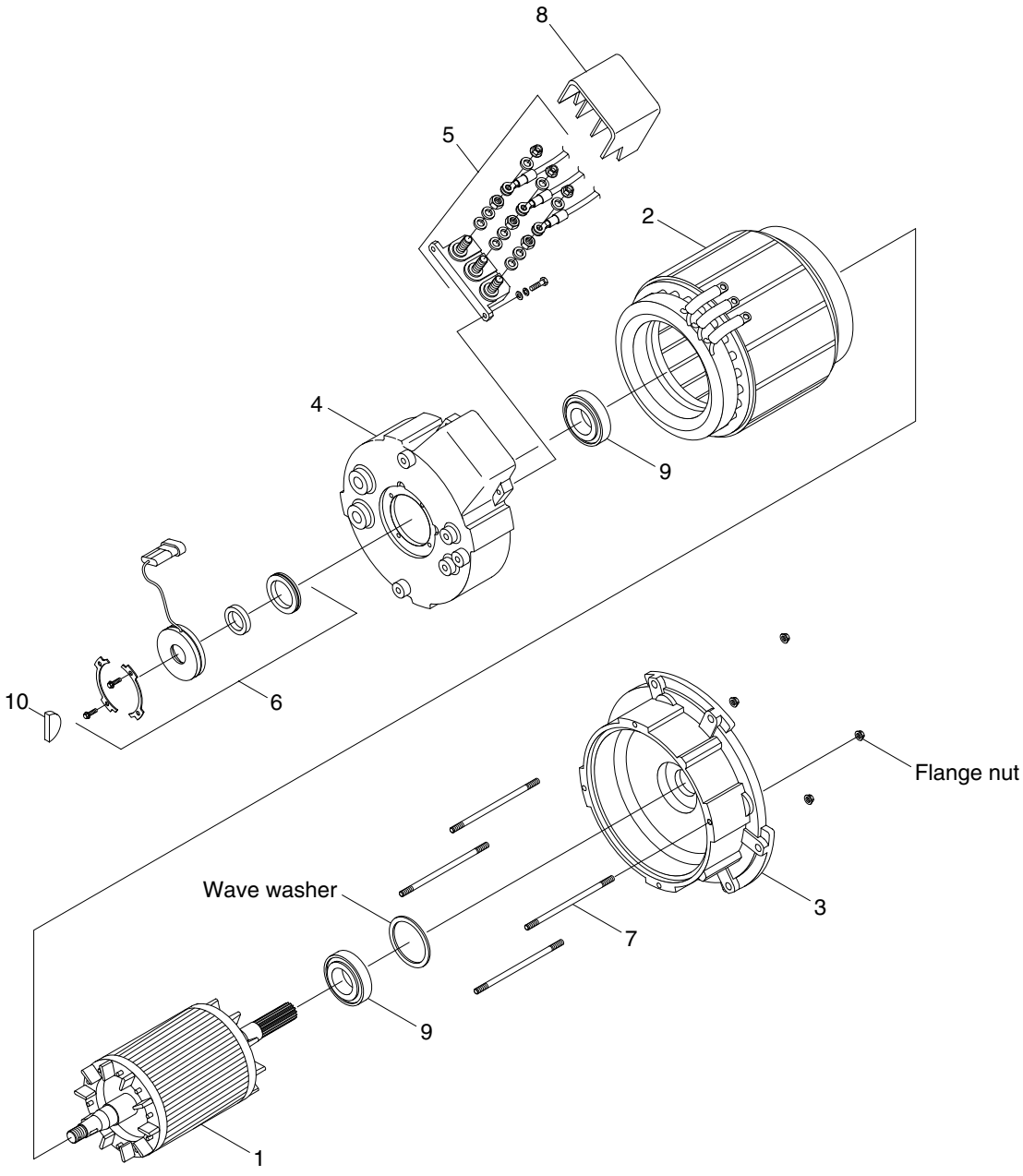
The operating temperature range of batteries is -10~45˚C (temperature of electrolyte). If the batteries are exposed to cold atmosphere in discharged condition, the electrolyte may freeze, and in extreme cases, the capacity will be decreased, but, if not frozen, no adverse effects will be exerted over the life. Contrarily if the temperature is high, especially if used at above 55˚C, 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 · Termination of connector or pole post etc.	· External impact, improper handling, excessive vibration · Excessive temperature rising or vibration/external impact	· Replace or install a new one · Replace
Sulfate	· Specific gravity drops and capacity is decreased. · Charge voltage rises rapidly with immature gassing in earlier stage but specific gravity does not rise and charge can't be carried out.	· When left in state of discharge or left long without equalizing charge. · Insufficient charge. · When electrolyte is so decreased that plate is deposed. · When concentration of electrolyte rises. · When impurities are mixed in electrolyte.	· Need equalizing charge · Need equalizing charge · Need equalizing charge · Adjust specific gravity · 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. · When left long period without refilling of water. · Short circuit.	· Replace · Refill water in regular period · Replace
Rise of specific gravity	· May be easily detected by measurement of the specific gravity.	· Diluted sulfuric acid is used in refilling. · When the electrolyte level excessively drops.	· Adjust specific gravity after full charge. · Refill distilled water.
Mixing of impurities	· Decrease of capacity. · Drop of charge and discharge voltage. · Odor of generated gas and coloring of the electrolyte.	· Metals such as iron, copper, nickel and manganese. · Impurities such as sea water, chloric acid, nitric acid etc. · Filling of impure water.	· 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. Charge fully and adjust the specific gravity to the specified value.

3. TRACTION MOTOR

1) STRUCTURE



15PA7EL07

1	Rotor assy	5	Terminal block	9	Bearing
2	Stator assy	6	Speed sensor kit	10	Woodruff key
3	Endbell de	7	Stud bolt		
4	Endbell	8	Terminal protector		

2) SPECIFICATION

Item	Unit	Specifications
Model	-	AMDF6001
Current	A	134
Rated voltage	V	28
Output	kW	5
Speed	rpm	2270

3) INTERNAL INVOLUTE SPLINE DATA

(Unit : mm)

Item	Specifications
Involute spline shaft	DIN 5480-25 × 1.25 × 30 × 18
Adendum modification	+0.5625
Number of teeth	18EA
Pitch circle dia	ø 22.5

(1) Tooth

(Unit : mm)

Item	Specifications
Tooth type	Stub tooth
Module	1.25
Pressure angle	30°

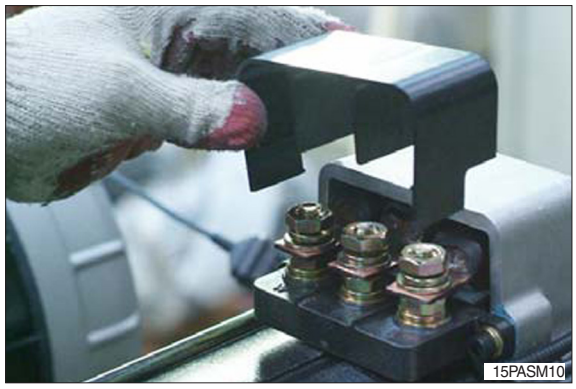
(2) Teeth profile

(Unit : mm)

Item	Specifications
Accuracy grade	DIN 5480
Over pin dia	ø 28.050 (Pin diameter ø 2.75)
Thickness of tooth	ø 13.446 (4EA)

4) DISASSEMBLY

(1) Before disassembling motor, remove terminal protector from the motor and separate thermistor and speed sensor connectors from hanger.

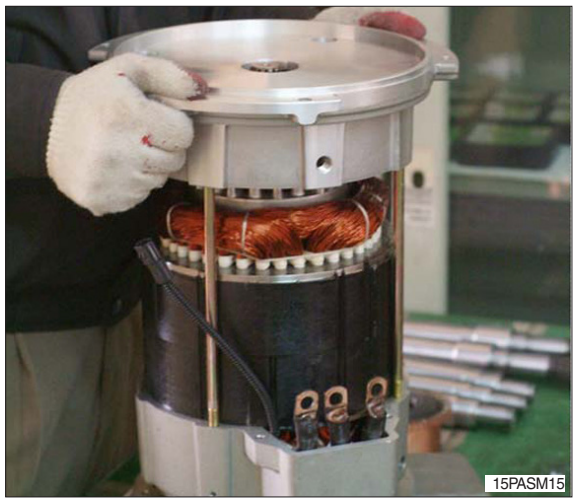


(2) Remove 3 nuts from terminal block of the motor to disassemble terminal block from the motor.

(3) Remove 4 screws fixing speed sensor on the enbell side and then disassemble speed sensor, fixed nut and toothed wheel of the motor.

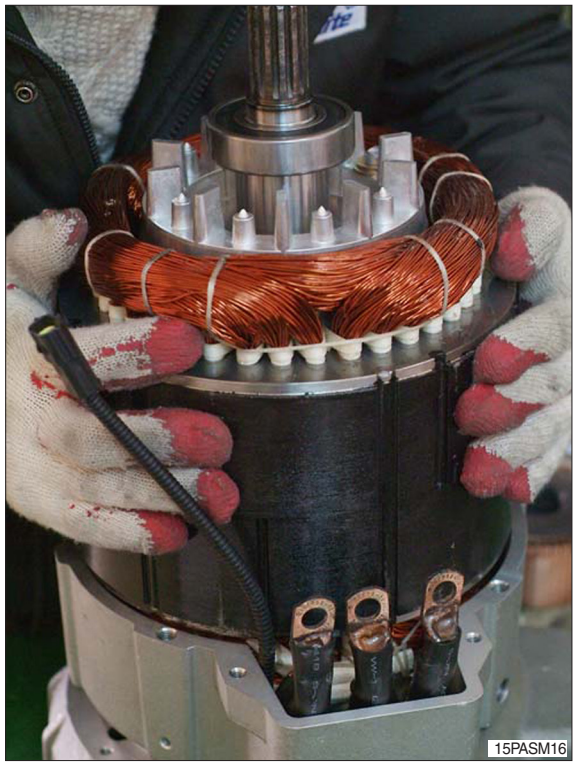
(4) Remove 4 flange nuts with available general tool on the endbell drive side.

(5) Remove endbell de and wave washer.



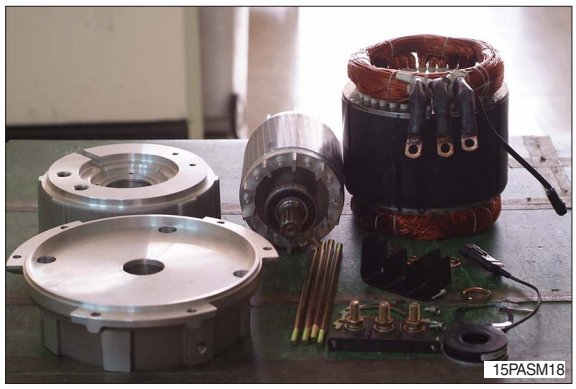
(6) Remove stator assembly by hand or suitable tool.

Removing stator.



(7) Remove endbell from rotor assembly by hand-puller as a right picture.

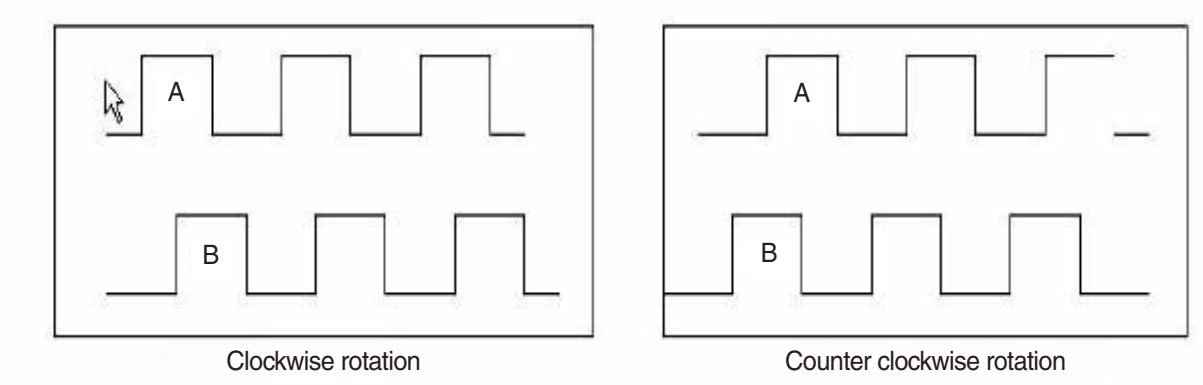
(8) The motor are composed of 5 parts.
(Rotor assembly, stator assembly, endbell de, endbell, ETC)



5) ASSEMBLY AND INSTALLATION

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

(2) After assembling, check for speed sensor. Normal signal is as below.



Clockwise rotation

Counter clockwise rotation

15PASM19

6) INSPECTION

(1) Rotor assembly inspection

① Rotor 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.

② Rotor out diameter : ø 123.1 ± 0.05

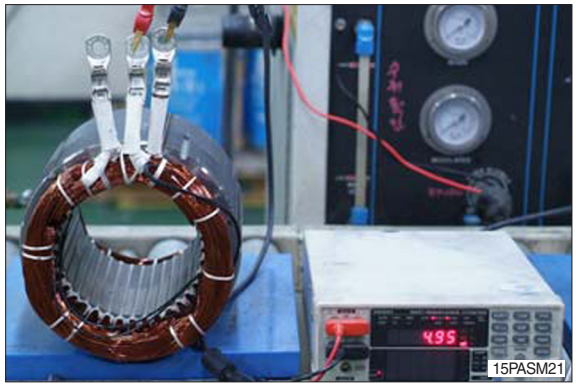
③ Tool : Vernier calipers and standard tool


15PASM20

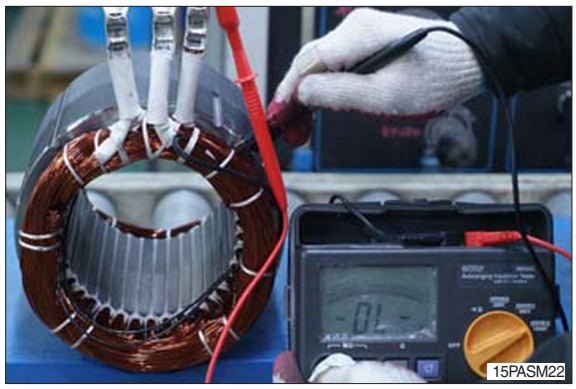
(2) Stator assembly inspection

① Stator 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 coil insulation.

② Use mmΩ tester and check for two power line of stator repeatedly (U-V, V-W, W-U).
At that time resistance is around 6.85 mmΩ .

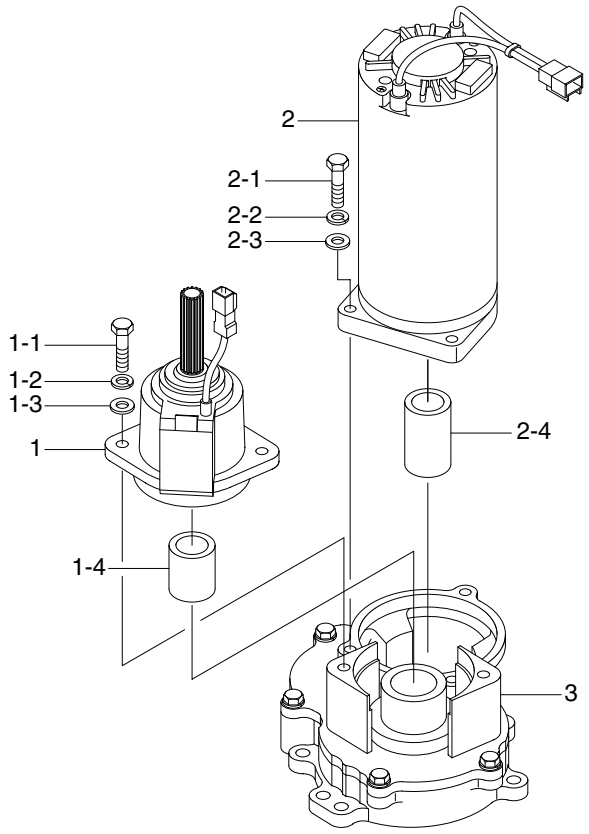

15PASM21

③ **Insulation test**
Use insulation tester (1000 Vac, min. 10MΩ) and measure as a picture.
If the insulation is defective, replace with new parts.


15PASM22

4. EPS ACTUATOR

1) STRUCTURE



15PA7EL18

1	Torque sensor	1-4	Joint coupling	2-3	Washer (M8)
1-1	Hexagon bolt (M8×20)	2	Motor	2-4	Coupling
1-2	Spring washer (M8)	2-1	Hexagon bolt (M8×20)	3	Actuator
1-3	Washer (M8)	2-2	Spring washer (M8)		

2) ACTUATOR ASSY

(1) Actuator assy consists of motor, torque sensor and actuator.

Actuator assy should always be cleaned with compressed air.


15PASM31

(2) Disassemble hexagon bolt (M8×20) which is assembled on torque sensor by using the below tool.

- Tool : Socket wrench set (socket : 13 mm)
- Part : Hexagon bolt (M8×20),
  M8 washer, M8 spring washer
- Quantity : 2EA

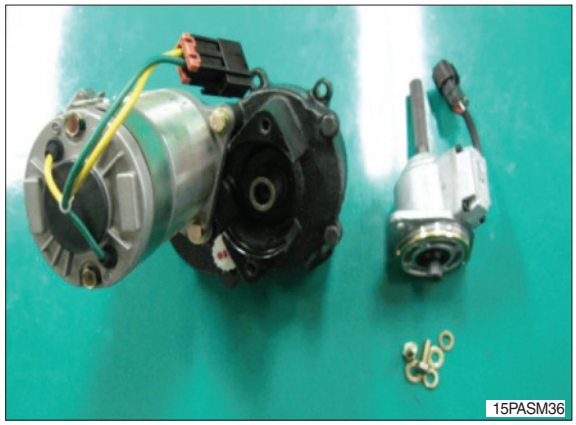

15PASM32


15PASM33

(3) Disassemble torque sensor from actuator assy.


15PASM34


15PASM35


15PASM36

(4) Disassemble joint coupling which is assembled on torque sensor.

- Part : Joint coupling
- Quantity : 1EA


15PASM37

(5) Disassemble hexagon bolt (M8×25) which is assembled on motor by using the below tool.

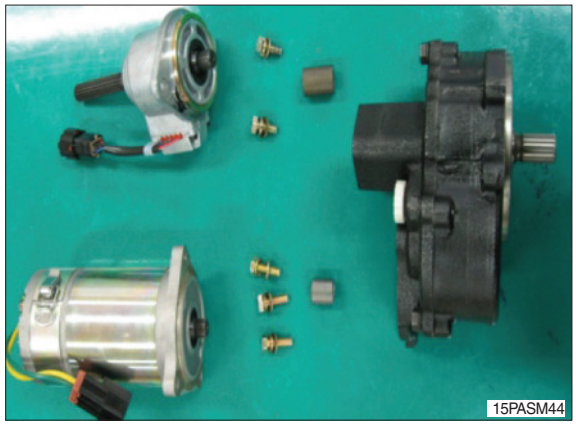
- Tool : Socket wrench set (socket : 13 ㎜)
- Part : Hexagon bolt (M8×25),
  M8 washer, M8 spring washer
- Quantity : 3EA


15PASM38

(6) Disassemble motor from actuator assy.

(7) Disassemble coupling which is assembled on motor.
- Part : Coupling
- Quantity : 1EA

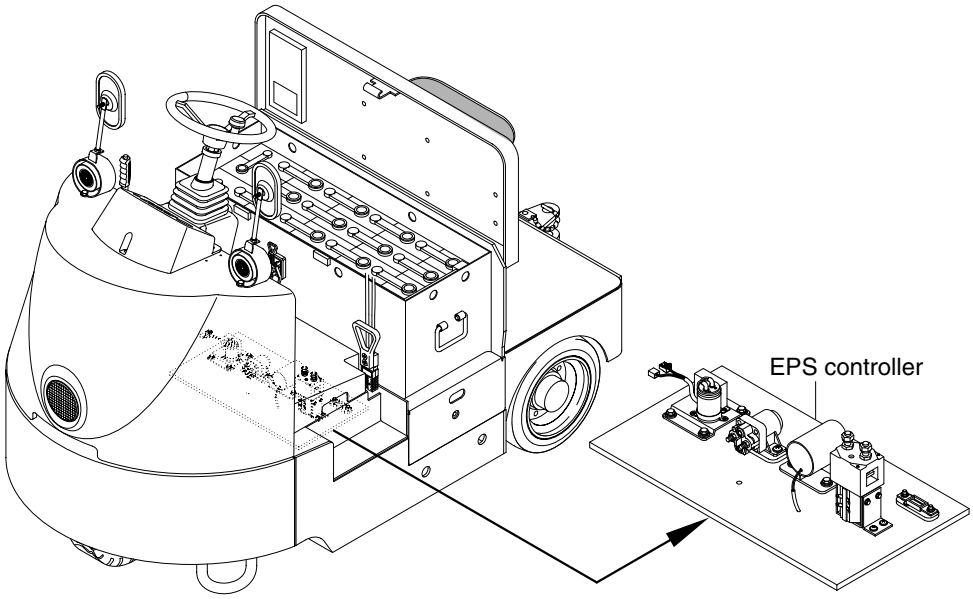
(8) The actuator assy is composed of 3 parts (actuator, motor, torque sensor).



※ Assembly procedure for EPS actuator is the reverse of disassembly procedure.

5. CONTROLLER SYSTEM

1) STRUCTURE



15PA7EL29

2) GENERAL

The 1234AC induction motor controllers deliver smooth power unlike any previous vehicle control system. They provide unprecedented flexibility and power through inclusion of a field-programmable logic controller embedded in a state-of-the-art motor controller.

The embedded logic controller runs a fully functional field-oriented AC motor control operating system (OS) that can be user-tailored via parameter modification.

The CAN bus communications included in the controller, allow these AC induction motor controllers to be part of an efficient distributed system. Inputs and outputs can be optimally shared throughout the system, minimizing wiring and creating integrated functions that often reduce the cost of the system.

The controllers are the ideal solution for traction, motor drive and vehicle control needs.

Like controllers, this controller offers superior operator control of motor drive performance.

Features include:

- High efficiency, field-oriented motor control algorithms
- Advanced Pulse Width Modulation technology for efficient use of battery voltage, low motor harmonics, low torque ripple, and minimized switching losses
- Extremely wide torque/speed range including full regeneration capability
- Smooth low speed control, including zero speed

- Adaptation of control algorithm to motor temperature variation so optimal performance is maintained under widely varying conditions.
- Real-time battery current, motor torque, and power estimates available.
- Power limiting maps allow performance customization for reduced motor heating and consistent performance over varying battery state-of-charge.
- Powerful operating system allows parallel processing of vehicle control tasks, motor control tasks, and user configurable programmable logic.
- A wide range of I/O can be applied wherever needed, for maximum distributed system control
- Internal battery-state-of-charge, hourmeter, and maintenance timers.
- Easily programmable through the Curtis 1311 handheld programmer.
- CAN bus connection allows communication with other CAN bus enabled system components; protocol meets CAN open standards.
- Field-programmable, with flash downloadable main operating code.
- Thermal cutback, warning, and automatic shutdown provide protection to motor and controller.
- Rugged sealed housing and connectors meet IP65 environmental sealing standards for use in harsh environments.
- Insulated metal substrate power base provides superior heat transfer for increased reliability.

※ Using the 1311 handheld programmer, you can set up the controller to perform all the basic operations. In this manual, we first show you how to wire your system and adjust its performance characteristics.

3) SPECIFICATION

Item	Unit	Specifications
Nominal input voltage	V	36-48
PWM operating frequency	kHz	10
Maximum encoder frequency	kHz	15
Maximum controller output frequency	Hz	300
Electrical isolation to heat sink	Vac (min)	500
Operating ambient temperature range	˚C	-40 to 50
Internal heatsink operating temp range	˚C	-40 to 95
Heatsink over temperature cutoff	-	Linear cutback starts at 85˚C (185˚F) Complete cutoff at 95˚C (203˚F)
Heatsink under temperature cutoff	-	Complete cutoff at -40˚C (-40˚F)
Package enviromental rating	-	IP 65
Dimension (W×L×H)	mm (in)	155×212×75 (6.1×8.3×3.0)
Weight	kg (lb)	2.84 (6.3)

4) INSTALLATION AND WIRING

(1) Mounting the controller

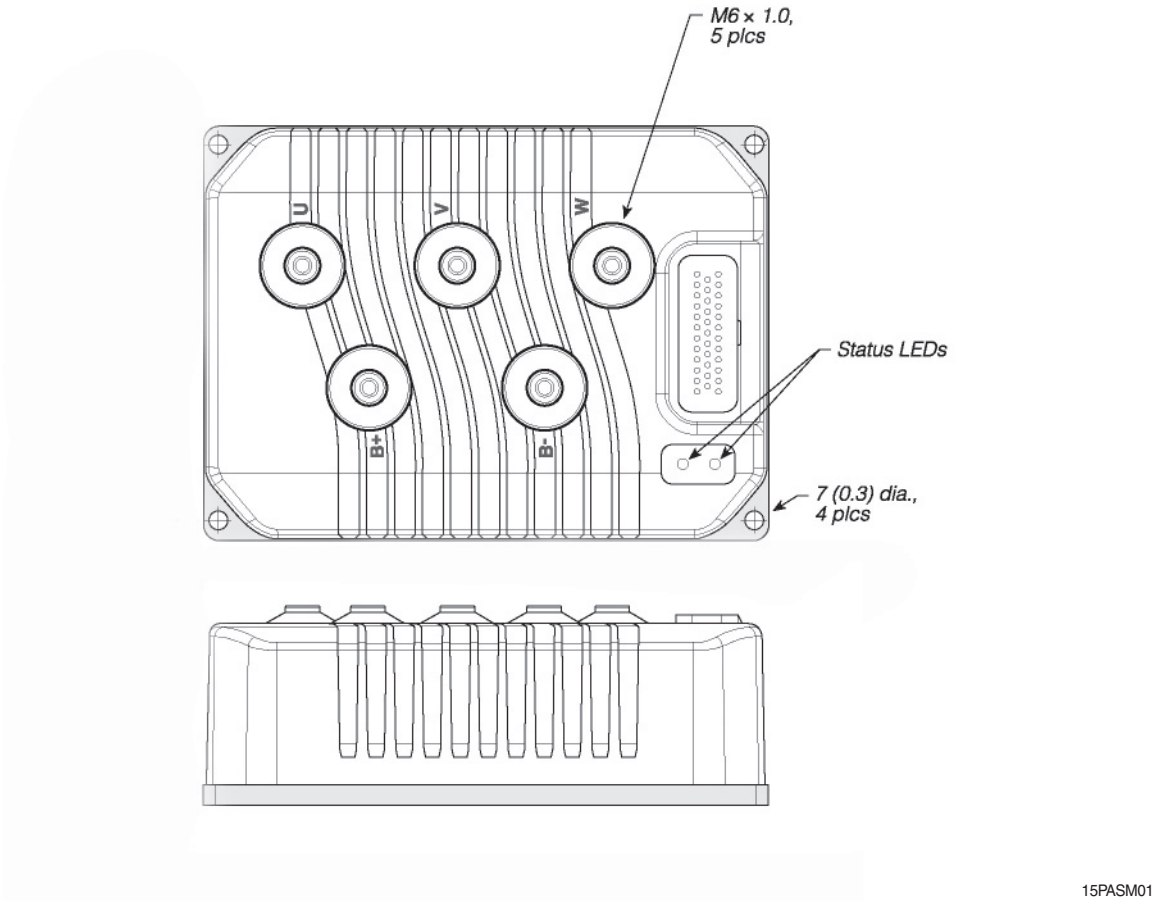
The outline and mounting hole dimensions for the 1234 inverter are shown in the following figure. These controllers meet the IP65 requirements for environmental protection against dust and water. Nevertheless, in order to prevent external corrosion and leakage paths from developing, the mounting location should be carefully chosen to keep the controller as clean and dry as possible.

It is recommended that the controller be fastened to a clean, flat metal surface with four 6㎜ (1/4") diameter bolts, using the holes provided. A thermal joint compound can be used to improve heat conduction from the controller heatsink to the mounting surface. Additional heatsinking or fan cooling may be necessary to meet the desired continuous ratings.

You will need to take steps during the design and development of your end product to ensure that its EMC performance complies with applicable regulations; suggestions are presented in Appendix B.

※ The 1234 inverter contain ESD-sensitive components. Use appropriate precautions in connecting, disconnecting, and handling the controller.

See installation suggestions in Appendix B for protecting the controller from ESD damage.



15PASM01

⚠ Working on electrical systems is potentially dangerous. You should protect yourself against uncontrolled operation, high current arcs, and outgassing from lead acid batteries:

UNCONTROLLED OPERATION-Some conditions could cause the motor to run out of control. Disconnect the motor or jack up the vehicle and get the drive wheels off the ground before attempting any work on the motor control circuitry.

HIGH CURRENT ARCS-Batteries can supply very high power, and arcing can occur if they are short circuited. Always open the battery circuit before working on the motor control circuit. Wear safety glasses, and use properly insulated tools to prevent shorts.

LEAD ACID BATTERIES-Charging or discharging generates hydrogen gas, which can build up in and around the batteries. Follow the battery manufacturer's safety recommendations. Wear safety glasses.

(2) High current connections

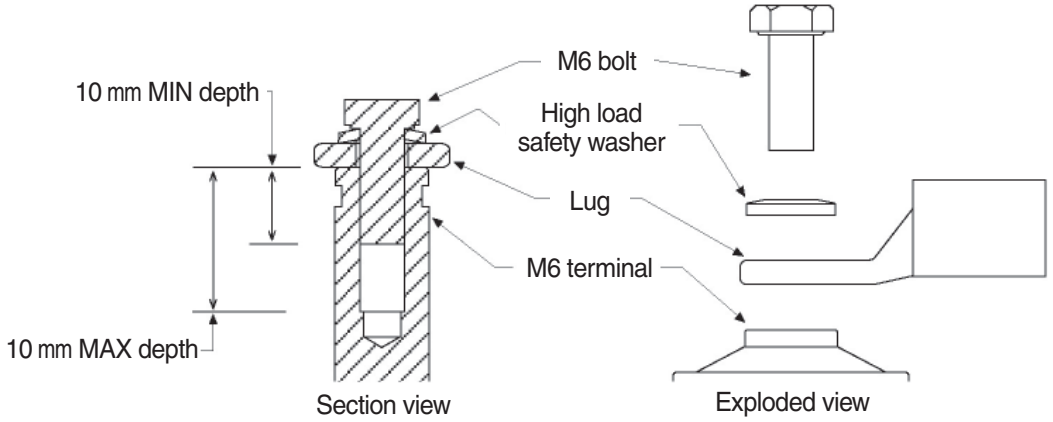
There are five high-current terminals, identified on the controller housing as B+, B-, U, V, and W.

High current connections	
Terminal	Function
B+	Positive battery to controller.
B-	Negative battery to controller.
U	Motor phase U.
V	Motor phase V.
W	Motor phase W.

① Lug assembly

Five aluminum M6 terminals are provided. Lugs should be installed as follows, using M6 bolts sized to provide proper engagement (see diagram):

- Place the lug on top of the aluminum terminal, followed by a high-load safety washer with its convex side on top. The washer should be a SCHNORR 416320, or equivalent.
- If two lugs are used on the same terminal, stack them so the lug carrying the least current is on top.
- Tighten the assembly to 10.2±1.1 Nm (90±10 in-lbs).



15PASM02

② High current wiring recommendations

- Battery cables (B+, B-)

  These two cables should be run close to each other between the controller and the battery. Use high quality copper lugs and observe the recommended torque ratings. For best noise immunity the cables should not run across the center section of the controller. With multiple high current controllers, use a star ground from the battery B- terminal.

- Motor wiring (U, V, W)

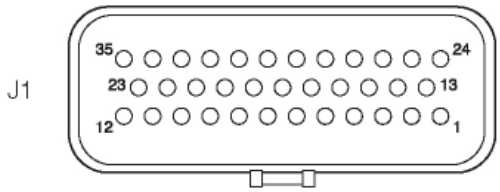
  The three phase wires should be close to the same length and bundled together as they run between the controller and the motor. The cable lengths should be kept as short as possible. Use high quality copper lugs and observe the recommended torque ratings. For best noise immunity the motor cables should not run across the center section of the controller. In applications that seek the lowest possible emissions, a shield can be placed around the bundled motor cables and connected to the B- terminal at the controller. Typical installations will readily pass the emissions standards without a shield. Low current signal wires should not be run next to the motor cables. When necessary they should cross the motor cables at a right angle to minimize noise coupling.

(3) Low current connections

All low power connections are made through a single 35-pin AMPSEAL connector.

The mating plug housing is AMP p/n 776164-1 and the contact pins are AMP p/n 770520-3. The connector will accept 20 to 16 AWG wire with a 1.7 to 2.7mm diameter thin-wall insulation.

The 35 individual pins are characterized in Table 2.



15PASM03

① Low current wiring recommendations

- Motor encoder (Pins 31, 32)

  All four encoder wires should be bundled together as they run between the motor and controller logic connector. These can often be run with the rest of the low current wiring harness. The encoder cables should not be run near the motor cables. In applications where this is necessary, shielded cable should be used with the ground shield connected to the I/O ground (pin 7) at only the controller side. In extreme applications, common mode filters (e.g. ferrite beads) could be used.

- All other low current wiring

  The remaining low current wiring should be run according to standard practices.

  Running low current wiring next to the high current wiring should always be avoided.

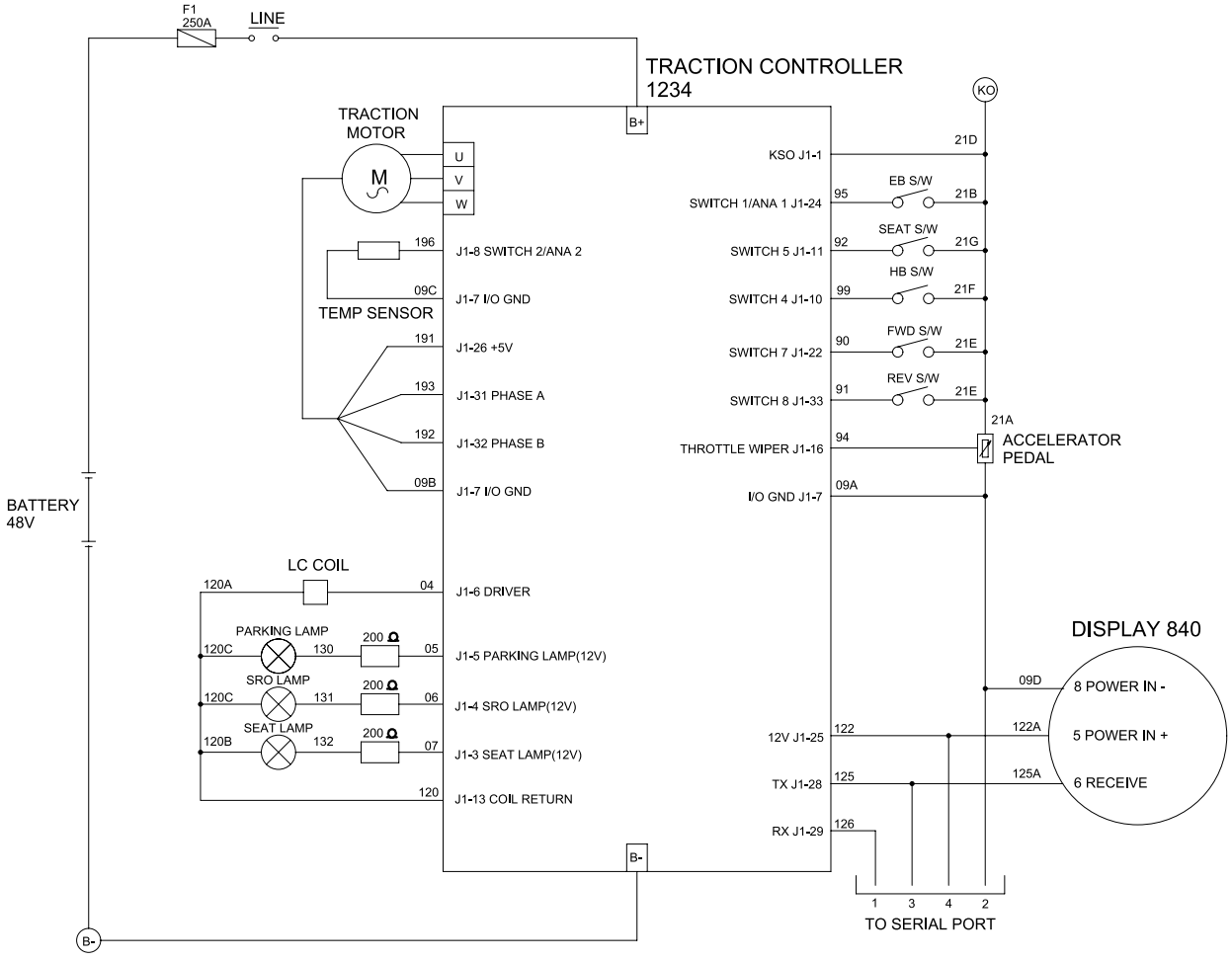
■ Low current connections, cont'd

Pin	Name	Description	Remark
1	KSI	Keyswitch input. Provides logic power for the controller and power for the coil drivers.	
3	Driver 4	Generic driver #4; can also be used as a digital input. Has low frequency PWM capabilities.	
4	Driver 3	Generic driver #3; can also be used as a digital input. Has low frequency PWM capabilities. Typically used for pump contact-or.	
5	Driver 2	Generic driver #2; can also be used as a digital input. Has low frequency PWM capabilities and a slightly higher current rating.Typically used for electromagne-tic brake.	
6	Driver 1	Generic driver #1; can also be used as a digital input. Has low frequency PWM capabilities. Typically used for main contact-or.	
7	I/O ground	Input and output ground reference.	
8	Switch 2 Analog 2	Can be used as generic switch input #2 or as generic analog input #2. Typically used as the motor temperature analog input.	
10	Switch 4	Generic switch input #4.	
11	Switch 5	Generic switch input #5.	
13	Coil Return	This is the coil return pin for all the contactor coils.	
16	Throttle Pot Wiper	Pot wiper connection for the throttle pot.	
22	Switch 7	Generic switch input #7. Typically used as the Forward switch.	
24	Switch 1 Analog 1	Can be used as generic switch input #1 or as generic analog input #1. Typically used for emergency reverse switch (if applicable).	
25	+12V Out	Unregulated low power +12V output.	
28	Serial TX	Serial transmit line for display or flash update.	
29	Serial RX	Serial receive line for flash update.	
31	Encoder A	Quadrature encoder input phase A.	
32	Encoder B	Quadrature encoder input phase B.	
33	Switch 8	Generic switch input #8. Typically used as the Reverse switch.	

■ CONTROLLER WIRING : BASIC CONFIGURATION

A basic wiring diagram is shown electric circuit. Throttle and brake are shown in the diagram as 3-wire potentiometers; other types of throttle and brake inputs are easily accommodated, and are discussed in the following throttle wiring section.

The main contactor coil must be wired directly to the controller as shown the following diagram to meet EEC safety requirements. The controller can be programmed to check for welded or missing contactor faults and uses the main contactor coil driver output to remove power from the controller and motor in the event of various other faults. If the main contactor coil is not wired to pin 6 of the 35-pin connector as shown, the controller will not be able to open the main contactor in serious fault conditions and the system will therefore not meet EEC safety requirements.



15PA7EL30

■ SWITCH INPUT WIRING

The following inputs are dedicated to specific functions when the parameter settings are as shown:

- Switch 1 : Accelerator cable input if the EMR enable = on and EMR type = 0
- Switch 5 : Seat switch input
- Switch 7 : Forward input
- Switch 8 : Reverse input

■ THROTTLE WIRING

In this manual, the term throttle is used in two senses: as another name for the drive throttle, and as a generic term covering both the drive throttle and the brake throttle. Wiring is the same, whether the throttle in question is used for braking or for acceleration.
Various throttles can be used with the 1234 controller. They are characterized as one of five types in the programming menu of the 1311 programmer.

- Type 2 : Single-ended 0–5V throttles, current source throttles,
  3-wire potentiometers, and electronic throttles

The two throttle inputs (drive throttle and brake throttle) are programmed independently.
For potentiometers, the controller provides complete throttle fault protection that meets all applicable EEC regulations. For voltage throttles, the controller protects against out-of-range wiper values, but does not detect wiring faults; it is therefore the responsibility of the OEM to provide full throttle fault protection in vehicles using voltage throttles.
Throttle types 1–3 use the forward and reverse inputs (switches 7 and 8) in addition to the throttle pot input to define the throttle command (see figure 13).
Throttle types 4 and 5 do not use the forward and reverse inputs.
Wiring for the most common throttles is described in the following text and shown in the accompanying illustrations. If a throttle you are planning to use is not covered, contact to Hyundai.

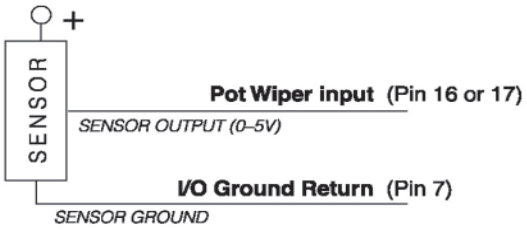
■ THROTTLE TYPE 2

With these throttles, the controller looks for a voltage signal at the wiper input.
Zero throttle request corresponds to 0 V and full throttle request to 5 V. A variety of devices can be used with this throttle input type, including voltage sources, current sources, 3-wire pots, and electronic throttles. The wiring for each is slightly different, as shown in figure 5, and they have varying levels of throttle fault protection.
When a voltage source is used as a throttle, it is the responsibility of the OEM to provide appropriate throttle fault detection. For ground-referenced 0–5V throttles, the controller will detect open breaks in the wiper input but cannot provide full throttle fault protection.
To use a current source as a throttle, a resistor must be added to the circuit to convert the current source value to a voltage; the resistor should be sized to provide a 0–5V signal variation over the full current range. It is the responsibility of the OEM to provide appropriate throttle fault detection.

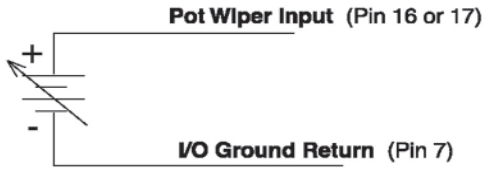
When a 3-wire potentiometer is used, the controller provides full fault protection in accordance with EEC requirements. The pot is used in its voltage divider mode, with the controller providing the voltage source and return. Pot High provides a current limited 5V source to the pot, and Pot Low provides the return path. This is the throttle shown in the basic wiring diagram (figure 3) for the drive throttle and for the brake throttle.
The ET-XXX electronic throttle is typically used only as a drive throttle.
The ET-XXX contains no built-in fault detection, and the controller will detect only open wiper faults. It is the responsibility of the OEM to provide any additional throttle fault detection necessary.

Voltage Source

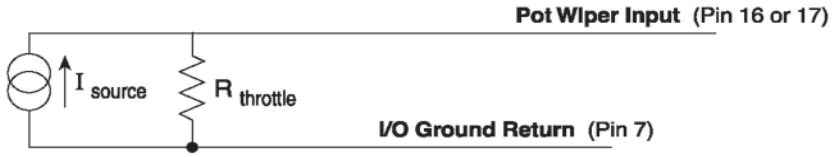
Sensor-referenced 0–5V source



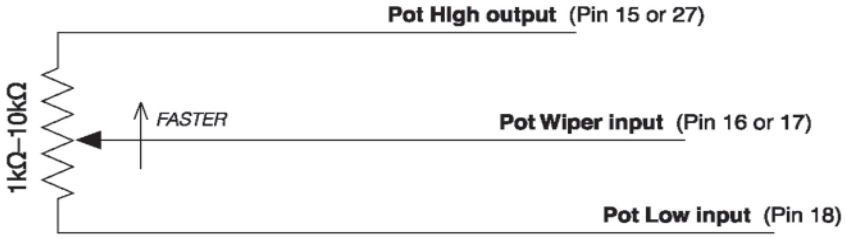
Ground-referenced 0–5V source



Current Source

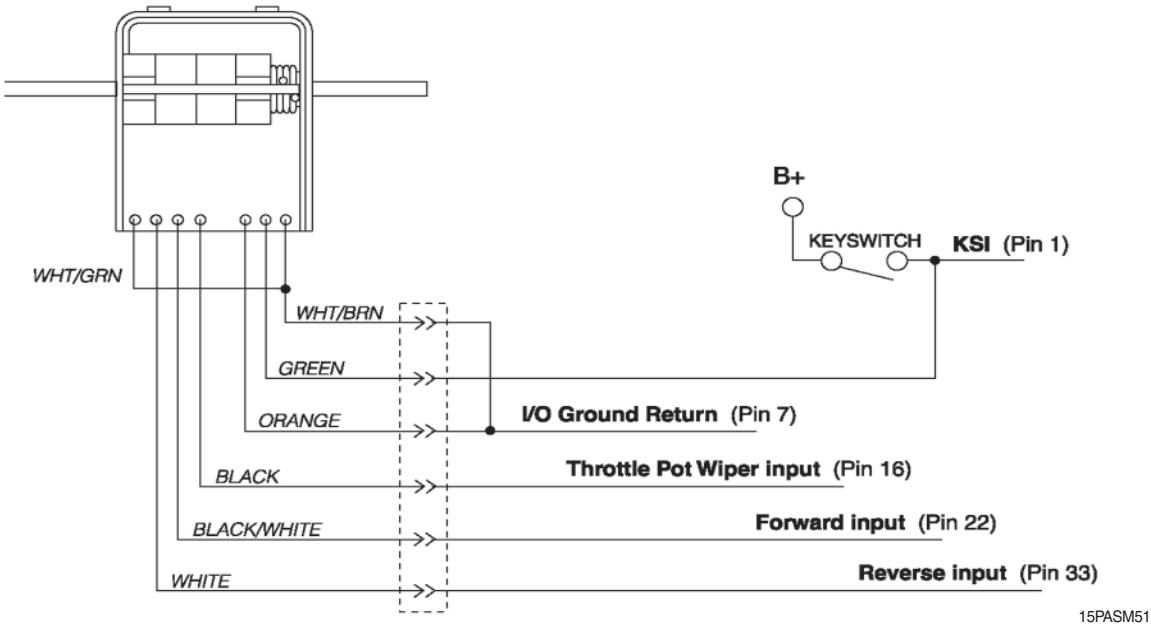


3-wire Potentiometer



NOTE: *Pins 15 and 16 are used together in the throttle pot; Pins 27 and 17 in the brake pot.*

Curtis ET-XXX Electronic Throttle



15PASM51

5) PROGRAMMABLE PARAMETERS

These controllers have a number of parameters that can be programmed using a 1311 handheld programmer. The programmable parameters allow the vehicle's performance to be customized to fit the needs of specific applications. For programmer operation, see appendix C.

PROGRAMMING MENUS

The programmable parameters are grouped into nested hierarchical menus, as shown in table 3.

Motor response tuning

Motor response characteristics can be tuned through speed control or through torque control, depending on the application. Use the control mode select parameter (page 6-37) to select which tuning mode you will use:

· Speed mode express

Speed mode express is a simplified version of speed mode with a reduced set of parameters that is adequate for most speed-controlled applications.
Use speed mode or speed mode express for applications where throttle input corresponds to motor speed output.
Use torque mode for applications where throttle input corresponds to motor torque output.

※ You can tune using torque control or speed control, but not both.
For example, if you adjust a torque control parameter while speed mode or speed mode express has been selected as your tuning mode, the programmer will show the new setting but it will have no effect.

※ We strongly urge you to contact Hyundai before adjusting any of the parameters!
Adjusting any of the parameters can only be set at the factory. The OEM can specify how these parameters are set, but they are programmable using the handheld programmed.

Table 3. Programmable parameter menus : 1311 programmer

CONTROL MODE SELECT ····· p. 6-37

0. SPEED MODE EXPRESS ····· p. 6-38
- Max speed
- Kp
- Ki
- Accel rate
- Decel rate
- Brake rate
- Pump enable

RESTRAINT MENU ····· p. 6-39
- Restraint forward
- Restraint back
- Soft stop speed
- **Position hold** ····· p. 6-39
  - · Position hold enable
  - · Kp
  - · Kp deadband (motor Deg)
  - · Kd
  - · Set speed settling time
  - · Set speed threshold
  - · Entry rate
  - · Exit rollback reduction

CURRENT LIMITS MENU ····· p. 6-40
- Drive current limit
- Regen current limit
- Brake current limit
- EMR current lmit
- Interlock brake current limit
- **Power limiting map** ····· p. 6-41
  - · PL nominal speed
  - · Delta speed
  - · **Drive limiting map** ····· p. 6-41
    - Nominal
    - Plus delta
    - Plus 2xdelta
    - Plus 4xdelta
    - Plus 8xdelta
  - · **Regen limiting map** ····· p. 6-42
    - Nominal
    - Plus delta
    - Plus 2xdelta
    - Plus 4xdelta
    - Plus 8xdelta

THROTTLE MENU ····· p. 6-43
- Throttle type
- Forward deadband
- Forward map
- Forward max
- Forward offset
- Reverse deadband
- Reverse map
- Reverse max
- Reverse offset
- HPD/SRO type
- Sequencing delay
- VCL throttle enable

BRAKE MENU ····· p. 6-46
- Brake pedal enable
- Brake type
- Brake deadband
- Brake map
- Brake max
- Brake offset
- VCL brake enable

Table 3. Programmable parameter menus : 1311 programmer, cont'd

DRIVERS MENU
- **Main contactor** ····· p. 6-47
  - · Main enable
  - · Pull In voltage
  - · Holding voltage
  - · Battery voltage comp
  - · Interlock type
  - · Open delay
  - · Checks enable
  - · Main DNC threshold
  - · Precharge enable
- **Hydraulic contactor** ····· p. 6-50
  - · Contactor enable
  - · Pull in voltage
  - · Holding voltage
- **Fault checking** ····· p. 6-50
  - · Driver 1 checks enable
  - · Driver 2 checks enable
  - · Driver 3 checks enable
  - · Driver 4 checks enable
  - · PD checks enable
  - · External supply max
  - · External supply min

MOTOR MENU ····· p. 6-50
- Typical max speed
- Swap encoder direction
- Swap two phases
- Encoder steps
- **Temperature control** ····· p. 6-51
  - · Sensor enable
  - · Sensor type
  - · Sensor offset
  - · Temperature hot
  - · Temperature max
  - · Motor temp LOS max speed

BATTERY MENU ····· p. 6-52
- Nominal voltage
- Under voltage cutback range
- User overvoltage
- User undervoltage
- Reset volts per cell
- Full volts per cell
- Empty volts per cell
- Discharge time
- BDI reset percent

VEHICLE MENU ····· p. 6-55
- Metric units
- Speed to RPM
- Capture speed 1
- Capture speed 2
- Capture distance 1
- Capture distance 2
- Capture distance 3

CONTROL MODE SELECT		
Parameter	Allowable range	Description
Control mode select	0-2	This parameter determines which control method will be in effect when programming motor response : 0 = Speed mode express 1 = Speed mode 2 = Torque mode Contact to Hyundai if you are interested in a custom control method. Do not change this parameter while the controller is powering the motor. Any time this parameter is changed a parameter change fault (fault code 49) is set and must be cleared by cycling power; this protects the controller and the operator.

⚠We use O (speed mode express) as the default value. Please don't change this setting to the other things.

※ Motor speed constraints

The maximum motor speed is a programmable parameter in each control mode.
Regardless of which control mode is used, the maximum motor speed the controller will allow is constrained by the number of motor poles, the number of encoder pulses per motor revolution, and the maximum speed constraint imposed by the firmware.

Electrical frequency constraint

The maximum electrical frequency the controller will output is 300 Hz.
To determine how fast this constraint will allow your motor to spin, use the equation

Max motor RPM = 36000 / number of motor poles
(e.g., a 6-pole motor can run up to 6000 rpm).

Encoder pulses / revolution constraint

The maximum encoder frequency the controller will accept is 10 kHz.
To determine how fast this constraint will allow your motor to spin, use the equation

Max motor RPM = 600000 / encoder size
(e.g., a motor with a 128-pulse encoder can run up to 4687 rpm).

※ Firmware max speed constraint

The maximum motor speed the controller will allow is 8000 rpm.

The overall maximum motor speed allowed is the least of these three constraints.

SPEED MODE EXPRESS MENU		
Parameter	Allowable range	Description
Max speed Max_speed_SpdMx	100–8000 rpm 100–8000	Defines the maximum requested motor rpm at full throttle. Partially applied throttle is scaled proportionately; e.g., 40% applied throttle corresponds to a request for 40% of the set max speed value. Note: The maximum motor rpm is subject to the constraints on page 6-37.
Kp Kp_SpdMx	0–100 % 0–8192	Determines how aggressively the speed controller attempts to match the speed of the motor to the commanded speed. Larger values ride tighter control. If the gain is set too high, you may experience oscillations as the controller tries to control speed. If it is set too low, the motor may behave sluggishly and be difficult to control.
Ki Ki_SpdMx	5–100 % 50–1000	The integral term (Ki) forces zero steady state error, so the motor will run at exactly the commanded speed. Larger values provide tighter control. If the gain is set too high, you may experience oscillations as the controller tries to control speed. If it is set too low, the motor may take a long time to approach the exact commanded speed.
Accel rate Accel_rate_SpdMx	0.1–30.0 sec 100–30000	Sets the rate (in seconds) at which the speed command increases when throttle is applied. Larger values represent slower response.
Decel rate Decel_rate_SpdMx	0.1–30.0 sec 100–30000	Sets the rate (in seconds) that is used to slow down the vehicle when the throttle is reduced. Larger values represent slower response.
Brake rate Brake_rate_SpdMx	0.1–30.0 sec 100–30000	Sets the rate (in seconds) at which the vehicle slows down when brake is applied or when throttle is applied in the opposite direction. Larger values represent slower response.
Pump enable AC_pump_enable_SpdM AC_pump_enable_SpdM_Bit0	ON/OFF ON/OFF	This parameter should be programmed ON to operate a pump motor rather than a vehicle drive motor. Speed controller responsiveness and stability are enhanced, and the motor is allowed to turn only in the forward direction.

RESTRAINT MENU		
Parameter	Allowable range	Description
Restraint forward Restraint_forward	0–100 % 0–32767	Increases torque when on a steep hill in order to limit roll-forward speed. Setting this parameter too high may cause oscillations in the motor as it attempts to limit the roll-forward speed.
Restraint back Restraint_back	0–100 % 0–32767	Increases torque when on a steep hill in order to limit roll-back speed. Setting this parameter too high may cause oscillations in the motor as it attempts to limit the roll-back speed.
Soft stop speed Soft_stop_speed	0–500 rpm 0–500	Defines the speed below which a much slower decel rate is used. A setting of zero disables the function. Note: This parameter works only in speed mode and speed mode express. Soft stop speed is useful for vehicles that have fast deceleration and vehicles operating on ramps using the position hold function. With vehicles that have fast deceleration, the driver may find the final speed reduction to zero rpm uncomfortable; the vehicle may even rock back as a result of tire wind-up. Soft stop speed allows the vehicle to slow at the same fast rate until it reaches the set threshold, at which point it changes to a slower (softer) deceleration rate. However, if the threshold is set too high, the vehicle will feel like it is “running on.” When throttle is released on a ramp, the vehicle may roll back before position hold (see below) takes control. Soft speed stop can be used to reduce the amount of rollback, but shouldn’t be set so high the vehicle drives up the ramp after the throttle is released.

POSITION HOLD MENU [SPEED MODE & SPEED MODE EXPRESS ONLY]		
Parameter	Allowable range	Description
Position hold enable Position_hold_enable Position_hold_enable_Bit0 [Bit 0]	ON/OFF ON/OFF	Allows the Position Hold mode to be entered at zero throttle when the vehicle comes to a stop. Note: EM brake type = 2 also enables the position hold function.
Kp Kp_position_hold	2–100 % 82–2048	Determines the stiffness with which position is regulated when in Position hold mode. High Kp will produce less rollback on a ramp, but more bouncing; see Kd below. Too much Kp will cause instability.
Kp deadband (motor degrees) Kp_deadband_position_hold	0–720 motor degrees 0–8192	Allows a position feedback deadband around the setpoint, to help avoid instability caused by gear slop.
Kd Kd_position_hold	0–100 % 0–8192	Determines the damping in position hold mode. Some damping must be present in the control system to keep the vehicle from oscillating slowly (“bouncing”). High Kd will improve the dynamic response of the position hold controller, but too much Kd will cause fast instability.
Set speed settling time **Set_speed_settling_time**	0–5000 rpm 0–156	This parameter appears twice in the menu structure.
Set speed threshold Set_speed_threshold	5–100 rpm 5–100	This parameter appears twice in the menu structure.

POSITION HOLD MENU, cont'd		
Parameter	Allowable range	Description
Entry rate Entry_rate_position_hold	5–100 % 50–1000	When the vehicle transitions from forward speed to reverse speed or from reverse speed to forward speed (for example, when coming to a stop going up a steep ramp), position hold is automatically entered immediately at zero speed—regardless of this parameter. This parameter applies when the vehicle needs to be brought to a stop without the assistance of gravity (for example, when moving forward down a ramp). This rate determines how quickly zero speed is attained after the ramped speed request reaches zero. Setting this parameter too high will make the stop seem very abrupt, and may even cause the vehicle to roll back slightly. When the parameter is set lower, the vehicle take longer to come to a stop and enter position hold mode.
Exit rollback reduction Exit_rollback_reduction	0–100 % 0–2048	This function is applicable only when the torque preload function has been disabled or its timer has expired. It introduces a proportional feedforward term into the speed controller based on the position signal. For example, suppose the vehicle is on a ramp and a forward throttle request is given such that the vehicle rolls back slightly before climbing the ramp (again, assuming the torque preload function is inactive). As the vehicle rolls back a feedforward torque term proportional to the rollback position will be added to the torque request until forward speed is sensed.

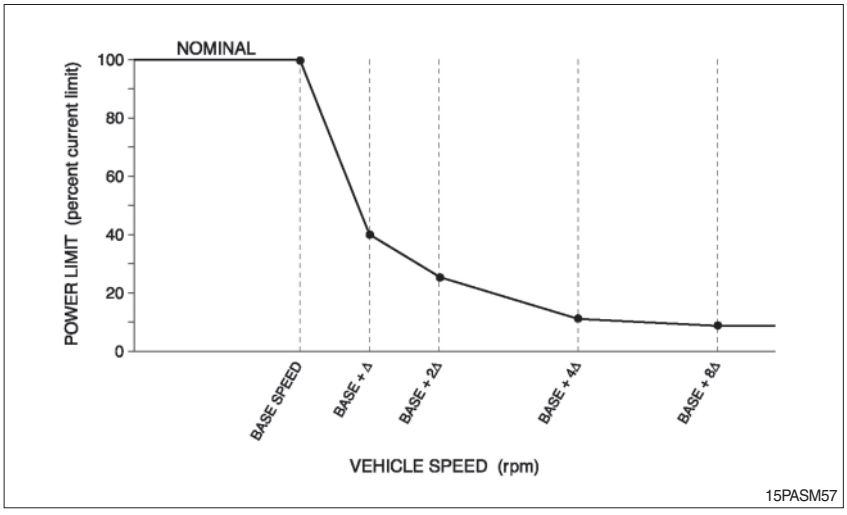
CURRENT LIMITS MENU		
Parameter	Allowable range	Description
Drive current limit Drive_current_lmit	5–100 % 1638–32767	Sets the maximum RMS current the controller will supply to the motor during drive operation, as a percentage of the controller's full rated current.* Reducing this value will reduce the maximum drive torque.
Regen current limit Regen_current_limit	5–100 % 1638–32767	Sets the maximum RMS regen current, as a percentage of the controller's full rated current.* The regen current limit applies during neutral braking, direction reversal braking, and speed limiting when traveling downhill.
Brake current limit Brake_current_limit	5–100 % 1638–32767	Sets the maximum RMS regen current during braking when a brake command is given, as a percentage of the controller's full rated current.* Typically the brake current limit is set equal to the regen current limit. The brake current limit overrides the regen current limit when the brake input is active.
EMR current limit EMR_current_limit	5–100 % 1638–32767	Sets the maximum RMS current allowed for braking and drive when in emergency reverse. The emergency reverse current limit is a percentage of the controller's full rated current.*
Interlock brake current limit Interlock_brake_current_limit	5–100 % 1638–32767	Sets the maximum RMS regen current during interlock braking, as a percentage of the controller's full rated current.*

* The full rated current depends on the controller model.

POWER LIMITING MAP MENU		
Parameter	Allowable range	Description
Nominal speed PL_nominal_speed	100–4000 rpm 100–4000	Sets the base speed that will be used in the drive limiting map and regen limiting map.
Delta speed PL_delta_speed	50–1000 rpm 50–1000	Sets the width of the delta increment that will be used in the drive limiting map and regen limiting map.

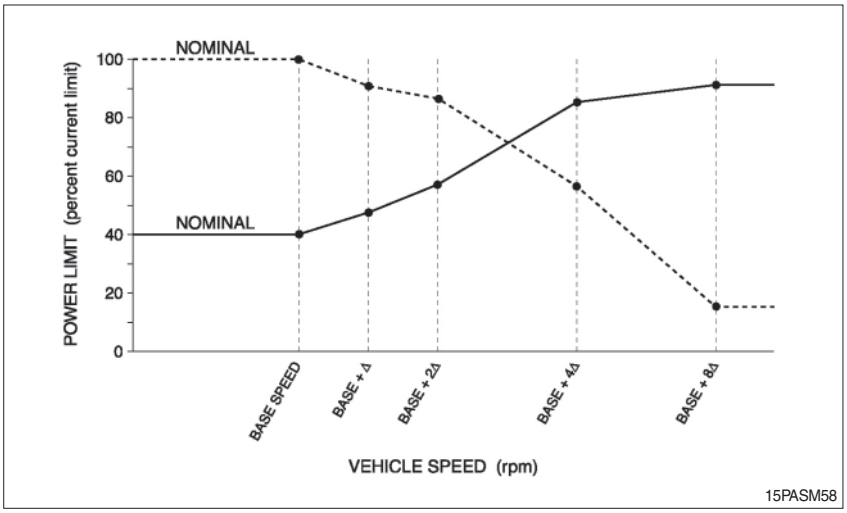
DRIVE LIMITING MAP MENU		
Parameter	Allowable range	Description
Nominal PL_drive_nominal	0–100 % 0–32767	These parameters define the percentage of drive current limit that will be applied at the speeds defined by the base speed and delta speed parameters. The resulting map allows the controller to reduce the drive current as a function of speed. Reducing the power requirements at certain speeds restricts performance. This can be useful for reducing motor heating. It can also be used to keep consistent vehicle power with changing battery state-of-charge.
Plus delta PL_drive_nominal_plus_delta	0–100 % 0–32767	
Plus 2x delta PL_drive_nominal_plus_2x delta	0–100 % 0–32767	
Plus 4x delta PL_drive_nominal_plus_4x delta	0–100 % 0–32767	
Plus 8x delta PL_drive_nominal_plus_8x delta	0–100 % 0–32767	

Drive current limiting map (typical example).



REGEN LIMITING MAP MENU		
Parameter	Allowable range	Description
Nominal PL_regen_nominal	0–100 % 0–32767	These parameters define the percentage of regen current limit that will be applied at the speeds defined by the base speed and delta speed parameters. The curve can be shaped to limit the available torque at various speeds. One possible use is to compensate for the torque-speed characteristic of the motor.
Plus delta PL_regen_nominal_plus_delta	0–100 % 0–32767	
Plus 2x delta PL_regen_nominal_plus_2x delta	0–100 % 0–32767	
Plus 4x delta PL_regen_nominal_plus_4x delta	0–100 % 0–32767	
Plus 8x delta PL_regen_nominal_plus_8x delta	0–100 % 0–32767	

Regen current limiting map (two examples).



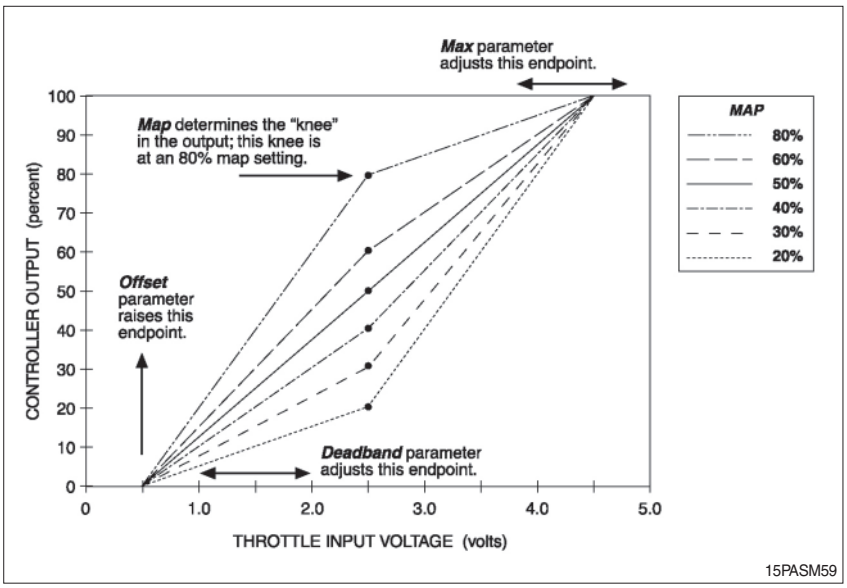
THROTTLE MENU		
Parameter	Allowable range	Description
Throttle type Throttle_type	1–5 1–5	The 1234 controllers accept a variety of throttle inputs. The throttle type parameter can be programmed as follows: 1 2-wire rheostat, 5kΩ–0 input 2 Single-ended 3-wire 1kΩ–10kΩ potentiometer, or 0–5V voltage source 3 2-wire rheostat, 0–5kΩ input 4 Wigwag 3-wire 1kΩ–10kΩ potentiometer, or 0–5V voltage source 5 VCL input (VCL_throttle) Note: Do not change this parameter while the controller is powering the motor. Any time this parameter is changed a parameter change fault (fault code 49) is set and must be cleared by cycling power; this protects the controller and the operator.
Forward deadband Forward_deadband	0–5.00 V 0–32767	Defines the wiper voltage at the throttle deadband threshold. Increasing the throttle deadband setting will increase the neutral range. This parameter is especially useful with throttle assemblies that do not reliably return to a well-defined neutral point, because it allows the deadband to be defined wide enough to ensure that the controller goes into neutral when the throttle mechanism is released.
Forward map Forward_map	0–100 % 0–32767	Modifies the vehicle's response to the throttle input. Setting the throttle map at 50% provides a linear output response to throttle position. Values below 50% reduce the controller output at low throttle settings, providing enhanced slow speed maneuverability. Values above 50% give the vehicle a faster, more responsive feel at low throttle settings. The map value is the percentage of controller output at half throttle ((deadband + max)/2).
Forward max Forward_max	0–5.00 V 0–32767	Defines the wiper voltage required to produce 100% controller output. Decreasing the throttle max setting reduces the wiper voltage and therefore the full stroke necessary to produce full controller output. This parameter allows reduced-range throttle assemblies to be accommodated.
Forward offset Forward_offset	0–100 % 0–32767	Defines the initial controller output generated when the throttle is first rotated out of the neutral deadband. For most vehicles, a setting of 0 is appropriate. For heavy vehicles, however, increasing the offset may improve controllability by reducing the amount of throttle required to start the vehicle moving.

※ All four throttle adjustment parameters — deadband, map, max, offset — condition the raw throttle voltage into a single % throttle command as shown in figure on page 6-44.

THROTTLE MENU, cont'd		
Parameter	Allowable range	Description
Reverse deadband Reverse_deadband	0–5.00 V 0–32767	The four throttle reverse parameters are the same as their throttle forward counterparts, and apply when the throttle direction is reversed.
Reverse map Reverse_map	0–100 % 0–32767	
Reverse max Reverse_max	0–5.00 V 0–32767	
Reverse offset Reverse_offset	0–100 % 0–32767	

Effect of throttle adjustment parameters.
Together these four generic parameters determine the controller's response to throttle demand (in forward or reverse) and to brake demand.

In the examples shown in this figure,
Deadband = 0.5V
Max = 4.5V
Offset = 0.



THROTTLE MENU, cont'd		
Parameter	Allowable range	Description
HPD/SRO type HPD_SRO_type OptionBits1 [Bit 4]	0–3 0–3	Determines whether the HPD/SRO feature will be active. One type of checks is available for material-handling vehicles, and two types for golf-style vehicles. If any of the HPD/SRO checks finds an input sequencing problem, an HPD/Sequencing fault (flash code 47) is set. - HPD/SRO feature is disabled. - HPD/SRO checks enabled for material-handling vehicle. At KSI on, a one-time check of the inputs is made to verify that the following inputs have been activated in the proper order: KSI first, then interlock before either direction input or a throttle input >25%. Continuous check every time the interlock turns OFF and the sequencing delay time has expired (the sequencing delay timer starts counting down when interlock switches off); a check is made the next time interlock is applied to verify that interlock was applied before either direction input or a throttle input >25%. - HPD/SRO checks enabled for golf-style vehicle. At KSI on, a one-time check is made to verify the throttle input <25%. Continuous check when the vehicle is stationary (bit variable park_state_speed_control = on means stationary) to verify the interlock and a direction switch were applied before throttle input >25%. The order of the interlock and direction switch does not matter. Once moving (park_state_speed_control = OFF), directional switching (forward to reverse, or reverse to forward) is allowed with throttle input >25%; i.e., no fault results. - HPD/SRO checks enabled for golf-style vehicle. At KSI on, a one-time check is made to verify the throttle input <25%. Continuous check to verify the interlock and a direction switch were applied before throttle input >25%. The order of the interlock and direction switch does not matter. Type 3 differs from type 2 in that it only checks this condition when the vehicle is stationary. With type 3 the interlock and a direction switch must always precede the throttle input regardless of vehicle speed.
Sequencing delay Sequencing_delay	0.0–5.0 sec 0–312	Typically the sequencing delay feature allows the interlock switch to be cycled within a set time (the defined sequencing delay), thus preventing inadvertent activation of HPD/SRO. This feature is especially useful in applications where the interlock switch may bounce or be momentarily cycled during operation.
VCL throttle enable VCL_throttle_enable VCL_throttle_enable_Bit0 [Bit 0]	ON/OFF ON/OFF	When programmed ON, the throttle processing with fault detection will operate normally;

BRAKE MENU		
Parameter	Allowable range	Description
Brake pedal enable Brake_pedal_enable OptionBits1 [Bit 3]	ON/OFF ON/OFF	Determines whether the brake input and algorithm are enabled, making the brake throttle part of the motor control command.
Brake type Brake_type	1–5 1–5	The 1234 controllers accept a variety of brake inputs. The brake type parameter can be programmed as follows: - VCL input (VCL_brake) Note: Do not change this parameter while the controller is powering the motor. Any time this parameter is changed a parameter change fault (fault code 49) is set and must be cleared by cycling power; this protects the controller and the operator.
Brake deadband Brake_deadband	0–5.00 V 0–32767	The four brake throttle adjustment parameters are the same as their drive throttle counterparts; see descriptions and figure on page 6-44.
Brake map Brake_map	0–100 % 0–32767	
Brake max Brake_max	0–5.00 V 0–32767	
Brake offset Brake_offset	0–100 % 0–32767	
VCL brake enable VCL_brake_enable VCL_brake_enable_Bit0 [Bit 0]	ON/OFF ON/OFF	When programmed ON, the brake processing with fault detection will operate normally; however, the brake command (see figure 14) will require VCL to define the connection between the OS_brake and VCL_brake variables. This allows VCL flexibility and customization of throttle processing, while still allowing brake_type 1–3 with brake fault detection.

MAIN CONTACTOR MENU		
Parameter	Allowable range	Description
Main enable Main_enable OptionBits1 [Bit 0]	ON/OFF ON/OFF	When programmed On, the controller's native software controls the main contactor when the interlock is enabled; when programmed Off, the contactor is controlled by VCL. Note: With Main Enable programmed Off, the controller will not be able to open the main contactor in serious fault conditions and the system will therefore not meet EEC safety requirements.
Pull In voltage Main_pull_in_voltage	0–100 % 0–32767	The main contactor pull-in voltage parameter allows a high initial voltage when the main contactor driver first turns on, to ensure contactor closure. After 1 second, this peak voltage drops to the contactor holding voltage. Note: The Battery Voltage Compensated parameter (below) controls whether the pull-in and holding voltages are battery voltage compensated.
Holding voltage Main_holding_voltage	0–100 % 0–32767	The main contactor holding voltage parameter allows a reduced average voltage to be applied to the contactor coil once it has closed. This parameter must be set high enough to hold the contactor closed under all shock and vibration conditions the vehicle will be subjected to. Note: The Battery Voltage Compensated parameter (below) controls whether the pull-in and holding voltages are battery voltage compensated.
Battery voltage compensated Main_driver_battery_voltage_compensated Main_driver_battery_voltage_compensated_Bit0 [Bit 0]	ON/OFF ON/OFF	This parameter determines whether the main pull-in and holding voltages are battery voltage compensated. When set On, the pull-in and holding voltages are set relative to the set Nominal Voltage (see battery menu, page 6-52). In other words, the output voltage is adjusted to compensate for swings in battery voltage, so the percentage is relative to the set nominal voltage—not to the actual voltage. For example, suppose Nominal Voltage is set to 48V and Holding Voltage is set to 75% (36V) to the output driver. Now suppose the bus voltage dips to 40V. If battery voltage compensated = On, the output will still be 36V (nominal voltage × holding voltage) to the coil. If battery voltage compensated = Off, the output will be 30V (actual voltage × holding voltage) to the coil.
Interlock type Interlock_type	0-2 0-2	Three interlock options are available: 0 = interlock turns on with switch 3. 1 = interlock controlled by VCL functions. 2 = interlock turns on with KSI.
Open delay Open_delay	0-40 sec 0–2500	Applicable only when Interlock type = 0 or 1. The delay can be set to allow the contactor to remain closed for a period of time (the delay) after the interlock switch is opened. The delay is useful for preventing unnecessary cycling of the contactor and for maintaining power to auxiliary functions that may be used for a short time after the interlock switch has opened.
Checks enable Checks_enable OptionBits1 [Bit 2]	ON/OFF ON/OFF	When programmed On, the controller performs ongoing checks to ensure that the main contactor has closed properly each time it is commanded to do so, and that it has not welded closed. These checks (main contactor welded and main contactor did not close) are not performed if this parameter is Off. The main contactor driver, however, is always protected from short circuits.

MAIN CONTACTOR MENU, cont'd		
Parameter	Allowable range	Description
Main DNC threshold Main_DNC_threshold	0–84.0 V 0–5376	When checks enable = On, this parameter is used as the threshold for detecting a main did not close fault. The main DNC threshold is the minimum voltage difference between the keyswitch and capacitor voltages. When the voltage difference is below this threshold, and the battery current is low, a main did not close fault will be set. Setting this parameter lower will increase the sensitivity of the fault detect. Setting this parameter too low may cause false fault trips due to normal voltage drops between the keyswitch and capacitor voltages. Setting this parameter = 0 V will disable the main did not close fault check.
Precharge enable Precharge_enable OptionBits2 [Bit 6]	ON/OFF ON/OFF	Turns the precharge feature on and off. Precharge provides a limited current charge of the controller's internal capacitor bank before the main contactor is closed. This decreases the arcing that would otherwise occur when the contactor is closed with the capacitor bank discharged.

HYDRAULIC CONTACTOR MENU		
Parameter	Allowable range	Description
Contactor enable Hydraulic_contactor_enable OptionBits4 [Bit 1]	ON/OFF ON/OFF	When programmed On, VCL functions control driver 3 as the hydraulic pump contactor. On: The VCL function start_pump() will close the pump contactor according to the defined pull-in and holding voltages. The VCL function stop_pump() will open the pump contactor. Off: Driver 3 will be available for general VCL usage. Start_pump() and stop_pump() will not have any effect.
Pull in voltage Hydraulic_pull_in_voltage	0–100 % 0–32767	The hydraulic contactor pull-in voltage parameter allows a high initial voltage when the hydraulic contactor driver first turns on, to ensure contactor closure. After 1 second, this peak voltage drops to the contactor holding voltage. Note: This voltage will be battery voltage compensated.
Holding voltage Hydraulic_holding_voltage	0–100 % 0–32767	The hydraulic contactor holding voltage parameter allows a reduced average voltage to be applied to the contactor coil once it has closed. This parameter must be set high enough to hold the contactor closed under all shock and vibration conditions the vehicle will be subjected to. Note: This voltage will be battery voltage compensated.

FAULT CHECKING MENU		
Parameter	Allowable range	Description
Driver1 checks enable Driver1_checks_cnable OptionBits2 [Bit 1]	ON/OFF ON/OFF	The five checks enable parameters are used to enable driver and coil fault detection at the five individual drivers (at pins J1-6, J1-5, J1-4, J1-3, and J1-2). When a checks parameter is enabled, the associated driver, driver wiring, and driver load are checked to verify that the driver correctly drives the load both high and low. The checks will occur regardless of the PWM output of the driver. The checks will detect both open and shorted conditions. When a fault is detected, the controller opens the driver and issues a fault code. If nothing is connected to a driver, its checks enable parameter should be set Off. Note: Short circuit protection is always active at these five drivers, regardless of how checks enable is set.
Driver2 checks enable Driver2_checks_enable OptionBits2 [Bit 2]	ON/OFF ON/OFF	
Driver3 checks enable Driver3_checks_enable OptionBits2 [Bit 3]	ON/OFF ON/OFF	
Driver4 checks enable Driver4_checks_enable OptionBits2 [Bit 4]	ON/OFF ON/OFF	
PD checks enable PD_checks_enable OptionBits2 [Bit 5]	ON/OFF ON/OFF	
External supply max External_supply_max	5–200 mA 52–800	Sets the upper threshold of the combined current of the 5V and 12V external supplies. At or above this threshold a fault will be created that can be read by VCL.
External supply min External_supply_min	5–200 mA 52–800	Sets the lower threshold of the combined current of the 5V and 12V external supplies. At or below this threshold a fault will be created that can be read by VCL.

MOTOR MENU		
Parameter	Allowable range	Description
Typical max speed Typical_max_speed	500–8000 rpm 500–8000	Set this parameter to the typical maximum motor speed of the vehicle. This value does not need to be set precisely; an estimate will do. All of the vehicle response rates are normalized to typical max Speed. For example, suppose typical_max_speed is fixed at 6000 rpm, and full_accel_rate_LS_SpdM = 3.0 seconds: If max_speed_SpdM = 6000 rpm, it will take 3.0 sec to accelerate from zero to top speed (6000 rpm). If max_speed_SpdM = 3000 rpm, it will take 1.5 sec to accelerate from zero to top speed (3000 rpm). If max_speed_SpdM = 1000 rpm, it will take 0.5 sec to accelerate from zero to top speed (1000 rpm).
Swap encoder direction Swap_encoder_direction OptionBits3 [Bit 0]	ON/OFF ON/OFF	Changes the motor encoder's effective direction of rotation. The encoder provides data used to calculate motor position and speed. This parameter must be set such that when the motor is turning forward, the controller reports back a positive motor speed. Positive motor speed must be in the forward direction in order for the emergency reverse feature to operate properly. Note: Do not change this parameter while the controller is powering the motor. Any time this parameter is changed a parameter change fault (fault code 49) is set and must be cleared by cycling power; this protects the controller and the operator.
Swap two phases Swap_two_phases OptionBits3 [Bit 3]	ON/OFF ON/OFF	If, after swap encoder direction has been set correctly, the vehicle drives in the wrong direction (i.e., drives forward when in reverse, and vice versa), try changing the setting of the swap two phases parameter. This parameter has the same effect as physically swapping the cables on any two of the three motor phase connections. Positive motor speed must be in the forward direction in order for the emergency reverse feature to operate properly. Note: Do not change this parameter while the controller is powering the motor. Any time this parameter is changed a parameter change fault (fault code 49) is set and must be cleared by cycling power; this protects the controller and the operator.
Encoder steps Encoder_steps	32–256 32–256	Sets the number of encoder pulses per revolution. This must be set to match the encoder; see motor nameplate. Note: Do not change this parameter while the controller is powering the motor. Any time this parameter is changed a parameter change fault (fault code 49) is set and must be cleared by cycling power; this protects the controller and the operator.

MOTOR TEMPERATURE CONTROL MENU		
Parameter	Allowable range	Description
Sensor enable Motor temp_sensor_enable OptionBits3 [Bit 1]	ON/OFF ON/OFF	When programmed On, the motor temperature cutback and the motor temperature compensation features are enabled. This parameter can be used only if a temperature sensor has been properly configured. The motor temperature cutback feature will linearly cutback the drive current from 100% to 0% between the temperature hot and temperature max temperatures. The motor temperature compensation feature will adapt the motor control algorithms to varying motor temperatures, for improved efficiency and more consistant performance.
Sensor type Motor temp_sensor_type	1–5 1–5	Five sensor types are predefined in the software:. Type 1 KTY83–122 Type 2 2× Type 1, in series Type 3 KTY84–130 or KTY84–150 Type 4 2× Type 3, in series Type 5 PT1000. Custom sensor types can be set up easily, if none of the five predefined types is appropriate for your application. Please contact Hyundai engineer. Note: The industry standard KTY temperature sensors are silicon temperature sensors with a polarity band; the polarity band of a KTY sensor must be the end connected to I/O ground (pin 7).
Sensor temp offset Motor temp_sensor_offset	-20 – 20˚C -200–200	Often the sensor is placed in the motor at a location with a known offset to the critical temperature; the offset can be corrected with this parameter. The parameter can also be used to correct a known offset in the sensor itself.
Temperature hot Motor temp_hot	0-250˚C 0-2500	Defines the temperature at which drive current cutback begins.
Temperature max **Motor temp_max**	0-250˚C 0-2500	Defines the temperature at which drive current is cut back to zero.
Motor temp LOS max speed Motor temp_LOS_max_speed	100–3000 rpm 100–3000	When a motor temp sensor fault (fault code 29) is set, a LOS (Limited Operating Strategy) mode is engaged. The maximum speed is reduced to the programmed max speed in the operating mode (max_speed_SpdMx, max_speed_SpdM, max_speed_TrqM) or to the motor temp_LOS_max_speed, whichever is lower.

<table>
<tr><th colspan="3">BATTERY MENU</th></tr>
<tr><th>Parameter</th><th>Allowable range</th><th>Description</th></tr>
<tr><td>Nominal voltage
Nominal_voltage</td><td>24–84 V
1536–5376</td><td>Must be set to the vehicle's nominal battery pack voltage. This parameter is used in determining the overvoltage and undervoltage protection thresholds for the electronic system.
Overvoltage protection cuts back regen braking to prevent damage to batteries and other electrical system components due to overvoltage.
Undervoltage protection prevents systems from operating at voltages below their design thresholds.
The four threshold points are calculated from the nominal voltage, undervoltage cutback range, user overvoltage, and user undervoltage parameter settings and the controller's minimum voltage and maximum voltage ratings:
<table><tr><th colspan="4">Voltage ratings</th></tr><tr><th>Controller</th><th>Brown voltage *</th><th>Min voltage</th><th>Max voltage</th></tr><tr><td>24 V</td><td>15 V</td><td>16.8 V</td><td>30 V</td></tr><tr><td>24–36 V</td><td>15 V</td><td>16.8 V</td><td>45 V</td></tr><tr><td>36–48 V</td><td>20 V</td><td>25.2 V</td><td>60 V</td></tr><tr><td>48–80 V</td><td>20 V</td><td>33.6 V</td><td>105 V</td></tr><tr><td>80–108 V</td><td>30 V</td><td>50.4 V</td><td>130 V</td></tr></table>Overvoltage = either max voltage (see voltage ratings table) or user overvoltage × nominal voltage, whichever is lower.
Severe overvoltage = overvoltage (see previous item) + 10V.
Undervoltage = either min voltage (see voltage ratings table) or user undervoltage × nominal voltage, whichever is higher.
Severe undervoltage = undervoltage point – undervoltage cutback range.
* The brownout Voltage is determined by the controller base type and cannot be changed. When the capacitor voltage falls below the brownout voltage the bridge is switched off (i.e., motor current is switched off). If the capacitor voltage stays below the brownout voltage for > 64 msec the controller will reset (equivalent to cycling the keyswitch). If the capacitor voltage rises above the brownout voltage before 64 msec have passed the bridge will be reenabled.
The severe undervoltage point can be set lower than the brownout voltage.</td></tr>
<tr><td>Undervoltage cutback range
Undervoltage_cutback_range</td><td>2.0–14.0 V
0–4096</td><td>This parameter sets the voltage range between the undervoltage and severe undervoltage points (see nominal voltage description). A severe undervoltage fault will be set if the capacitor voltage falls below either the severe undervoltage point (drive current limit set to 0) or the brownout voltage (bridge disabled, motor current set to 0).</td></tr>
<tr><td>User overvoltage
User_overvoltage</td><td>115–200 %
293–512</td><td>The value of this parameter is a percentage of the Nominal Voltage setting.
The user overvoltage parameter can be used to adjust the overvoltage threshold, which is the voltage at which the controller will cut back regen braking to prevent damage to the electrical system. Typically this parameter is changed only when the controller is being used in an application at the low end of the controller's range: such as a 48–80V controller being used in a system with a 48V battery pack. In this case, the overvoltage threshold can be raised by setting the user overvoltage to a higher value. The overvoltage threshold can never be raised above the controller's power base maximum voltage rating.</td></tr>
</table>

BATTERY MENU, cont'd		
Parameter	Allowable range	Description
User undervoltage User_undervoltage	50–80 % 128–204	The value of this parameter is a percentage of the nominal voltage setting. The user undervoltage parameter can be used to adjust the undervoltage threshold, which is the voltage at which the controller will cut back drive current to prevent damage to the electrical system. Typically this parameter is changed only when the controller is being used in an application at the high end of the controller's range: such as a 24–36V controller being used in a system with a 36V battery pack. In this case, the undervoltage threshold can be lowered by setting the user undervoltage to a lower value. The undervoltage threshold can never be lowered below the controller's power base minimum voltage rating.

BDI Algorithm

The BDI (battery discharge indicator) algorithm continuously calculates the battery state-of-charge whenever KSI is on. The result of the BDI algorithm is the variable BDI percentage, which is viewable in the 1311 menu monitor » battery. When KSI is turned off, the present BDI percentage is stored in nonvolatile memory.
The standard values for volts per cell are as follows, for flooded lead acid and sealed maintenance-free batteries.

	Battery type	
	Flooded	Sealed
Reset volts per cell	2.09	2.09
Full volts per cell	2.04	2.04
Empty volts per cell	1.73	1.90

Use the standard values for your type of batteries as the starting point in setting the reset, full, and empty volts-per-cell parameters.

BATTERY MENU, cont'd		
Parameter	Allowable range	Description
Reset volts per cell BDI_reset_volts_per_cell	0.90–3.00 V 900–3000	The reset voltage level is checked only once, when KSI is first turned on. Note that the BDI reset percent parameter also influences the algorithm that determines whether BDI percentage is reset to 100%. Reset volts per cell should always be set higher than full volts per cell. Reset voltage level = reset volts per cell × number of cells in the battery pack.*
Full volts per cell BDI_full_volts_per_cell	0.90–3.00 V 900–3000	The full voltage level sets the keyswitch Voltage that is considered to be 100% state-of-charge; when a loaded battery drops below this voltage, it begins to lose charge. Keyswitch voltage is viewable in the 1311 menu monitor » battery. Full voltage level = full volts per cell × number of cells in the battery pack.*
Empty volts per cell BDI_empty_volts_per_cell	0.90–3.00 V 900–3000	The empty voltage level sets the keyswitch_voltage that is considered to be 0% state-of-charge. Empty voltage level = empty volts per cell × number of cells in the battery pack.*
Discharge time BDI_discharge_time	0–600 min 0–600	Sets the minimum time for the BDI algorithm to count down the BDI percentage from 100% to 0%. The BDI algorithm integrates the time the filtered keyswitch voltage is below the state of charge voltage level. When that cumulative time exceeds the discharge Time / 100, the BDI percentage is decremented by one percentage point and a new state of charge voltage level is calculated. State of charge level = ((full voltage level - empty voltage level) × BDI percentage / 100) + empty voltage level.
BDI reset percent BDI_reset_percent	0–100 % 0–100	When a battery has a high BDI percentage, its float voltage at KSI on can sometimes cause false resets. The BDI reset percent parameter addresses this problem by allowing the user to define a BDI percentage value above which the BDI percentage variable will not reset. When KSI is first powered on, the BDI percentage variable will reset to 100% only if ((keyswitch voltage > reset voltage level) and (BDI percentage < BDI reset percent)).

* To determine the number of cells in your battery pack, divide your nominal voltage setting (page 6-52) by 2.

VEHICLE MENU		
Parameter	Allowable range	Description
Metric units Metric_units OptionBits3 [Bit 5]	ON/OFF ON/OFF	When this parameter is programmed On, the distance variables (vehicle odometer, braking distance captured, distance since stop, distance fine, and the capture distance variables) will accumulate and display in metric units (km, meters, or decimeters). When programmed Off, the distance variables will accumulate and display in english units (miles, feet, or inches). Distance variables are displayed in the monitor » vehicle menu, page 6-63.
Speed to RPM Speed_to_RPM	10.0–3000.0 100–30000	This parameter affects the vehicle speed displayed in the monitor » motor menu (see page 68), and also modifies the VCL variable vehicle_speed; it does not affect actual vehicle performance. The value entered for speed to RPM is a conversion factor that scales motor speed to vehicle speed. KPH to RPM : (G/d)*53.05, where G = gear ratio, d = tire diameter [cm]. MPH to RPM : (G/d)*33.61, where G = gear ratio, d = tire diameter [in].
Capture speed 1 Capture_speed_1	0–8000 rpm 0–8000	The controller captures the time it takes the motor to go from 0 rpm to the programmed capture speed. The result is stored as “Time to speed 1” in the monitor » vehicle menu (page 6-63). This timer starts every time the motor accelerates from zero speed.
Capture speed 2 Capture_speed_2	0–8000 rpm 0–8000	This parameter allows a second capture speed to be defined, and works identically to capture speed 1. The result is stored as “Time to speed 2” in the monitor » vehicle menu (page 6-63).
Capture distance 1 Capture_distance_1	1–1320 1–1320	The controller captures the time it takes the vehicle to travel from 0 rpm to the programmed capture distance. The result is stored as “Time to Dist 1” in the monitor » vehicle menu (page 6-63). This timer starts every time the vehicle accelerates from zero speed. Note: For accurate distance measuring, the speed to RPM parameter must be set correctly. With the metric units parameter programmed Off, distance is in units of feet. With metric units programmed On, distance is in units of meters.
Capture distance 2 Capture_distance_2	1–1320 1–1320	This parameter allows a second capture distance to be defined, and works identically to capture distance 1. The result is stored as “Time to Dist 2” in the monitor » vehicle menu.
Capture distance 3 Capture_distance_3	1–1320 1–1320	This parameter allows a third capture distance to be defined, and works identically to capture distance 1. The result is stored as “Time to Dist 3” in the monitor » vehicle menu.

6) MONITOR MENU

Through its monitor menu, the 1311 programmer provides access to real-time data during vehicle operation.
This information is helpful during diagnostics and troubleshooting, and also while adjusting programmable parameters.

MONITOR MENU

MONITOR MENU: INPUTS		
Variable	Display range	Description
Throttle command Throttle_command	-100–100 % -32768–32767	Throttle request to slew rate block.
Mapped throttle Mapped_throttle	-100–100 % -32768–32767	Mapped throttle request.
Throttle pot Throttle_pot_raw	0–5.5 V 0–36044	Voltage at throttle pot wiper (pin 16).
Brake command Brake_command	0–100 % 0–32767	Brake request to slew rate block.
Mapped brake Mapped_brake	0–100 % 0–32767	Mapped brake request.
Pot2 raw Pot2_raw	0–5.5 V 0–36044	Voltage at pot2 wiper (pin 17).
PD throttle PD_throttle	0–100 % 0–32767	Proportional driver current request.
Steer pot Steer_pot_raw	0–5.5 V 0–36044	Voltage at steer pot wiper (pin 17) on dual drive traction slave.
Steer angle Steer_angle	-90 – 90 deg -90 – 90	Steer angle calculated in dual drive traction master.
Interlock Interlock_state System_flags1 [Bit 0]	ON/OFF ON/OFF	Interlock input ON or OFF. The source of the interlock input is determined by the Interlock type parameter : from switch 3 (pin 9) if Interlock type = 0 from VCL function if Interlock type = 1 from KSI (pin 1) if Interlock type = 2.

MONITOR MENU : INPUTS		
Variable	Display range	Description
Emer Rev EMR_state System_Flags1 [Bit 1]	ON/OFF ON/OFF	Emergency reverse input ON or OFF. The source of the emergency reverse input is determined by the EMR type parameter: from switch 1 (pin 24) if EMR type = 0 from VCL function if EMR type = 1.
Analog 1 Analog 1_input	0–10.0 V 0–1023	Voltage at analog 1 (pin 24).
Analog 2 Analog 2_input	0–10.0 V 0–1023	Voltage at analog 2 (pin 8).
Switch 1 Sw_1 Switches [Bit 0]	ON/OFF ON/OFF	Switch 1 ON or OFF (pin 24).
Switch 2 Sw_2 Switches [Bit 1]	ON/OFF ON/OFF	Switch 2 ON or OFF (pin 8).
Switch 3 Sw_3 Switches [Bit 2]	ON/OFF ON/OFF	Switch 3 ON or OFF (pin 9).
Switch 4 Sw_4 Switches [Bit 3]	ON/OFF ON/OFF	Switch 4 ON or OFF (pin 10).
Switch 5 Sw_5 Switches [Bit 4]	ON/OFF ON/OFF	Switch 5 ON or OFF (pin 11).
Switch 6 Sw_6 Switches [Bit 5]	ON/OFF ON/OFF	Switch 6 ON or OFF (pin 12).
Switch 7 Sw_7 Switches [Bit 6]	ON/OFF ON/OFF	Switch 7 ON or OFF (pin 22).
Switch 8 Sw_8 Switches [Bit 7]	ON/OFF ON/OFF	Switch 8 ON or OFF (pin 33).
Driver 1 input Sw_9 Switches [Bit 8]	ON/OFF ON/OFF	Driver 1 input ON or OFF (pin 6).
Driver 2 input Sw_10 Switches [Bit 9]	ON/OFF ON/OFF	Driver 2 input ON or OFF (pin 5).

MONITOR MENU : INPUTS, cont'd		
Variable	Display range	Description
Driver 3 input Sw_11 Switches [Bit 10]	ON/OFF ON/OFF	Driver 3 input ON or OFF (pin 4).
Driver 4 input Sw_12 Switches [Bit 11]	ON/OFF ON/OFF	Driver 4 input ON or OFF (pin 3).
PD input Sw_13 Switches [Bit 12]	ON/OFF ON/OFF	Proportional driver ON or OFF (pin 2).
Dig out6 input Sw_14 Switches [Bit 13]	ON/OFF ON/OFF	Digital out 6 input ON or OFF (pin 19).
Dig out7 input Sw_15 Switches [Bit 14]	ON/OFF ON/OFF	Digital out 7 input ON or OFF (pin 20).
Switch 16 Sw_16 Switches [Bit 15]	ON/OFF ON/OFF	Switch 16 ON or OFF (pin 14).

MONITOR MENU : OUTPUTS		
Variable	Display range	Description
Analog out Analog_output	0–10.0 V 0–32767	Voltage at analog output (pin 30).
Digital out 6 Dig 6 _output	ON/OFF ON/OFF	Digital out 6 output ON or OFF (pin 19).
Digital out 7 Dig 7_output	ON/OFF ON/OFF	Digital out 7 output ON or OFF (pin 20).
Driver 1 PWM PWM 1_output	0–100 % 0–32767	Driver 1 PWM output (pin 6).
Driver 2 PWM PWM 2_output	0–100 % 0–32767	Driver 2 PWM output (pin 5).
Driver 3 PWM PWM 3_output	0–100 % 0–32767	Driver 3 PWM output (pin 4).
Driver 4 PWM PWM 4_output	0–100 % 0–32767	Driver 4 PWM output (pin 3).
PD PWM PD_output	0–100 % 0–32767	Proportional driver PWM output (pin 2).
PD current PD_current	0–2.0 A 0–607	Current at proportional driver (pin 2).
5 Volts 5_Volts_output	0–6.25 V 0–1023	Voltage at +5V output (pin 26).
Ext supply current Ext_supply_current	5–200 mA 52–800	Combined current of the external +12V and +5V voltage supplies (pins 25 and 26).
Pot Low Pot_low_output	0–6.25 V 0–1023	Voltage at pot low (pin 18).

MONITOR MENU : BATTERY		
Variable	Display range	Description
BDI BDI_Percentage	0–100 % 0–100	Battery state of charge.
Capacitor voltage Capacitor_voltage	0–105 V 0–6720	Voltage of controller's internal capacitor bank at B+ terminal.
Keyswitch voltage Keyswitch_voltage	0–105 V 0–10500	Voltage at KSI (pin 1).

MONITOR MENU : MOTOR		
Variable	Display range	Description
Motor RPM Motor_RPM	-12000–12000 rpm -12000–12000	Motor speed in revolutions per minute.
Temperature Motor_temperature	-100–300˚C -1000–3000	Temperature sensor readout.
Motor speed A Motor speed A	0–12000 rpm 0–12000	Motor encoder phase A speed in revolutions per minute. This can be used to verify that phase A of the encoder is operating correctly. Motor speed A should equal motor speed B in a properly operating motor encoder. Motor speed A does not indicate direction.
Motor speed B Motor speed B	0–12000 rpm 0–12000	Motor encoder phase A speed in revolutions per minute. This can be used to verify that phase B of the encoder is operating correctly. Motor speed B should equal Motor speed A in a properly operating motor encoder. Motor speed B does not indicate direction.

MONITOR MENU : CONTROLLER		
Variable	Display range	Description
Current (RMS) Current_RMS	0–1000 A 0–10000	RMS current of the controller, taking all three phases into account.
Modulation depth Modulation_depth	0–100 % 0–1182	Percentage of available voltage being used.
Frequency Frequency	-300–300 Hz -18000–18000	Controller electrical frequency.
Temperature Controller_temperature	-100–300 °C -1000–3000	Controller internal temperature.
Main state Main_state	0–10 0–10	Main contactor state : 0 = Open 1 = Precharge 2 = Weld check 3 = Closing delay 4 = Missing check 5 = Closed (when main enable = ON) 6 = Delay 7 = Arc check 8 = Open delay 9 = Fault 10 = Closed (when main enable = OFF).
Regen Regen_state System_flags1 [Bit 2]	ON/OFF ON/OFF	On when regen braking is taking place; Off when it is not.
VCL error module Last_VCL_error_module **VCL error** Last_VCL_error	0–65536 0–65536 0–65536 0–65536	A VCL runtime error (fault code 68) will store additional information about the cause of a VCL runtime error in the VCL error module and VCL error variables. The resulting non-zero values can be compared to the runtime VCL module ID and error code definitions listed in the controller's OS sysInfo file, which should help pinpoint the VCL error that caused the runtime error.
Motor characterization error Motor_characterization_error	0–65536 0–65536	A motor characterization error (fault code 87) will store additional information in the motor characterization error variable : 0 = None 1 = Encoder signal seen but unable to determine step size; must set up encoder step size manually 2 = Motor temp sensor fault 3 = Motor temp hot cutback fault 4 = Controller overtemp cutback fault 5 = Controller undertemp cutback fault 6 = Undervoltage cutback fault 7 = Severe overvoltage fault 8 = Encoder signal not seen, or one or both channels missing 9 = Motor parameters out of characterization range.

MONITOR MENU: CUTBACKS		
Variable	Display range	Description
Motor temp cutback Motor temp cutback	0–100 % 0–4096	Displays the current available as a result of the motor temperature cutback function. A value of 100% indicates no cutback in current.
Controller temp cutback Controller temp cutback	0–100 % 0–4096	Displays the current available as a result the controller temperature cutback function. A value of 100% indicates no cutback in current.
Under voltage cutback Under voltage cutback	0–100 % 0–4096	Displays the current available as a result the undervoltage cutback function. A value of 100% indicates no cutback in current.
Over voltage cutback Over voltage cutback	0–100 % 0–4096	Displays the current available as a result the overvoltage cutback function. A value of 100% indicates no cutback in current.

MONITOR MENU: VEHICLE		
Variable	Display range	Description
Vehicle speed Vehicle_speed	-327.7–327.7 -32768–32767	Vehicle speed, in units of MPH or KPH, depending on the setting of the metric units parameter (see program » vehicle menu, page 6-55). For accurate speed estimates, the speed to RPM parameter must be set correctly (page 6-55).
Vehicle odometer Vehicle_odometer	0–42949672.9 0–4294967295	Vehicle distance traveled, in units of miles or km, depending on the setting of the metric units parameter (page 6-55). For accurate distance measurements, the speed to RPM parameter must be set correctly (page 6-55).
Vehicle acceleration Vehicle_acceleration	0–10 g 0–1000	Vehicle acceleration. The speed to RPM parameter must be set correctly for accurate measurement.
Time to speed 1 Time_to_capture_speed_1	0–128 sec 0–32000	Time taken for the vehicle to go from zero rpm to the programmed capture speed 1(see program » vehicle menu, page 6-55) during its most recent such acceleration.
Time to speed 2 Time_to_capture_speed_2	0–128 sec 0–32000	Time taken for the vehicle to go from zero rpm to the programmed capture speed 2 (see program » vehicle menu) during its most recent such acceleration.
Time between speeds Time_between_capture_speeds	0–128 sec 0–32000	Time taken for the vehicle to go from programmed capture speed 1 to programmed capture speed 2 (see program » vehicle menu, page 6-55) during its most recent such acceleration.
Time to dist 1 Time_to_capture_dist_1	0–128 sec 0–32000	Time taken for the vehicle to travel from zero rpm to the programmed capture distance 1 (see program » vehicle menu, page 6-55) during its most recent such trip. For accurate distance measurements, the speed to RPM parameter must be set correctly (page 6-55).
Time to dist 2 Time_to_capture_dist_2	0–128 sec 0–32000	Time taken for the vehicle to travel from zero rpm to the programmed capture distance 2 (see program » vehicle menu) during its most recent such trip. For accurate distance measurements, the speed to RPM parameter must be set correctly (page 6-55).

MONITOR MENU: VEHICLE, cont'd		
Variable	Display range	Description
Time to dist 3 Time_to_capture_dist_3	0–128 sec 0–32000	Time taken for the vehicle to travel from zero rpm to the programmed capture distance 3 (see program » vehicle menu) during its most recent such trip. For accurate distance measurements, the speed to RPM parameter must be set correctly (page 6-55).
Braking distance captured Braking_distance_captured	0–1000000.0 0–400000000	Distance traveled by the vehicle starting with vehicle braking (initiated by throttle reversal, brake pot, or VCL_brake) and ending when motor_RPM = 0. units are meters or feet, depending on the setting of the metric units parameter (page 6-55). For accurate distance measurements, the speed to RPM parameter must be set correctly (page 6-55).
Distance since stop Distance_since_stop	0–1000000.0 0–400000000	Distance traveled by the vehicle starting from a stop. In effect, the vehicle is used as a tape measure. (In other words, if you travel 300 feet forward and then 300 feet in reverse, the distance would be 600.) The distance is continuously updated and will stop (and restart) when motor_RPM = 0. For accurate distance measurements, the speed to RPM parameter must be set correctly (page 6-55). Units are meters or feet, depending on the setting of the metric units parameter (page 6-55).
Distance fine Distance_fine_long	-214748364.8– 214748364.7 -2147483648– 2147483647	Position measurement. Net distance in both the forward and reverse directions. (In other words, if you travel 20 inches forward and then 20 inches in reverse, the distance would be zero.) The distance is continuously updated and will roll over when the variable goes over the limits. Units are decimeters or inches, depending on the setting of the metric units parameter (page 6-55). For accurate distance measurements, the speed to RPM parameter must be set correctly (page 6-55).

7) CONTROLLER INFORMATION MENU

This menu provides ID and version numbers for your controller hardware and software.

CONTROLLER INFORMATION MENU		
Variable	Display range	Description
Model number Model_number	0–4294967295 0–4294967295	Model number. For example, if you have a 1236 controller with the model number 1236-4501, the model number variable will have a value of 12364501.
Serial number Serial number	0–4294967295 0–4294967295	Serial number. For example, if the serial number printed on your controller is 08045L.11493, the serial number variable will have the value of 11493.
Mfg date code Manuf_date	0–32767 0–32767	Controller date of manufacture, with the first two digits indicating the year and the last three indicating the day. For example, if the serial number printed on your controller is 08045L.11493, the Mfg date code variable will have the value of 08045 (45th day of 2008).
Hardware version Hardware_Ver	0–32.767 0–32767	The hardware version number uniquely describes the combination of power base assembly and the logic, cap, and IMS board assemblies used in the controller.
OS version OS_Ver	0–32767 0–32767	Version number of the operating system software that is loaded into the controller. This variable specifies the major version number of the controller's operating system.
Build number Build_number	0–32767 0–32767	Build number of the operating system software that is loaded into the controller. This variable specifies the minor version number of the controller's operating system.
SM version SM_Ver	0–327.67 0–32767	Version number of the start manager software that is loaded into the controller.
Param Blk version Param_Blk_Ver	0–327.67 0–32767	Version number of the parameter block that is loaded into the controller.
VCL App version VCL_App_Ver	0–327.67 0–32767	Version number of the VCL application software that is loaded into the controller. This value is set in the VCL program by assigning a value to the VCL_App_Ver variable.

8) DIAGNOSTICS AND TROUBLESHOOTING

These controllers detect a wide variety of faults or error conditions. Faults can be detected by the operating system. This section describes the faults detected by the operating system.

(1) Diagnostics

Diagnostics information can be obtained in either of two ways: (1) by reading the display on a programmer or(2) by observing the fault codes issued by the status LEDs. See table for a summary of LED display formats.

The programmer will display all faults that are currently set as well as a history of the faults that have been set since the history log was last cleared.

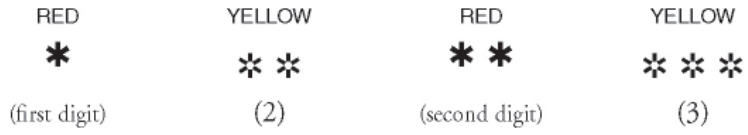
The displays the faults by name.

The pair of LEDs built into the controller (one red, one yellow) produce flash codes displaying all the currently set faults in a repeating cycle. Each code consists of two digits. The red LED flashes once to indicate that the first digit of the code will follow; the yellow LED then flashes the appropriate number of times for the first digit. The red LED flashes twice to indicate that the second digit of the code will follow; the yellow LED flashes the appropriate number of times for the second digit.

Example: Battery undervoltage (code 23).

In the Fault menu of the programmer, the words undervoltage cutback will be displayed; the real-time battery voltage is displayed in the monitor menu ("keyswitch voltage").

The controller's two LEDs will display this repeating pattern:



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The numerical codes used by the yellow LED are listed in the troubleshooting chart, which also lists possible fault causes and describes the conditions that set and clear each fault.

① Summary of LED display formats

The two LEDs have four different display modes, indicating the type of information they are providing.

Display	Status
Neither LED illuminated	Controller is not powered on; or vehicle has dead battery; or severe damage.
Yellow LED flashing	Controller is operating normally.
Yellow and red LEDs both on solid	Controller is in Flash program mode.
Red LED on solid	Watchdog failure or no software loaded. Cycle KSI to restart, and if necessary load software.
Red LED and yellow LED flashing alternately	Controller has detected a fault. 2-digit code flashed by yellow LED identifies the specific fault; one or two flashes by red LED indicate whether first or second code digit will follow.

(2) Troubleshooting

The troubleshooting chart, following page, provides the following information on all the controller faults:

- Fault code
- Fault name as displayed on the programmer's LCD
- The effect of the fault
- Possible causes of the fault
- Fault set conditions
- Fault clear conditions.

Whenever a fault is encountered and no wiring or vehicle fault can be found, shut off KSI and turn it back on to see if the fault clears. If it does not, shut off KSI and remove the 35-pin connector. Check the connector for corrosion or damage, clean it if necessary, and re-insert it.

■ **Troubleshooting chart**

Code	Problem	Probable cause	Remedy
12	Controller overcurrent Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· External short of phase U,V, or W motor connections. · Motor parameters are mis-tuned. Controller defective.	Set: Phase current exceeded the current measurement limit. Clear: Cycle KSI.
13	Current sensor fault Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· Leakage to vehicle frame from phase U, V, or W (short in motor stator). · Controller defective.	Set: Controller current sensors have invalid offset reading. Clear: Cycle KSI.
14	Precharge failed Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· External load on capacitor bank(B+ connection terminal) that prevents the capacitor bank from charging. · See Monitor menu ≫ Battery : capacitor voltage.	Set: Precharge failed to charge the capacitor bank to the KSI voltage. Clear: Cycle Interlock input or use VCL function precharge().
15	Controller severe undertemp Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· See Monitor menu ≫ Controller : Temperature. · Controller is operating in an extreme environment.	Set: Heatsink temperature below -40˚C. Clear: Bring heatsink temperature above -40˚C, and cycle interlock or KSI.
16	Controller severe overtemp Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· See Monitor menu ≫ Controller: Temperature. · Controller is operating in an extreme environment. · Excessive load on vehicle. · Improper mounting of controller.	Set: Heatsink temperature above +95˚C. Clear: Bring heatsink temperature below +95˚C, and cycle interlock or KSI.
17	Severe undervoltage reduced drive torque.	· Battery menu parameters are misadjusted. · Non-controller system drain on battery. · Battery resistance too high. · Battery disconnected while driving. · See monitor menu "Battery: capacitor voltage. · Blown B+ fuse or main contactor did not close.	Set: Capacitor bank voltage dropped below the severe undervoltage limit (see page 6-57) with FET bridge enabled. Clear: Bring capacitor voltage above severe undervoltage limit.

Code	Problem	Probable cause	Remedy
18	Severe overvoltage Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· See monitor menu ≫ Battery: capacitor voltage. · Battery menu parameters are misadjusted. · Battery resistance too high for given regen current. · Battery disconnected while regen braking.	Set: Capacitor bank voltage exceeded the severe overvoltage limit (see page 6-53) with FET bridge enabled. Clear: Bring capacitor voltage below severe overvoltage limit, and then cycle KSI.
22	Controller overtemp cutback Reduced drive and brake torque.	· See monitor menu ≫ Controller: Temperature. · Controller is performance-limited at this temperature. · Controller is operating in an extreme environment. · Excessive load on vehicle. · Improper mounting of controller.	Set: Heatsink temperature exceeded 85˚C. Clear: Bring heatsink temperature below 85˚C.
23	Undervoltage cutback Reduced drive torque.	· Normal operation. Fault shows that the batteries need recharging. · Controller is performance limited at this voltage. · Battery parameters are misadjusted. · Non-controller system drain on battery. · Battery resistance too high. · Battery disconnected while driving. · See Monitor menu ≫ Battery : capacitor voltage. · Blown B+ fuse or main contactor did not close.	Set: Capacitor bank voltage dropped below the undervoltage limit (see page 6-53) with the FET bridge enabled. Clear: Bring capacitor voltage above the undervoltage limit.
24	Overvoltage Cutback Reduced brake torque.	· Normal operation. Fault shows that regen braking currents elevated the battery voltage during regen braking. · Controller is performance limited at this voltage. · Battery parameters are misadjusted. · Battery resistance too high for given regen current. · Battery disconnected while regen braking. See monitor menu ≫ Battery : capacitor voltage.	Set: Capacitor bank voltage exceeded the overvoltage (see page 6-53) with the FET bridge enabled. Clear: Bring capacitor voltage below the overvoltage limit.

Code	Problem	Probable cause	Remedy
25	+5V Supply failure none, unless a fault action is programmed in VCL.	· External load impedance on the +5V supply (pin 26) is too low. · See monitor menu ≫ outputs : 5 volts and Ext supply current.	Set: +5V supply (pin 26) outside the +5V ± 10% range. Clear: Bring voltage within range.
26	Digital out 6 overcurrent Digital output 6 driver will not turn on.	· External load impedance on Digital output 6 driver (pin 19) is too low.	Set: Digital output 6 (pin 19) current exceeded 15 mA. Clear: Remedy the overcurrent cause
27	Digital out 7 overcurrent Digital output 7 driver will not turn on.	· External load impedance on Digital output 7 driver (pin 20) is too low.	Set: Digital output 7 (pin 20) current exceeded 15 mA. Clear: Remedy the overcurrent cause
28	Motor Temp hot cutback reduced drive torque.	· Motor temperature is at or above the programmed temperature hot setting, and the requested current is being cut back. · Motor temperature control menu parameters are mis-tuned. · See monitor menu ≫ motor: Temperature and ≫ inputs: analog2. · If the application doesn't use a motor thermistor, Temp compensation and temp cutback should be programmed OFF.	Set: Motor temperature is at or above the temperature hot parameter setting. Clear: Bring the motor temperature within range.
29	Motor Temp sensor fault max speed reduced (LOS, Limited Operating Strategy), and motor temperature cutback disabled.	· Motor thermistor is not connected properly. · If the application doesn't use a motor thermistor, motor temp sensor enable should be programmed OFF. · See monitor menu ≫ motor: Temperature and ≫ inputs: analog2.	Set: Motor thermistor input (pin 8) is at the voltage rail (0 or 10V). Clear: Bring the motor thermistor input voltage within range.
31	Coil1 driver open/short shutdown driver1.	· Open or short on driver load. · Dirty connector pins. · Bad crimps or faulty wiring.	Set: Driver 1 (pin 6) is either open or shorted. This fault can be set only when main enable = Off. Clear: Correct open or short, and cycle driver.
31	Main open/short Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· Open or short on driver load. · Dirty connector pins. · Bad crimps or faulty wiring.	Set: Main contactor drive (pin 6) is either open or shorted. This fault can be set only when main enable = ON. Clear: Correct open or short, and cycle driver.

Code	Problem	Probable cause	Remedy
32	Coil 2 driver open/short shutdown driver 2.	· Open or short on driver load. · Dirty connector pins. · Bad crimps or faulty wiring.	Set: Driver 2 (pin 5) is either open or shorted. This fault can be set only when EM brake type = 0. Clear: Correct open or short, and cycle driver.
32	EM Brake open/short Shutdown EM brake; Shutdown throttle; Full brake.	· Open or short on driver load. · Dirty connector pins. · Bad crimps or faulty wiring.	Set: Electromagnetic brake driver (pin 5) is either open or shorted. This fault can be set only when EM brake type > 0. Clear: Correct open or short, and cycle driver.
33	Coil 3 driver open/short shutdown driver 3.	· Open or short on driver load. · Dirty connector pins. · Bad crimps or faulty wiring.	Set: Driver 3 (pin 4) is either open or shorted. Clear: Correct open or short, and cycle driver.
34	Coil 4 driver open/short shutdown driver 4.	· Open or short on driver load. · Dirty connector pins. · Bad crimps or faulty wiring.	Set: Driver 4 (pin 3) is either open or shorted. Clear: Correct open or short, and cycle driver.
35	PD open/short shutdown PD.	· Open or short on driver load. · Dirty connector pins. · Bad crimps or faulty wiring.	Set: Proportional driver (pin 2) is either open or shorted. Clear: Correct open or short, and cycle driver.
36	Encoder fault shutdown EM brake.	· Motor encoder failure. · Bad crimps or faulty wiring. · See Monitor menu ≫ Motor: Motor RPM.	Set: Motor encoder phase failure detected. Clear: Cycle KSI.
37	Motor open Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· Motor phase is open. · Bad crimps or faulty wiring.	Set: Motor phase U, V, or W detected open. Clear: Cycle KSI.
38	Main contactor welded Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· Main contactor tips are welded closed. · Motor phase U or V is disconnected or open. · An alternate voltage path (such as an external precharge resistor) is providing a current to the capacitor bank (B+ connection terminal).	Set: Just prior to the main contactor closing, the capacitor bank voltage (B+ connection terminal) was loaded for a short time and the voltage did not discharge. Clear: Cycle KSI

Code	Problem	Probable cause	Remedy
39	Main contactor did not close Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· Main contactor did not close. · Main contactor tips are oxidized, burned, or not making good contact. · External load on capacitor bank (B+ connection terminal) that prevents capacitor bank from charging. Blown B+ fuse.	Set: With the main contactor commanded closed, the capacitor bank voltage (B+ connection terminal) did not charge to B+. Clear: Cycle KSI.
41	Throttle wiper high Shutdown throttle.	· See Monitor menu ≫ Inputs: Throttle Pot. · Throttle pot wiper voltage too high.	Set: Throttle pot wiper (pin 16) voltage is higher than the high fault threshold (can be changed with the VCL function Setup_Pot_Faults()). Clear: Bring throttle pot wiper voltage below the fault threshold.
42	Throttle wiper low Shutdown throttle.	· See Monitor menu ≫ Inputs: Throttle Pot. Throttle pot wiper voltage too low.	Set: Throttle pot wiper (pin 16) voltage is lower than the low fault threshold (can be changed with the VCL function Setup_Pot_Faults()). Clear: Bring throttle pot wiper voltage above the fault threshold.
43	Pot 2 wiper high Full brake.	· See Monitor menu ≫ Inputs: Pot 2 Raw. · Pot 2 wiper voltage too high.	Set: Pot 2 wiper (pin 17) voltage is higher than the high fault threshold (can be changed with the VCL function Setup_Pot_Faults()). Clear: Bring Pot2 wiper voltage below the fault threshold.
44	Pot 2 wiper low Full brake.	· See monitor menu ≫ Inputs: Pot 2 raw. · Pot 2 wiper voltage too low.	Set: Pot 2 wiper (pin 17) voltage is lower than the low fault threshold (can be changed with the VCL function Setup_Pot_Faults()). Clear: Bring Pot2 wiper voltage above the fault threshold.
45	Pot low overcurrent Shutdown throttle; Full brake.	· See monitor menu ≫ Outputs: Pot low. · Combined pot resistance connected to pot low is too low.	Set: Pot low (pin 18) current exceeds 10mA. Clear: Clear pot low overcurrent condition and cycle KSI.

Code	Problem	Probable cause	Remedy
46	EEPROM failure Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Shutdown interlock; Shutdown driver 1; Shutdown driver 2; Shutdown driver 3; Shutdown driver 4; Shutdown PD; Full brake; Shutdown pump.	· Failure to write to EEPROM memory. This can be caused by EEPROM memory writes initiated by VCL, by the CAN bus, by adjusting parameters with the programmer, or by loading new software into the controller.	Set: Controller operating system tried to write to EEPROM memory and failed. Clear: Download the correct software (OS) and matching parameter default settings into the controller and cycle KSI.
47	HPD/Sequencing fault Shutdown throttle.	· KSI, interlock, direction, and throttle inputs applied in incorrect sequence. · Faulty wiring, crimps, or switches at KSI, interlock, direction, or throttle inputs. · See Monitor menu ≫ Inputs.	Set: HPD (High Pedal Disable) or sequencing fault caused by incorrect sequence of KSI, interlock, direction, and throttle inputs. Clear: Reapply inputs in correct sequence.
47	Emer Rev HPD Shutdown throttle; Shutdown EM brake.	· Emergency reverse operation has concluded, but the throttle, forward and reverse inputs, and interlock have not been returned to neutral.	Set : At the conclusion of emergency reverse, the fault was set because various inputs were not returned to neutral. Clear: If EMR_Interlock = ON, clear the interlock, throttle, and direction inputs. If EMR_Interlock = OFF, clear the throttle and direction inputs.
49	Parameter change fault Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· This is a safety fault caused by a change in certain parameter settings so that the vehicle will not operate until KSI is cycled. · For example, if a user changes the throttle type this fault will appear and require cycling KSI before the vehicle can operate.	Set: Adjustment of a parameter setting that requires cycling of KSI. Clear: Cycle KSI.
51-67	OEM faults (See OEM documentation.)	· These faults can be defined by the OEM and are implemented in the application-specific VCL code. See OEM documentation.	

Code	Problem	Probable cause	Remedy
68	VCL Run time error Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Shutdown interlock; Shutdown driver 1; Shutdown driver 2; Shutdown driver 3; Shutdown driver 4; Shutdown PD; Full brake; Shutdown pump.	· VCL code encountered a runtime VCL error. · See monitor menu ≫ Controller : VCL error module and VCL error. · This error can then be compared to the runtime VCL module ID and error code definitions found in the specific OS system information file.	Set: Runtime VCL code error condition. Clear: Edit VCL application software to fix this error condition ; flash the new compiled software and matching parameter defaults ; cycle KSI.
69	External supply out of range None, unless a fault action is programmed in VCL.	· External load on the 5V and 12V supplies draws either too much or too little current. · Fault checking menu parameters Ext supply max and Ext supply min are mis-tuned. · See monitor menu ≫ Outputs: Ext supply current.	Set: The external supply current (combined current used by the 5V supply [pin 26] and 12V supply [pin 25]) is either greater than the upper current threshold or lower than the lower current threshold. The two thresholds are defined by the external supply max and external supply min parameter settings (page 6-49). Clear: Bring the external supply current within range.
71	OS general Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Shutdown Interlock; Shutdown driver 1; Shutdown driver 2; Shutdown driver 3; Shutdown driver 4; Shutdown PD; Full brake; Shutdown pump.	· Internal controller fault.	Set: Internal controller fault detected. Clear: Cycle KSI.
72	PDO timeout Shutdown Interlock; CAN NMT state set to pre-operational.	· Time between CAN PDO messages received exceeded the PDO timeout Period.	Set: Time between CAN PDO messages received exceeded the PDO timeout period. Clear: Cycle KSI or receive CAN NMT message.

Code	Problem	Probable cause	Remedy
73	Stall detected Shutdown EM brake; Control mode changed to LOS (Limited Operating Strategy).	· Stalled motor. · Motor encoder failure. · Bad crimps or faulty wiring. · Problems with power supply for the motor encoder. · See monitor menu ≫ Motor : Motor RPM.	Set: No motor encoder movement detected. Clear: Either cycle KSI, or detect valid motor encoder signals while operating in LOS mode and return Throttle Command = 0 and Motor RPM = 0.
74	Fault on other traction controller	· Dual drive fault: see dual drive manual.	
75	Dual severe fault	· Dual drive fault: see dual drive manual.	
87	Motor characterization fault Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· Motor characterization failed during characterization process. See monitor menu ≫ Controller: Motor characterization error for cause: 0=none 1 = Encoder signal seen, but step size not determined; set encoder step size manually 2 = Motor temp sensor fault 3 = Motor temp hot cutback fault 4 = Controller overtemp cutback fault 5 = Controller undertemp cutback fault 6 = Undervoltage cutback fault 7 = Severe overvoltage fault 8 = Encoder signal not seen, or one or both channels missing 9 = Motor parameters out of characterization range.	Set: No motor encoder movement detected. Clear: Either cycle KSI, or detect valid motor encoder signals while operating in LOS mode and return Throttle command = 0 and Motor RPM = 0.
89	Motor type fault Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· The motor_type parameter value is out of range.	Set: motor_type parameter is set to an illegal value. Clear: Set motor_type to correct value and cycle KSI.

Code	Problem	Probable cause	Remedy
91	VCL/OS Mismatch Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Shutdown interlock; Shutdown driver 1; Shutdown driver 2; Shutdown driver 3; Shutdown driver 4; Shutdown PD; Full brake; Shutdown pump.	· The VCL software in the controller does not match the OS software in the controller.	Set: VCL and OS software do not match ; when KSI cycles, a check is made to verify that they match and a fault is issued when they do not. Clear: Download the correct VCL and OS software into the controller.
92	EM Brake failed to set Shutdown EM brake; Shutdown throttle.	· Vehicle movement sensed after the EM brake has been commanded to set. · EM brake will not hold the motor from rotating.	Set: After the EM brake was commanded to set and time has elapsed to allow the brake to fully engage, vehicle movement has been sensed. Clear: Activate the throttle.
93	Encoder LOS (Limited Operating Strategy) Enter LOS control mode.	· Limited Operating Strategy (LOS) control mode has been activated, as a result of either an encoder fault (code 36) or a stall detect fault (code 73). · Motor encoder failure. · Bad crimps or faulty wiring. · Vehicle is stalled.	Set: Encoder fault (code 36) or stall detect fault (code 73) was activated, and brake or interlock has been applied to activate LOS control mode, allowing limited motor control. Clear: Cycle KSI or, if LOS mode was activated by the stall fault, clear by ensuring encoder senses proper operation, Motor RPM = 0, and Throttle command = 0.
94	Emer Rev timeout Shutdown EM brake; Shutdown throttle.	· Emergency reverse was activated and concluded because the EMR timeout timer has expired. · The emergency reverse input is stuck ON.	Set: Emergency reverse was activated and ran until the EMR timeout timer expired. Clear: Turn the emergency reverse input OFF.
98	Illegal model number Shutdown motor; Shutdown main contactor; Shutdown EM brake; Shutdown throttle; Full brake; Shutdown pump.	· Model_Number variable contains illegal value (not this controller). · Software and hardware do not match. · Controller defective.	Set: Illegal Model_Number variable; when KSI cycles, a check is made to confirm a legal Model_Number, and a fault is issued if one is not found. Clear: Download appropriate software for your controller model.
99	Dualmotor parameter Mismatch	· Dual drive fault: see dual drive manual.	

9) MAINTENANCE

There are no user serviceable parts in the controllers. No attempt should be made to open, repair, or otherwise modify the controller. Doing so may damage the controller and will void the warranty.

It is recommended that the controller and connections be kept clean and dry and that the controller's fault history file be checked and cleared periodically.

(1) Cleaning

Periodically cleaning the controller exterior will help protect it against corrosion and possible electrical control problems created by dirt, grime, and chemicals that are part of the operating environment and that normally exist in battery powered systems.

When working around any battery powered system, proper safety precautions should be taken. These include, but are not limited to: proper training, wearing eye protection, and avoiding loose clothing and jewelry.

Use the following cleaning procedure for routine maintenance. Never use a high pressure washer to clean the controller.

① Remove power by disconnecting the battery.
② Discharge the capacitors in the controller by connecting a load (such as a contactor coil) across the controller's B^+ and B^- terminals.
③ Remove any dirt or corrosion from the power and signal connector areas. The controller should be wiped clean with a moist rag. Dry it before reconnecting the battery.
④ Make sure the connections are tight. Refer to page 6-26, for maximum tightening torque specifications for the battery and motor connections.

(2) Fault history

The programmer can be used to access the controller's fault history file. The programmer will read out all the faults the controller has experienced since the last time the fault history file was cleared. Faults such as contactor faults may be the result of loose wires ; contactor wiring should be carefully checked. Faults such as overtemperature may be caused by operator habits or by overloading.

After a problem has been diagnosed and corrected, it is a good idea to clear the fault history file. This allows the controller to accumulate a new file of faults. By checking the new fault history file at a later date, you can readily determine whether the problem was indeed fixed.

10) PROGRAMMERS

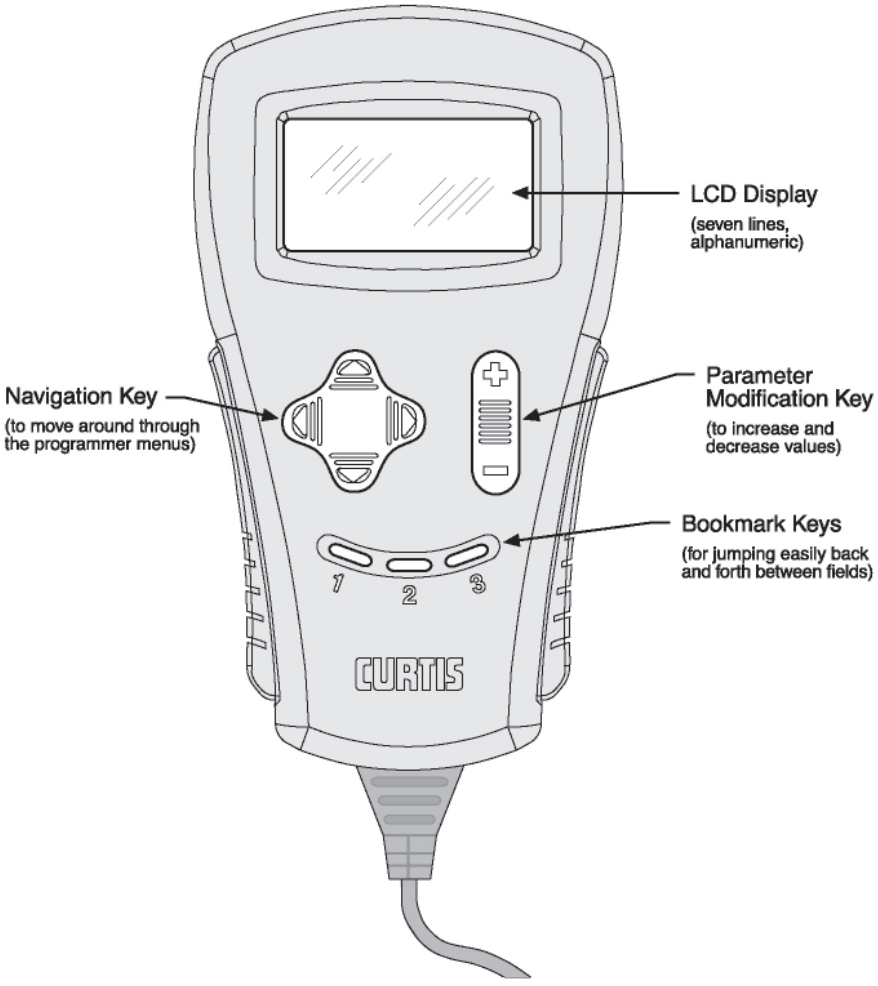
Curtis programmers provide programming, diagnostic, and test capabilities for 1234 controllers. The power for operating the programmer is supplied by the host controller via a 4-pin connector. Two programmers are available: the PC Programming Station (1314) and the handheld programmer (1311). The programming station has features not available on the handheld unit; on the other hand, the handheld programmer has the advantage of being more portable.

Typically the Programming Station is used to set up the parameters initially and the handheld programmer is used to made adjustments in the field.

Several versions of each programmer are available (user, service, dealer, OEM): the User programmers can adjust only User-access parameters, whereas the OEM programmers can adjust all the parameters.

HANDHELD PROGRAMMER (1311)

The 1311 programmer is easy to use, with self-explanatory functions. After plugging in the programmer, wait a few seconds for it to boot up and gather information from the controller.



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For experimenting with settings, the programmer can be left plugged in while the vehicle is driven.
The bookmark keys can make parameter adjustment more convenient.
To set a bookmark, press one of the three bookmark keys for more than two seconds. To jump to a bookmarked location, press the appropriate bookmark key quickly (for less than two seconds). For example, in setting the drive forward throttle parameters, you might set a bookmark at the first of these parameters [program » throttle » forward offset] and another at the raw throttle readout [monitor » inputs » throttle pot]; this way you can easily toggle between the readout and the parameters.
The bookmark keys also have another function that makes programming easier. When setting the value of a parameter, you can use these keys to adjust the increments by which the value changes—with bookmark key 1, the value changes in 10-digit steps up or down; with bookmark key 2 pressed, the value changes in 100-digit steps; and with bookmark key 3, in 1000-digit steps—which, for most parameters, takes you from the maximum to the minimum, or vice versa.

PROGRAMMER MENUS

The programmers have six menus, which in turn lead to nested submenus.
Program — provides access to the programmable parameters (page 6-34).
Monitor — presents real-time values during vehicle operation; these include all inputs and outputs, as well as the mapped throttle values and conditioned throttle requests (page 6-56).
Faults — presents diagnostic information, and also a means to clear the fault history file (page 6-66).
Functions — provides access to the controller-cloning commands and to the “reset” command.
Information — displays data about the host controller: model and serial numbers, date of manufacture, hardware and software revisions, and itemization of other devices that may be associated with the controller’s operation.
Programmer setup — displays data about the programmer: model and serial numbers, and date of manufacture.