This service manual has been elaborated to help service personnel to provide efficient and correct service and maintenance on the **TM31** (formerly called DKS 32) compressor (for HFC-134a) for automotive air conditioning.

This manual includes the operation specifications, procedures for disassembly, reassembly, and inspection of the compressor.

The contents of this manual, including illustrations, drawings and specifications were the latest available at the time of printing.

Valeo Japan reserves the right to make changes in specifications and procedures at any time without notice.

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**WARNINGS**

The following warning signs are used in this service manual. These are extremely important to ensure safe operation and to prevent body injuries and property damage. They must be fully understood before starting the air conditioner maintenance.

**WARNING!**  Maintenance must be properly done to avoid serious injury risks.

**CAUTION!**  Improper maintenance can result in injury or property damage.

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**MEANING OF MARKS**

The following marks are used in this service manual to facilitate correct air conditioner maintenance.

**Advice**  Procedures necessary to ensure the best air conditioner maintenance.

**Note**  Information to optimize the air conditioner maintenance.
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### Compressor

<table>
<thead>
<tr>
<th>MODEL</th>
<th><strong>TM31</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>TECHNOLOGY</td>
<td>Heavy Duty Swash Plate</td>
</tr>
<tr>
<td>DISPLACEMENT</td>
<td>313 cc (19.1 cu in) per rev.</td>
</tr>
<tr>
<td>NUMBER OF CYLINDERS</td>
<td>10</td>
</tr>
<tr>
<td>REVOLUTION RANGE</td>
<td>700-6,000 rpm (maximum peak : 7,000 rpm)</td>
</tr>
<tr>
<td>DIRECTION OF ROTATION</td>
<td>Clockwise viewed from clutch</td>
</tr>
<tr>
<td>BORE</td>
<td>36 mm (1.42 in)</td>
</tr>
<tr>
<td>STROKE</td>
<td>30.7 mm (1.21 in)</td>
</tr>
<tr>
<td>SHAFT SEAL</td>
<td>Lip seal type</td>
</tr>
<tr>
<td>LUBRICATION SYSTEM</td>
<td>Lubrication by gear pump</td>
</tr>
<tr>
<td>REFRIGERANT</td>
<td>HFC-134a</td>
</tr>
<tr>
<td>OIL (QUANTITY)</td>
<td>ZXL 100 PG PAG OIL (DH-PS): 500 cc (30.5 cu in)</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>9.5 kg (21 lb) (w/o Clutch w/o oil)</td>
</tr>
<tr>
<td>DIMENSIONS (with clutch)</td>
<td>278.5 - 143 - 178 (mm)</td>
</tr>
<tr>
<td>MOUNTING</td>
<td>Direct (side or base)</td>
</tr>
</tbody>
</table>

#### Valeo **TM31** Application limits for HFC-134a

<table>
<thead>
<tr>
<th>PSIA</th>
<th>PSIG</th>
<th>°F</th>
<th>MPaA</th>
<th>MPaG</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>358</td>
<td>343</td>
<td>171</td>
<td>2.47</td>
<td>2.37</td>
<td>77</td>
</tr>
<tr>
<td>244</td>
<td>229</td>
<td>140</td>
<td>1.68</td>
<td>1.58</td>
<td>60</td>
</tr>
<tr>
<td>191</td>
<td>177</td>
<td>122</td>
<td>1.32</td>
<td>1.22</td>
<td>50</td>
</tr>
<tr>
<td>100</td>
<td>85</td>
<td>79</td>
<td>0.69</td>
<td>0.58</td>
<td>26</td>
</tr>
</tbody>
</table>

- **t_c**: Condensing temperature
- **t_e**: Evaporating gas temperature

#### Saturated evaporating conditions

<table>
<thead>
<tr>
<th>PSIA</th>
<th>PSIG</th>
<th>°F</th>
<th>MPaA</th>
<th>MPaG</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.10</td>
<td>0.25</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>0.20</td>
<td>0.35</td>
<td>0.47</td>
<td></td>
</tr>
</tbody>
</table>

#### Saturated condensing conditions

<table>
<thead>
<tr>
<th>PSIA</th>
<th>PSIG</th>
<th>°F</th>
<th>MPaA</th>
<th>MPaG</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>41</td>
<td>57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>14</td>
<td>36</td>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>29</td>
<td>51</td>
<td>69</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# 1- Product description - Magnetic clutch

## Specifications

<table>
<thead>
<tr>
<th>TYPE</th>
<th>Electromagnetic single-plate dry clutch</th>
</tr>
</thead>
<tbody>
<tr>
<td>RATED VOLTAGE</td>
<td>24V DC or 12 V DC</td>
</tr>
<tr>
<td>POWER CONSUMPTION</td>
<td>48 W maximum</td>
</tr>
<tr>
<td>STATIC TORQUE</td>
<td>78 N·m {8.0 kgf·m, 58 lbf·ft}</td>
</tr>
<tr>
<td>DIRECTION OF ROTATION</td>
<td>Clockwise, viewed from clutch</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>Approx 4.5 kg {10 lb}</td>
</tr>
<tr>
<td>V-BELT TYPE</td>
<td>V-groove (A or B) or V-ribbed (PK)</td>
</tr>
</tbody>
</table>

※The above specifications may vary with the compressor.
The performance data below were measured under the following conditions:
- Compressor speed: 1450 rpm
- Suction gas temperature: 20°C

### Valeo TM31 performance data (R134a)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Cooling capacity Q (kW) &amp; Power consumption P (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cond temp (°C)</td>
<td>Pd (MPaG)</td>
</tr>
<tr>
<td>Ps (MPaG)</td>
<td>0.35</td>
</tr>
<tr>
<td>40</td>
<td>0.91</td>
</tr>
<tr>
<td>Q (kW)</td>
<td>22.64</td>
</tr>
<tr>
<td>50</td>
<td>1.21</td>
</tr>
<tr>
<td>Q (kW)</td>
<td>21.22</td>
</tr>
<tr>
<td>60</td>
<td>1.58</td>
</tr>
<tr>
<td>Q (kW)</td>
<td>17.25</td>
</tr>
</tbody>
</table>

### Valeo TM31 conversion factors

Power consumption data at different rotation speed can be approximated with the conversion factors below.

- Lip-seal type shaft seal
The compressor has a lip-seal type shaft seal. This type of shaft seal greatly improves the sealing of the compressor to increase its performance and durability.
1- Product description - Dimensions

**TM31 compressors with magnetic clutch**

Unit: mm

![Diagram of TM31 compressors with magnetic clutch]

Other connecting type

- 6 -
1. Center bolt
2. Armature assembly
3. Adjusting shim
4. Snapring
5. Pulley assembly
6. Screw
7. Field coil
8. Bolt
9. Washer
10. Front cylinder head
11. Shaft seal assembly
12. Gasket
13. Valve plate assembly
14. Suction valve
15. O-ring
16. Cylinder shaft assembly
17. Oil filler plug
18. O-ring
19. Strainer (option)
20. O-ring
21. Suction valve
22. Valve plate assembly
23. Gasket
24. Gear pump
25. Rear cylinder head
Valeo TMS1 are 10-cylinder swash plate type compressors. With this type of compressors, the cylinders and pistons are arranged axially along the drive shaft. The pistons operate within the cylinders and are driven by a swash plate to perform suction, compression and discharge.

**Swash plate system**

The drive shaft, which is driven by the engine through the magnetic clutch, is equipped with a swash plate. The drive shaft is supported by two radial bearings and two thrust bearings. The swash plate is rotated by the drive shaft, and moves the pistons back and forth.

**Piston drive system**

The pistons in the cylinders are mounted on the swash plate through a drive ball and a shoe disk. Each piston has a compression head at each end. The rotation of the swash plate rotation results in a reciprocating piston movement parallel to the drive shaft. The cylinders, which are arranged at 72° intervals around the drive shaft, are each divided into 2 chambers, providing 5 front and 5 rear bores. As each piston performs suction and compression at either end, the compressor operates as a 10 cylinder compressor.
The compressor is lubricated by a gear pump in the rear cylinder head which is connected to the compressor.

**Oil flow**

When the compressor starts operating, the gear pump draws oil from the reservoir and pumps it through an oil passage in the shaft. The oil then flows through ports in the shaft to lubricate the bearings and the shaft seal.

The area between the swash plate and the shoe disks is lubricated by the splashing action of the oil flowing through the thrust bearings. Oil also flows through ports in the pistons to lubricate the cylinders and the pistons.
1- Product description

Compressor

1. The direction of rotation is clockwise as viewed from the clutch side.
2. Each compressor is delivered filled with a specified quantity of compressor oil as described on its label. The total amount of oil your air conditioning system requires is provided by the system designer or supplier.

3. The compressor must be operated under the conditions shown in the operation conditions table shown at the left.

CAUTION!
The A/C cycle components must be designed so that the pressure in the cycle does not exceed 2.4 MPaG (20 kgf/cm², 348 psig).

4. Inclination limit at installation
   The compressor must be installed on the vehicle within the inclination range shown at the left.

Compressor bracket

1. Install the bracket securely on the chassis frame or engine body. As the engine vibrations may be severe, the bracket and mounting bolts must be installed securely.
2. Vibration resistance
   There must not be any resonance under 250 Hz.

Operation conditions table

<table>
<thead>
<tr>
<th>Item</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surrounding temperature</td>
<td>Under 100°C (212°F)</td>
</tr>
<tr>
<td>Speed</td>
<td>Maximum: 7,000 rpm</td>
</tr>
<tr>
<td></td>
<td>Continuous: 6,000 rpm</td>
</tr>
<tr>
<td>Pressure</td>
<td>Maximum: 2.4 MPaG</td>
</tr>
<tr>
<td></td>
<td>(24.5kgf/cm², 348 psig)</td>
</tr>
</tbody>
</table>
1- Product description

Magnetic clutch

1. Voltage
   DC 24 V
   The terminal voltage of the magnetic clutch must exceed 21 V.
   DC 12 V
   The terminal voltage of the magnetic clutch must exceed 10.5 V.

2. Ratio of magnetic clutch to drive pulley
   - When the compressor is driven from the pulley drive of the vehicle, the magnetic clutch to drive pulley ratio should avoid the range 1: 0.92-1.08 to limit vibration and resonance.
   - Compressor speed must not exceed the specified speed.

   **CAUTION!**

   Pulley ratio is the ratio of the magnetic clutch diameter to the drive pulley diameter.

3. Pulley alignment tolerance is less than 1mm (0.04 in).
4. Pulley groove: V-groove or V-ribbed.
5. The belt tension must be adjusted to the tension specified by the belt maker.
1- Product description

Control switches

1. **Thermo switch**
   A thermo switch is necessary. The following specification is recommended.
   Compressor OFF:
   Evaporator fin surface temperature of 0°C (32°F) or below.
   The thermo switch is used to prevent the evaporator from freezing.

2. **Dual pressure switch**
   A dual pressure switch is necessary. The following specifications are recommended.
   Compressor OFF:
   - High pressure control
     2.65 MPaG (27 kgf/cm², 384 psig) or higher
   - Low pressure control
     0.18 MPaG (1.8 kgf/cm², 26 psig) or lower

   The dual pressure switch controls high and low pressure.
   - High pressure control
     When abnormally high pressure develops, the compressor is turned OFF to protect the system.
   - Low pressure control
     When there is insufficient refrigerant in the system, compressor operation is stopped to prevent the compressor from seizing.
1. During the off season of the air conditioner, operate the compressor for a few minutes once a week.
2. Do not drive through water. Water may damage the magnetic clutch, thus preventing normal operation.
3. Do not allow a compressor that has not been used for a long period to become wet.
4. Always charge the A/C system with the specified quantity of refrigerant.
5. Keep the compressor clear of water projection while cleaning the vehicle.
3- Handling instructions

Maintenance precautions

Work area
As the components of air conditioners are particularly sensitive to moisture, dirt and rust, always observe the following:

• Work indoors whenever possible
• Select a flat ground work area
• Keep the work area clean
• Select a work area with adequate ventilation.

CAUTION!
Refrigerant itself is not harmful, but excessive accumulation in a closed area can cause oxygen deficiency.

• Keep open flame and inflammables away from the vehicle in which the air conditioner is being installed.
  (Fire is particularly dangerous during the gas leak inspection following installation)

WARNING!
Contact with flame and high temperatures can generate toxic gases.

Refrigerant handling

WARNING!
Direct contact with refrigerant can cause frostbite or blindness.
Always wear safety glasses and protective gloves.
Do not work with refrigerant close to your face.

1. Do not misidentify refrigerants
If an HFC-134a air conditioning system is mistakenly charged with another refrigerant, serious problems such as compressor seizing may occur. Therefore, confirm before charging with refrigerant that the type of air conditioning system is an HFC-134a system.
2. Do not release refrigerant into the air
Although HFC-134a is not subject to CFC regulations, it can have effect on global warming and so should not be released into the air. When removing refrigerant from the air conditioning system, always use a refrigerant recovery unit made specifically for HFC-134a.

Compressor handling
Do not strike or unnecessarily turn the compressor upside down. If the compressor is knocked over or turned upside down during handling or installation, rotate the armature plate 5 or 6 times to circulate the oil. Otherwise, oil in the cylinder during compressor start-up will cause valve damage and reduce durability.

Compressor removal
When the compressor is operational
1. Perform the oil return operation (see p.16).
2. Recover the refrigerant from the system using a refrigerant recovery unit.
3. Remove the compressor.
4. Drain the oil from the compressor and close all open connections immediately.
5. Check the oil quantity and the degree of contamination (see p.17).

When the compressor is inoperable
1. Recover the refrigerant from the system using a refrigerant recovery unit if the shut-off valves are to be removed with the compressor.
2. Remove the compressor.
3. Drain the oil from the compressor and close all open connections immediately.
4. Check the oil quantity and the degree of contamination (see p.17).
3- Handling instructions

Oil return operation
Compressor oil mixed with refrigerant is circulating in the air conditioning system. Perform the oil return operation to return this oil to the compressor before removing components from the system.

1. Open the doors and windows and operate the blower motor at maximum speed.
2. Operate the vehicle engine at idling during at least 20 minutes.

Note: The maximum amount of oil cannot be recovered at higher speeds. This operation also requires a warm ambient temperature.

Oil handling

Oil specification
Use only ZXL 100PG PAG (DH-PS).

Oil quantity inspection
There is no particular need for frequent inspection or replacement, although it is recommended to check operating refrigerant pressures and oil levels at the start of the season. Please replace the refrigerant and restore the system oil and refrigerant charge to factory specifications if:

• the AC system is opened for repair or replacement of any component (e.g.: evaporator, condenser or receiver drier)
• any loss of charge - refrigerant or oil - is detected.

Oil level can be read through the sight glass of the compressor (see on the left).

Handling precautions

1. The oil must be free from dust, metal filings, etc.
2. Do not mix oils.
3. The moisture content must not exceed 1,000 ppm. (PAG oil only)
4. The oil easily absorbs moisture when the container is open. Therefore always seal the container immediately after use. (PAG oil only)
3- Handling instructions

Oil contamination

Unlike engine oil, no cleaning agent is added to the compressor oil. Even if the compressor is run for a long period (approximately 1 season), the oil never becomes turbid as long as there is nothing wrong with the compressor or its method of use. Inspect the extracted oil for any of the following:

- Increased opacity of the oil.
- Color change to red.
- Presence of foreign matter, metal filings, etc.

**WARNING!**

When system (oil) contamination is found during compressor replacement, flush the A/C system with a fluid that meets SAE J2670 and replace the drier (or accumulator).

Oil check

The compressor oil must be checked as follows when being charged into a used system.

1. Perform the oil return operation (see p. 16).
2. Remove the compressor from the vehicle.
3. Remove the oil filler plug and drain the oil through the oil filler plug and the high and low pressure connectors.
4. Check the oil for contamination.
5. Fill the compressor with the specified amount of oil through the oil filler plug (see p. 18).
3- Handling instructions

<table>
<thead>
<tr>
<th>Specified charge</th>
<th>Amount recovered</th>
<th>Charging amount</th>
<th>Amount to remove from new compressor</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>350 or more</td>
<td>Same as recovered</td>
<td>500-(amount recovered + 20)</td>
</tr>
<tr>
<td>Under 350</td>
<td>350</td>
<td></td>
<td>130</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specified charge</th>
<th>Amount recovered</th>
<th>Charging amount</th>
<th>Amount to remove from new compressor</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.5</td>
<td>21.4 or more</td>
<td>Same as recovered</td>
<td>30.5-(amount recovered + 1.2)</td>
</tr>
<tr>
<td>Under 21.4</td>
<td>21.4</td>
<td></td>
<td>7.9</td>
</tr>
</tbody>
</table>

**CAUTION!**
The specified oil quantity differs, depending on the type of air conditioning system. A label describing the specified quantity is attached to the compressor. Additionally, all of the oil cannot be removed when draining the compressor, as some remains as an oil film on the inside of the compressor and the system components. Therefore, refer to the table at the left when recharging the compressor with oil. Excess oil adversely affects the cooling capacity and the compressor.

6. Install the oil filler plug and tighten it to the specified torque.
Specified torque: 14 ~ 16 N·m
(1.4 ~ 1.6 kgf·m, 10.3 ~ 11.8 lbf·ft)

**CAUTION!**
The oil filler plug O-ring must be replaced with a new one.

Replacement of components

When replacing the system’s component parts, supply the following amount of oil to the compressor.

<table>
<thead>
<tr>
<th>Component mounted</th>
<th>Amount of oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporator</td>
<td>100 cm³ (6.1 cu in)</td>
</tr>
<tr>
<td>Condenser</td>
<td>60 cm³ (3.7 cu in)</td>
</tr>
<tr>
<td>Receiver drier</td>
<td>30 cm³ (1.8 cu in)</td>
</tr>
<tr>
<td>Pipe or hose</td>
<td>30 cm³ (1.8 cu in)</td>
</tr>
</tbody>
</table>

After installing these component parts, check the compressor oil. (See p.16).
3- Handling instructions

Running-in operation
Whenever moving parts have been replaced, it is necessary to run-in both the compressor and the magnetic clutch.

Compressor running-in
Reassembled compressors must be run-in after the leak test (see next page).
1. Check that the compressor contains the specified amount of oil.
2. Install the compressor on the test bench.
3. Install the high pressure connector (T44375C) and the low pressure connector (T44373C) to the ports and tighten the bolts to the specified torque.
   Specified torque: 20 ~ 24 N·m
   {2.0 ~ 2.4 kgf·m, 14 ~ 17 lbf·ft}
4. Connect the two connector ports using a flexible hose.
5. Run the compressor at 1,000 rpm for at least 30 minutes.
6. Replace the oil.
7. Repeat the leak test.

CAUTION!
While the compressor is being run-in in step 5 above, check the outside temperature of the front head. If the temperature exceeds 80°C (176°F), stop the running-in operation. Resume the operation when the head has cooled.

Magnetic clutch running-in
1. Install the clutch on the compressor.
2. Install the compressor on the test bench, and operate the compressor by running the system.
3. Maintain the compressor speed at 500 rpm. Operate the A/C switch through the ON/OFF cycle at least 50 times (“ON” for 10 seconds and “OFF” for 10 seconds).
3- Handling instructions

Leak test

The compressor must be checked for refrigerant leaks after it is repaired. The procedure is as follows.

1. Fit plates to the suction and discharge connections, and tighten it to the specified torque.
   **Specified torque:** 20 ~ 24 N·m
   \{2.0 ~ 2.4 kgf·m, 14 ~ 17 lbf·ft\}

2. Using the valve assembly (597017-1120), fill the compressor with refrigerant through the suction side, raising the refrigerant pressure to at least 0.49 MPaG {5 kgf/cm², 71 psig}.

3. Check the compressor for leaks using a leak detector.

Refrigerant charging

In order to prevent a liquid charge and greatly increase risks of compressor damage, do not shake or turn the refrigerant bottle upside-down.

Storing a repaired compressor

If it is necessary to store a repaired compressor for some time before installation, evacuate the compressor and fill it with dry nitrogen gas through the suction fitting to raise the pressure to 49~150kPa {0.5~1.5kgf/cm², 7.1~21psig}.
Compressor troubleshooting

When a problem occurs during the compressor operation, it is often difficult to pinpoint exact the cause of the malfunction. As long as the compressor maintenance is done correctly, there should not be any problem throughout the whole vehicle life, but should it happen, we hope this troubleshooting can help you solve the issue efficiently.

Below are listed most of the issues you may encounter while the A/C is ON. Please refer to the compressor troubleshooting tree to localize the malfunction symptom, then look at the table (p.22 - 23) for the appropriate counter measure.

Most of the malfunction symptoms can be classified in the following categories:
1. Insufficient cooling capacity
2. Abnormal noise
3. Smoke

In case of insufficient cooling capacity, we recommend that you prepare a gauge manifold to measure the pressure of both discharge and suction sides (for a detailed diagnosis by gauge pressure, see p.24 - 25).

Compressor troubleshooting tree

1. Insufficient cooling capacity
   A. Compressor is not running
   B. Compressor is running
   C. Compressor runs intermittently

2. Abnormal noise
   A. Abnormal noise from compressor
   B. Abnormal noise from magnetic clutch
   C. Belt slipping noise

3. Smoke
   A. Magnetic clutch friction surface slipping
   B. Magnetic clutch belt slipping
   C. Smoke from magnetic clutch
   D. Smoke from compressor
## 4. Troubleshooting

### 1. Insufficient cooling capacity

<table>
<thead>
<tr>
<th>Issue</th>
<th>Symptom</th>
<th>Possible cause</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Compressor is not running (No cool blow coming out)</td>
<td>Magnetic clutch slips when turning on the A/C switch</td>
<td>Compressor internal part damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low pressure cut switch operate (see p.24 - 25)</td>
<td>Refrigerant shortage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The magnetic clutch slips or does not engage when the compressor runs</td>
<td>Lead wire short circuit or wiring connector not seated properly</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Magnetic clutch damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Magnetic clutch air gap too wide</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low magnetic clutch voltage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The magnetic clutch engages but the armature does not rotate</td>
<td>Belt slipping</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Compressor internal part damage or magnetic clutch damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bolt drop off/ Armature drop off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Belt run off the pulley</td>
<td>Belt run off the pulley</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Center bolt is loose / Center bolt is missing</td>
<td>Center bolt is loose / Center bolt is missing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Compressor is running normally</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No difference of temperature between discharge side and suction side (see p.24 - 25)</td>
<td>Poor compression</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Refrigerant shortage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Magnetic clutch friction surface slipping</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Loose connection of the magnetic clutch electrical circuit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Magnetic clutch belt slipping</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Defective sensor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Compressor runs intermittently (Cool blow comes out only from time to time)</td>
<td>Both discharge and suction pressures are high</td>
<td>Excess of refrigerant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Condenser fan failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Loose connection of the magnetic clutch electrical circuit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Defective sensor</td>
</tr>
</tbody>
</table>
## 4- Troubleshooting

### 2. Abnormal noise

<table>
<thead>
<tr>
<th>Issue</th>
<th>Symptom</th>
<th>Possible cause</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Abnormal vibration after turning on the A/C switch</td>
<td>Compressor installation bolt is loose</td>
<td>Increase tightening torque of the loose bolts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wide gap at the attaching portion between the compressor and the bracket</td>
<td>Improve the compressor attaching portion</td>
</tr>
<tr>
<td></td>
<td>Abnormal noise from the compressor body</td>
<td>Compressor body internal component damage</td>
<td>Replace the compressor</td>
</tr>
<tr>
<td>B</td>
<td>The magnetic clutch has a backlash and slips</td>
<td>Magnetic clutch damage</td>
<td>Replace the magnetic clutch</td>
</tr>
<tr>
<td></td>
<td>Strange noise when the magnetic clutch engages</td>
<td>Air gap too wide</td>
<td>Adjust air gap or replace magnetic clutch</td>
</tr>
<tr>
<td></td>
<td>Armature slips / does not engage when the compressor is running</td>
<td>Magnetic clutch friction, slippery surface</td>
<td>Charge battery or replace magnetic clutch</td>
</tr>
<tr>
<td>C</td>
<td>Armature does not rotate when magnetic clutch engages</td>
<td>Belt slipping</td>
<td>Replace the compressor if locked. Readjust the belt tension if the belt is loose</td>
</tr>
</tbody>
</table>

### 3. Smoke

<table>
<thead>
<tr>
<th>Issue</th>
<th>Symptom</th>
<th>Possible cause</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>The magnetic clutch slips / does not engage when the compressor is running</td>
<td>Magnetic clutch air gap too wide</td>
<td>Adjust air gap or replace magnetic clutch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low magnetic clutch voltage</td>
<td>Charge battery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Magnetic clutch friction, greasy surface</td>
<td>Clean friction surface or replace magnetic clutch</td>
</tr>
<tr>
<td>B</td>
<td>The magnetic clutch slips / does not engage when the compressor is running</td>
<td>Belt alignment is not correct</td>
<td>Adjust the compressor installation position</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Magnetic clutch belt is greasy</td>
<td>Clean or replace the belt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Magnetic clutch belt tension is loose</td>
<td>Adjust belt tension</td>
</tr>
<tr>
<td>C</td>
<td>The magnetic clutch does not engage</td>
<td>Coil open or shorted</td>
<td>Replace the magnetic clutch</td>
</tr>
<tr>
<td>D</td>
<td>Refrigerant / oil is blowing out</td>
<td>Refrigerant leaking, uncoupled piping or piping burst</td>
<td>Fix the refrigerant leakage then fill with refrigerant until having the right amount</td>
</tr>
</tbody>
</table>
# A/C cycle diagnosis by gauge pressure

Following is a diagnosis procedure to connect gauge manifold to A/C cycle, measure suction and discharge pressures and analyze the defects of the cycle.

**Operation conditions of the A/C cycle for pressure measuring:**
1. Ambient temperature: 30 - 35 °C
2. Engine speed: 1,500 rpm
3. A/C switch: ON
4. Blower speed: high
5. Temperature control: full cold

<table>
<thead>
<tr>
<th>Gauge pressure indication</th>
<th>Cause</th>
<th>Confirmation method</th>
<th>Action to take</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure is normal</td>
<td>A/C cycle operates normally. If there is any defect (poor cooling performance), there must be another cause</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both discharge and suction pressures are low</td>
<td>Refrigerant shortage</td>
<td>Connect gauge manifold to cycle</td>
<td>Recover refrigerant, then refill with the right amount of refrigerant</td>
</tr>
<tr>
<td>Suction pressure becomes vacuum</td>
<td>Receiver dryer is clogged</td>
<td>Temperature difference between inlet and outlet pipes. Dryer is covered with frost</td>
<td>Replace parts</td>
</tr>
<tr>
<td></td>
<td>Expansion valve is clogged</td>
<td>Expansion valve was covered with frost</td>
<td>Clean or replace part</td>
</tr>
<tr>
<td></td>
<td>Enclosure leakage from Expansion valve's temperature sensing tube. (Expansion valve operates to close the valve opening)</td>
<td>Outlet side of Expansion valve is not cooling. (Low side of gauge indicates vacuum)</td>
<td>Replace part</td>
</tr>
<tr>
<td></td>
<td>Temperature sensing device at outlet air is defective</td>
<td>Evaporator becomes frozen up</td>
<td>Adjust or replace the part</td>
</tr>
<tr>
<td></td>
<td>Refrigerant piping is clogged or crashed</td>
<td>If any part between the dryer and the compressor is clogged or crashed, the low side pressure becomes vacuum</td>
<td>Adjust or replace the part</td>
</tr>
</tbody>
</table>

- Discharge pressure: around 1.0 - 1.7 MPaG (10 - 17 kgf/cm²)
- Suction pressure: around 0.13 - 0.20 MPaG (1.3 - 2.0 kgf/cm²)
<table>
<thead>
<tr>
<th>Gauge pressure indication</th>
<th>Cause</th>
<th>Confirmation method</th>
<th>Action to take</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both discharge and suction pressures are high</td>
<td>Excess of refrigerant</td>
<td>Connect gauge manifold to cycle</td>
<td>Recover refrigerant, then refill with the right amount of refrigerant</td>
</tr>
<tr>
<td>Condenser cooling malfunction</td>
<td>Condenser becomes muddy and fins are clogged and collapsed. Defect of cooling fan rotation. Malfunction of fan motor for condenser.</td>
<td></td>
<td>Clean up, hand repair of fin and replacement</td>
</tr>
<tr>
<td>Misaligned Expansion valve or thermal sensing tube of the Expansion valve is not fit on regularly. (Excess opening of Expansion valve)</td>
<td>Defective refrigerant flow control, the thermal sensing tube is not closely in contact with the evaporator pipe</td>
<td></td>
<td>Adjustment or replacement</td>
</tr>
<tr>
<td>Air mixed in refrigeration cycle</td>
<td>Just after compressor stops, discharge pressure will come down immediately to 0.29 - 0.39 MPaG (3 - 4 kgf/cm²)</td>
<td></td>
<td>Evacuate air from cycle, the charge with the adequate amount of refrigerant</td>
</tr>
<tr>
<td>Discharge pressure is high and suction pressure is low</td>
<td>Refrigerant cycle is clogged between compressor and condenser</td>
<td>Appreciable temperature difference at the clogged location</td>
<td>Clean up inside the cycle or replace the part</td>
</tr>
<tr>
<td>Discharge pressure is low and suction pressure is high</td>
<td>Defect of the compressor valve or gasket</td>
<td>Discharge and suction pressures balance immediately after the compressor stops. (Defective compression of compressor)</td>
<td>Replace the compressor</td>
</tr>
</tbody>
</table>
### 5- Tightening torques

<table>
<thead>
<tr>
<th>Part</th>
<th>Thread size</th>
<th>Tightening torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Center bolt</td>
<td>M8 x 1.25</td>
<td>20 - 22 (2.0 - 2.2, 14 - 16)</td>
</tr>
<tr>
<td>2. Field coil screws</td>
<td>M6 x 1.0</td>
<td>4.2 - 7.2 (0.4 - 0.7, 3.1 - 5.3)</td>
</tr>
<tr>
<td>3. Bolt</td>
<td>M10 x 1.5</td>
<td>25 - 30 (2.5 - 3.0, 18 - 22)</td>
</tr>
<tr>
<td>4. Oil filler plug</td>
<td>M10 x 1.5</td>
<td>14 - 16 (1.4 - 1.6, 10 - 12)</td>
</tr>
<tr>
<td>5. Connector bolt</td>
<td>M8 x 1.25</td>
<td>20 - 24 (2.0 - 2.4, 14 - 17) for connectors</td>
</tr>
</tbody>
</table>

Unit: N·m (kgf·m, lbf·ft.)
Magnetic clutch

Removal

1. Remove the center bolt using the drive plate holder (597031-3000) to prevent the armature assembly from rotating.

2. Remove the armature assembly.

3. Remove the snap ring using external snap ring pliers.

4. Position the center pulley puller (597033-1700) at the end of the driveshaft.

5. Attach a suitable pulley puller to the pulley. Hook the puller claws to the edge of the pulley as shown.

6. Tighten the center pulley puller bolt to remove the pulley.

**CAUTION!**
Do not clip the puller claws into the pulley groove to prevent pulley groove damage.
5. Remove the lead wire bushing of the field coil using the remover (597035-3820).
6. Remove the three field coil/compressor screws. Then remove the field coil.

**CAUTION!**
Do not hold the field coil by the harness.

**Inspection**
1. If the contact surface has been damaged by excessive heat, the armature and pulley must be replaced.
2. Check the appearance of the pulley assembly. If the contact surface of the pulley is excessively grooved due to slippage, both the pulley and the armature must be replaced. The contact surface of the pulley assembly must be cleaned with a suitable solvent before reinstallation.
3. Check the field coil for a loose connector or cracked insulation.
6- Service procedures - Magnetic clutch

Magnetic clutch

Installation

1. Install the field coil on the compressor (with the harness on top) and tighten the mounting screws to the specified torque.
   Specified torque: 4.2 ~ 7.2 N·m
   {0.4 ~ 0.7 kgf·m, 3.1 ~ 5.3 lbf·ft}

2. Carefully place the wire harness bushing.

3. Install the pulley assembly using the pulley installer (597034-5700) and a hand press.

4. Install the snap ring (beveled edge up) using external snap ring pliers.
5. Install the armature assembly on the driveshaft together with the original shim(s). Press the armature assembly down by hand.
6. Install the center bolt and tighten to the specified torque using the drive plate holder (597031-3000) to prevent the armature assembly from rotating.
   Specified torque: 20 ~ 22 N·m
   {2.0 ~ 2.2 kgf·m, 14 ~ 16 lbf·ft}

   **CAUTION!**

   After tightening the center bolt, check that the pulley rotates smoothly.

7. Check that the clutch clearance is as specified. If necessary adjust the clearance using shim(s).

   Adjusting shims are available in the following thickness:

<table>
<thead>
<tr>
<th>Shim Part No.</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>596541-2600</td>
<td>0.1 mm (0.004 in)</td>
</tr>
<tr>
<td>596541-2700</td>
<td>0.3 mm (0.012 in)</td>
</tr>
<tr>
<td>596541-2800</td>
<td>0.5 mm (0.020 in)</td>
</tr>
<tr>
<td>596541-2900</td>
<td>0.8 mm (0.031 in)</td>
</tr>
</tbody>
</table>

   Specified clearance: 0.3 ~ 0.6 mm
   {0.01 ~ 0.02 in}

8. Run-in the clutch as described on page 19.
Shaft seal assembly

Removal

1. Remove the magnetic clutch assembly as described on page 27.
2. Remove the four bolts securing the connectors, and then remove the connectors and strainer from the cylinder shaft assembly.
3. Remove the oil filler plug and then drain the oil.
4. Remove the five bolts securing the heads.

5. Alternately tap the two projections on the front head using the remover (597035-0500) and a mallet to remove the front cylinder head.

6. Remove the shaft seal assembly using the remover (597035-4700).
7- Service procedures - Shaft seal assembly

**Inspection**

The shaft seal must not be reused. Always use a new shaft seal when reassembling the compressor. Ensure that the seal seat is free from lint and dirt that could damage the shaft seal lip.

**Installation**

1. Clean the portion of the front cylinder head where the shaft seal is to be assembled.
2. Assemble the shaft seal on the remover (597035-4700).
3. Coat the shaft seal well with compressor oil and install the shaft seal in the front cylinder head.
4. Remove the shaft seal remover.
5. Position the guide (597067-6100) on the shaft.
6. Coat the new O-ring with clean compressor oil and install it in the front cylinder head.
7. Install the front cylinder head.

**CAUTION!**

Align the roll pins and tap the head lightly and evenly with a plastic hammer.

8. Remove the guide (597067-6100).
9. Install the five bolts from the front cylinder head side and tighten them to the specified torque.

   **Specified torque:** 25 ~ 30 N·m
   
   \{2.5 ~ 3.0 kgf·m, 18 ~ 22 lbf·ft\}

   Tighten each bolt gradually (in three or more stages) to ensure the specified torque.
10. Turn the drive shaft 2 ~ 3 times by hand to ensure that the shaft rotates smoothly.
11. Fill the compressor with the specified amount of clean compressor oil through the oil filler.

12. Install the oil filler plug with a new O-ring, and tighten it to the specified torque.
   Specified torque: 14 ~ 16 N·m
   \{1.4 ~ 1.6 kgf·m, 10 ~ 12 lbf·ft\}

13. Install the strainer in the suction port.

**When the connectors are installed**

14. Fit plates to the suction and discharge connections, and tighten them to the specified torque.
   Specified torque: 20 ~ 24 N·m
   \{2.0 ~ 2.4 kgf·m, 14 ~ 17 lbf·ft\}

15. Install the magnetic clutch as described on page 29.

16. Run-in the compressor as described on page 19.

17. Perform the leak test as described on page 20.
Cylinder heads (Front & Rear)

Disassembly

1. Remove the magnetic clutch assembly as described on page 27.
2. Remove the four bolts securing the connectors, and then remove the connectors and strainer from the cylinder shaft assembly.
3. Remove the oil filler plug and then drain the oil.
4. Remove the five bolts securing the heads.
5. Alternately tap the two projections on the front head using the remover (597035-0500) and a mallet to remove the front cylinder head.
6. Remove the front valve plate assembly and then the suction valve (in that order).
7. Remove and discard the O-ring from the front cylinder head.
8. Remove all gasket material from the front cylinder head and the front valve plate.
9. Screw two bolts into the opposite sides of the rear cylinder head and tap alternate bolts lightly with a plastic hammer to remove the head.

**CAUTION!**

Screw the bolts fully into the head to prevent rear head thread damage.

10. Remove the rear valve plate assembly and then the suction valve (in that order).
11. Remove and discard the O-ring from the rear cylinder head.
12. Remove all gasket material from the rear cylinder head and the rear valve plate.
13. Remove the gear pump from the rear cylinder head or the end of the driveshaft.
8- Service procedures - Cylinder head

Inspection

Check the front and rear valve plates for scratched, bent or damaged parts.
Inspect both cylinder heads and both valve plates for nicks or burrs on the sealing surfaces.
Clean both cylinder heads and both valve plates or replace them if they are cracked or damaged.
Check that none of the passages in the valve plates are blocked.
Reassembly

Rear cylinder head
1. Place the cylinder shaft assembly on the bench with the rear side up.
2. Install the rear suction valve so that it matches the roll pins.

**CAUTION!**
Ensure each valve matches each cylinder valve escape groove.

3. Install the rear valve plate on the rear suction valve.

**CAUTION!**
Do not mistake the front and rear valve plates.

4. Coat the new gasket with clean compressor oil and install it on the rear valve plate.
5. Coat the new gear pump with clean compressor oil and install it on the end of the drive shaft.

6. Coat the new O-ring with clean compressor oil and install it on the rear cylinder head.
7. Install the rear cylinder head.
   When positioning the head, ensure the gear pump is inserted into the hole in the cylinder head.
8- Service procedures- Cylinder head

Front cylinder head
1. Place the cylinder shaft assembly on the bench with the front side up.
2. Install the front suction valve so that it matches the spring pins.

**CAUTION!**
Ensure each valve matches each cylinder’s valve escape groove.

3. Install the front valve plate on the front suction valve.
4. Coat the new gasket with clean compressor oil and install it on the front valve plate.
5. Position the guide (597067-6100) on the shaft.
6. Coat the new O-ring with clean compressor oil and install it on the front cylinder head.
7. Install the front cylinder head.

**CAUTION!**
Align the roll pins and tap the head lightly and evenly with a plastic hammer.

8. Remove the guide (597067-6100).
9. Install the five bolts from the front cylinder head side and tighten them to the specified torque.

**Specified torque: 25 ~ 29 N·m**
{2.5 ~ 3.0 kgf·m, 18 ~ 22 lbf·ft}
Tighten each bolt gradually (in three or more stages) to ensure the specified torque.

10. Turn the drive shaft 2 ~ 3 times by hand to ensure that the shaft rotates smoothly.
11. Fill the compressor with the specified amount of clean compressor oil through the oil filler.
12. Install the oil filler plug with a new O-ring, and tighten it to the specified torque.

**Specified torque: 14 ~ 16 N·m**
{1.4 ~ 1.6 kgf·m, 10 ~ 12 lbf·ft}

13. Install the strainer in the suction port.

**When the connectors are installed**
14. Fit blanking plates to the suction and discharge connections, and tighten it to the specified torque.

**Specified torque: 20 ~ 24 N·m**
{2.0 ~ 2.4 kgf·m, 14 ~ 17 lbf·ft}

15. Install the magnetic clutch (see p. 29).
17. Perform the leak test (see p. 20).
In addition to standard tools, numerous special tools are necessary to service the Valeo TM31 compressor. The use of these special tools enables prompt and correct compressor service.

The special tools are classified into three groups: those for magnetic clutch disassembly and reassembly; those for compressor disassembly and reassembly; and those for testing and running-in operation.

**MAGNETIC CLUTCH TOOLS**

<table>
<thead>
<tr>
<th>Part name</th>
<th>Part No.</th>
<th>Shape</th>
<th>Reference page</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive plate holder</td>
<td>597031-3000</td>
<td></td>
<td>27 31</td>
<td>For fixing drive plate</td>
</tr>
<tr>
<td>Center pulley puller</td>
<td>597033-1700</td>
<td></td>
<td>27</td>
<td>For removing pulley</td>
</tr>
<tr>
<td>Remover</td>
<td>597035-3820</td>
<td></td>
<td>28</td>
<td>For removing lead wire bushing</td>
</tr>
<tr>
<td>Installer</td>
<td>597034-5700</td>
<td></td>
<td>30</td>
<td>For installing pulley</td>
</tr>
</tbody>
</table>
## Compressor tools

<table>
<thead>
<tr>
<th>Part name</th>
<th>Part No.</th>
<th>Shape</th>
<th>Reference page</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remover</td>
<td>597035-0500</td>
<td></td>
<td>32 35</td>
<td>For removing cylinder head and cylinder block</td>
</tr>
<tr>
<td>Remover</td>
<td>597035-4700</td>
<td></td>
<td>32 33</td>
<td>For removing and installing shaft seal</td>
</tr>
<tr>
<td>Guide</td>
<td>597067-6100</td>
<td></td>
<td>33 39</td>
<td>For installing shaft seal</td>
</tr>
</tbody>
</table>

## Test and inspection tools

<table>
<thead>
<tr>
<th>Part name</th>
<th>Part No.</th>
<th>Shape</th>
<th>Reference page</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connector</td>
<td>T44375C</td>
<td></td>
<td>19</td>
<td>For high pressure port</td>
</tr>
<tr>
<td>Connector</td>
<td>T44373C</td>
<td></td>
<td>19</td>
<td>For low pressure port</td>
</tr>
<tr>
<td>O-ring</td>
<td>569300-9200</td>
<td></td>
<td>19</td>
<td>For maintaining connector air tightness</td>
</tr>
<tr>
<td>Valve assembly</td>
<td>597017-1120</td>
<td></td>
<td>20</td>
<td>For charging refrigerant</td>
</tr>
<tr>
<td>Gas leak detector</td>
<td>597001-1020</td>
<td></td>
<td>20</td>
<td>For detecting gas leaks</td>
</tr>
</tbody>
</table>
9 - Service tools

Drive plate holder

Center Pulley Puller
**9 - Service tools**

**Remover Bush**

Unless otherwise specified, the edges are slightly chamfered to avoid burrs and fluff.

**Installer Pulley**

Unless otherwise specified, the edges are slightly chamfered to avoid burrs and fluff.
10- Service parts

1. Compressor body service kits, sets and parts

<table>
<thead>
<tr>
<th>Item</th>
<th>Part name</th>
<th>Reference</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OVERHAUL KIT (O-RING SET + GASKET SET + SHAFT SEAL)</td>
<td>5699306221</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>O-RING SET</td>
<td>569920-4420</td>
<td>-</td>
</tr>
<tr>
<td>15,20</td>
<td>O-ring body (front &amp; rear head)</td>
<td>569300-8900</td>
<td>n=2</td>
</tr>
<tr>
<td>18</td>
<td>O-ring drain</td>
<td>569300-4000</td>
<td>n=1</td>
</tr>
<tr>
<td></td>
<td>GASKET SET</td>
<td>569941-1921</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>Gasket front head</td>
<td>569310-6000</td>
<td>n=1</td>
</tr>
<tr>
<td>23</td>
<td>Gasket rear head</td>
<td>569310-6100</td>
<td>n=1</td>
</tr>
<tr>
<td>9</td>
<td>Gasket (bolt) 7 per set</td>
<td>569310-6200</td>
<td>n=7</td>
</tr>
<tr>
<td></td>
<td>SHAFT SEAL (for service)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>Shaft seal</td>
<td>569942-1320</td>
<td>n=1</td>
</tr>
<tr>
<td></td>
<td>OTHER COMPRESSOR PARTS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>Valve plate assy (front)</td>
<td>561420-2120</td>
<td>n=1</td>
</tr>
<tr>
<td>22</td>
<td>Valve plate assy (rear)</td>
<td>561420-2020</td>
<td>n=1</td>
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<td>14,21</td>
<td>Suction valve</td>
<td>561410-1300</td>
<td>n=2</td>
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</table>

* see product description - Exploded view p.7

2. Oil

<table>
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<tr>
<th>Item</th>
<th>Part name</th>
<th>Reference</th>
<th>Quantity</th>
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<tbody>
<tr>
<td></td>
<td>ZXL 100PG</td>
<td>569900-0600</td>
<td>250 cc</td>
</tr>
</tbody>
</table>
Valeo **TM31** Compressor for Bus Air-Conditioning

Valeo **TM31** Benefits

- High reliability
- Integration flexibility
- Great cooling capacity
- Enhanced performance
- Lower fuel consumption
- Compact & robust design
- Improved field serviceability
- Reduced noise and vibrations
- Staggering value through innovation

www.valeocompressors.com

**Europe, Middle East & Africa**
ul. Bestwinska
43-500 Czechowice, Poland
Phone: +48 (0) 3273 79 775
Email: valeo.compressors.europe.sales.mailbox@valeo.com

**Americas**
2520 Esters Blvd #100
Dallas, TX 75261 United States
Phone: +1 972 456 1077
Fax: +1 972 456 1090
Email: vc-dallas-sales@valeo.com

**China**
No.2677 Shiji Avenue, Eco. & Tec. Dvt Zone 130031 Changchun, Jilin PRC
Phone: +86 (0) 431  8499 2025
Fax: +86 (0) 431  8499 2004
Email: vc-changchun-sales@valeo.com

**Asia**
39 Sendai, Kumagaya-shi
Saitama-ken 360-0193 Japan
Phone: +81 (0) 48 539 3800
Fax: +81 (0) 48 539 3843
Email: vc-oura-sales@valeo.com