Staffa Fixed Displacement Hydraulic Motor
1. GENERAL DESCRIPTION

Kawasaki “Staffa” high torque, low speed radial piston motors use hydrostatic balancing techniques to achieve high efficiency, combined with good breakout torque and smooth running capability.

The HMC series dual displacement models have two pre-set displacements which can be chosen from a wide range to suit specific application requirements. The displacements are hydraulically selected by a directional control valve which can be remote from, or mounted directly on, the motor. Displacements can be changed while the motor is running.

The range of HMC motors extends from the HMC010 of 202 cm³ (12.3 in³) to the HMC325 of 5330 cm³ (325 in³) displacement.

These motors are also available in a continuously variable version using either hydro-mechanical or electro-hydraulic control methods.

Other mounting options are available on request to match many of the competitor interfaces.

2. FUNCTIONAL SYMBOLS

All model types with variants in model code positions 6 & 7.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-F(M)3-X-</td>
<td>P1/P2 DR</td>
</tr>
<tr>
<td>-SO3-X-</td>
<td>PC A P B T</td>
</tr>
<tr>
<td>-F(M)2-X-</td>
<td>Min. DR</td>
</tr>
<tr>
<td>-F(M)3-C-</td>
<td>P1/P2 DR</td>
</tr>
<tr>
<td>-SO3-C-</td>
<td>PC A P B T</td>
</tr>
<tr>
<td>-F(M)2-C-</td>
<td>Min. DR</td>
</tr>
<tr>
<td>-F(M)3-C1</td>
<td>(F(M)3-C2- in brackets)</td>
</tr>
<tr>
<td>-SO3-C1</td>
<td>(SO3-C2- in brackets)</td>
</tr>
</tbody>
</table>

▲ -F(M)3-models only
3. MODEL CODE

Features shown in brackets ( ) may be left blank according to requirements. All other features must be specified.

\[(F**)\cdot(HM(*))C045\cdot**\cdot**\cdot**\cdot(T*)\cdot30\cdot(PL**)\]

1. **FLUID TYPE**
   - Blank = Petroleum oil
   - F3 = Phosphate ester (HFD fluid)
   - F11 = Water-based fluids (HFA, HFB and HFC)

2. **MODEL TYPE**
   - Blank = Standard ("HMC")
   - M = To NCB (UK) specification 463/1981 ("HMMC")

3. **SHAFT TYPE**
   - P* = Cylindrical shaft with parallel key
   - S* = Cylindrical, 17 splines to BS 3550
   - Q* = Female, 21 splines to BS 3550
   - Z* = Cylindrical shaft to DIN 5480 (W55 x 3 x 7h)

   * For installations where shaft is vertically upwards specify "V" after shaft type letter to ensure that additional high level drain port is provided.

4. **HIGH DISPLACEMENT CODE**
   - 35 to 45 in³, in 5 in³ steps

5. **LOW DISPLACEMENT CODE**
   - 05 to 30 in³, in 5 in³ steps

6. **MAIN PORT CONNECTIONS**
   - Models with 3" distributor valve
   - SO3 = 6-bolt (UNF) flange (Staffa original valve housing)
   - F3 = SAE 1 1/4" 4-bolt (UNC) flanges
   - FM3 = SAE 1 1/4" 4-bolt (metric) flanges
   - Models with 2 1/4" distributor valve
   - F2 = SAE 1" 4-bolt (UNC) flanges
   - FM2 = SAE 1" 4-bolt (metric) flange

   ▼ 2 1/4" valve reduces overall length but may affect maximum permissible speed and power - consult Kawasaki.

7. **DISPLACEMENT CONTROL PORTS (AND SHUTTLE VALVE)**
   - Threaded ports/bi-directional shaft rotation:
     - X = X and Y ports G 1/4" (BSPF to ISO 228/1)
   - ISO 4401 size 03 mounting face/bi-directional shaft rotation:
     - C = No shuttle valve
     - CS = With shuttle valve
   - ISO 4401 size 03 mounting face/uni-directional shaft rotation (viewed on shaft end):
     - C1 = Control pressure from main port 1 (shaft rotation clockwise with flow into port 1)
     - C2 = Control pressure from main port 2 (shaft rotation counter-clockwise with flow into port 2)

   ▲ Only available with "F(M)3" type main port connections

8. **TACHO/ENCODER DRIVE**
   - T = Staffa original tacho drive
   - T1 = Suitable for Hohner 3000 series encoders. (Encoder to be ordered separately)
   - Omit if not required.

9. **DESIGN NUMBER, 30 SERIES**
   - Subject to change. Installation and performance details remain unaltered for design numbers 30 to 39 inclusive.

10. **SPECIAL FEATURES**
    - PL** = Non-catalogued features, e.g.:
      - High pressure shaft seals
      - Alternative port connections
      - Stainless steel shaft sleeves
      - Alternative encoder and tacho drives
      - Motor valve housing orientation
      - Shaft variants
      - Special paint

    ** Number assigned as required to specific customer build.
4. PERFORMANCE DATA

Performance data is valid for Staffa HMC045 motors fully run in and operating with petroleum oil. Leakage values are at fluid viscosity of 50 cSt (232 SUS).

MOTOR SELECTION

Use table 1 to select appropriate displacements for each application. Refer to table 2 for pressure and speed limits when using fire-resistant fluids.

**TABLE 1**

<table>
<thead>
<tr>
<th>Displacement code* (Model code positions A &amp; B)</th>
<th>45</th>
<th>40</th>
<th>35</th>
<th>30</th>
<th>25</th>
<th>20</th>
<th>15</th>
<th>10</th>
<th>05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement cm³</td>
<td>737</td>
<td>655</td>
<td>573</td>
<td>491</td>
<td>410</td>
<td>327</td>
<td>246</td>
<td>163</td>
<td>81</td>
</tr>
<tr>
<td>Volume/r in³</td>
<td>45</td>
<td>40</td>
<td>35</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Average actual running torque Nm/bar</td>
<td>10.65</td>
<td>9.4</td>
<td>8.04</td>
<td>6.88</td>
<td>5.68</td>
<td>4.4</td>
<td>3.2</td>
<td>1.55</td>
<td>0</td>
</tr>
<tr>
<td>Volume/r in³ lbf ft/psi</td>
<td>0.542</td>
<td>0.478</td>
<td>0.409</td>
<td>0.35</td>
<td>0.289</td>
<td>0.224</td>
<td>0.163</td>
<td>0.077</td>
<td>0</td>
</tr>
<tr>
<td>Max. continuous speed r/min</td>
<td>450</td>
<td>550</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>1000</td>
</tr>
<tr>
<td>Max. continuous kW</td>
<td>80</td>
<td>72</td>
<td>64</td>
<td>54</td>
<td>44</td>
<td>34</td>
<td>24</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Max. continuous output power hp</td>
<td>108</td>
<td>97</td>
<td>85</td>
<td>72</td>
<td>59</td>
<td>46</td>
<td>33</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Max. intermittent kW</td>
<td>96</td>
<td>85</td>
<td>78</td>
<td>66</td>
<td>55</td>
<td>42</td>
<td>31</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Max. intermittent output power hp</td>
<td>126</td>
<td>114</td>
<td>104</td>
<td>88</td>
<td>74</td>
<td>57</td>
<td>41</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Max. continuous pressure bar</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>17</td>
</tr>
<tr>
<td>Max. continuous pressure psi</td>
<td>3626</td>
<td>3626</td>
<td>3626</td>
<td>3626</td>
<td>3626</td>
<td>3626</td>
<td>3626</td>
<td>3626</td>
<td>250</td>
</tr>
<tr>
<td>Max. intermittent pressure bar</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td>17</td>
</tr>
<tr>
<td>Max. intermittent pressure psi</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td>250</td>
</tr>
</tbody>
</table>

* Intermediate displacements are available to special order.
* See “Small displacements” page 7 for information about higher pressure applications.

**TABLE 2**

<table>
<thead>
<tr>
<th>Fluid type</th>
<th>Pressure, bar (psi)</th>
<th>Max. speed r/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFA, 5/95% oil-in-water emulsion</td>
<td>103 (1500)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>138 (2000)</td>
<td>50% of limits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>for petroleum oil</td>
</tr>
<tr>
<td>HFB, 60/40% water-in-oil emulsion</td>
<td>138 (2000)</td>
<td>172 (2500)</td>
</tr>
<tr>
<td></td>
<td>As for petroleum oil</td>
<td></td>
</tr>
<tr>
<td>HFC, water glycol</td>
<td>103 (1500)</td>
<td>138 (2000)</td>
</tr>
<tr>
<td></td>
<td>50% of limits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>for petroleum oil</td>
<td></td>
</tr>
<tr>
<td>HFD, phosphate ester</td>
<td>250 (3625)</td>
<td>275 (4000)</td>
</tr>
<tr>
<td></td>
<td>As for petroleum oil</td>
<td></td>
</tr>
</tbody>
</table>

**RATING DEFINITIONS**

- **CONTINUOUS RATING**
  For continuous duty the motor must be operating within each of the maximum values for speed, pressure and power as specified for each displacement code.

- **INTERMITTENT RATING**
  Operation within the intermittent power rating (up to the maximum continuous speed) is permitted on a 15% duty basis, for periods up to 5 minutes maximum.

- **INTERMITTENT MAX. PRESSURE**
  Up to 275 bar (4000 psi) is allowable on the following basis:
  (a) Up to 50 r/min: 15% duty for periods up to 5 minutes maximum.
  (b) Over 50 r/min: 2% duty for periods up to 30 seconds maximum.
The torque curves indicate, for each displacement, the maximum output torque of the motor with an inlet pressure of 250 bar (3626 psi) and zero output pressure. High return line pressures will reduce the torque for any given pressure differential.

The solid line portion of each curve indicates the levels of maximum torque and speed that are permitted on a “continuous” basis.

The dotted portion of each curve indicates the levels of torque and speed at which the motor can operate at an “intermittent” rating.

The starting torques shown on the graph are average and will vary with crankshaft angle.
The nomograph allows the median bearing life to be determined for conditions of:
1. No side load and no axial thrust
2. Side load and no axial thrust

To determine L10 life predictions per ISO 281-1-1977 multiply the mean figure by 0.2.

For more precise life prediction, or where axial thrusts are incurred, a computer analysis can be provided by Kawasaki on receipt of machine duty cycle.

**SHAFT STRESS LIMIT**
The shaft stress limit in the nomograph is based on the fatigue rating of the shaft. Infrequent loading above these limits may be permitted; consult Kawasaki.

**VOLUMETRIC EFFICIENCY**
The nomograph on page 7 enables the average volumetric efficiency, crankcase (drain) leakage and “winch slip”/shaft creep speed to be estimated.

Example (follow chain dotted line):
Given:
1. Pressure ............175 bar (2500 psi)
2. Displacement code ..........40 (in³/r)
3. Speed .................200 r/min
To obtain:
4. Volumetric efficiency .........93.5%
5. Crankcase leakage ............3.5 l/min
6. Shaft creep speed ..............8.5 r/min

The shaft creep speed occurs when the load attempts to rotate the motor against closed ports as may occur, for example, in winch applications.
5. CIRCUIT AND APPLICATION NOTES

DISPLACEMENT SELECTION
To select either displacement, a pressure at least equal to 2/3 of the motor inlet/outlet pressure (whichever is higher) is required. In most applications the motor inlet pressure will be used.

For inlet/outlet pressures below 3.5 bar (50 psi) a minimum control pressure of 3.5 bar (50 psi) is required. In the event of loss of control pressure the motor will shift to its highest displacement.

For rapid reversing applications it is recommended to externally source the control oil supply direct from the system pump (use displacement control type “X” or “C” - not “CS”, “C1” or “C2” - in model code position 7).

STARTING TORQUES
The starting torques shown on the graph on page 4 are average and will vary with system parameters. For motors with low displacement below 15 in³ and starting under load it is recommended to select high displacement for start-up.

LOW SPEED OPERATION
(High displacement mode)
Minimum operating speeds are determined by load conditions (load inertia, drive elasticity, etc.) For operation at speeds below 6 r/min consult Kawasaki.

SMALL DISPLACEMENTS
(5 in³ and below)
The pressures given in the table on page 4 for displacement code “05” (and below) are based on 1000 r/min output shaft speed. These pressures can be increased for shaft speeds less than 1000 r/min; consult Kawasaki for details.

In addition to 5 in³, a zero swept volume displacement (for free wheeling requirements) is available on request, subject to Kawasaki approving the application.

HIGH BACK PRESSURE
When both inlet and outlet ports are pressurized continuously, the lower pressure in one port must not exceed 70 bar (1000 psi) at any time. Consult Kawasaki on applications beyond this limit. Note that high back pressures reduce the effective torque output of the motor.

BOOST PRESSURE
When operating as a motor the outlet pressure should equal or exceed the crankcase pressure. If pumping occurs (i.e. overrunning loads) then a positive pressure, “P”, is required at the motor ports. Calculate “P” (bar/psi) from the appropriate formula:

\[ P (\text{bar}) = 1 + \frac{N^2 \times V^2}{D_{\text{bar}}} + C \]

Where:
- \( C \) = crankcase pressure, bar
- \( D \) = see table
- \( N \) = speed, r/min
- \( V \) = displacement, cm³/r

\[ P (\text{bar}) = 1 + \frac{N^2 \times V^2}{D_{\text{psi}}} + C \]

Where:
- \( C \) = crankcase pressure, psi
- \( D \) = see table
- \( N \) = speed, r/min
- \( V \) = displacement, cm³/r

<table>
<thead>
<tr>
<th>Port</th>
<th>D value connection type</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3, FM3, S03</td>
<td>D_{\text{bar}} = 1.6 \times 10^{10} \ D_{\text{psi}} = 4.1 \times 10^6</td>
</tr>
<tr>
<td>F2, FM2</td>
<td>D_{\text{bar}} = 3.7 \times 10^9 \ D_{\text{psi}} = 9.5 \times 10^8</td>
</tr>
</tbody>
</table>

The flow rate of oil needed for the make-up system can be estimated from the crankcase leakage figure (see Volumetric Efficiency graph above) plus an allowance for changing displacement; e.g. to change high to low in 0.25 sec requires 15 l/min (4.0 USgpm).

Allowance should be made for other system losses and also for “fair wear and tear” during the life of the motor, pump and other system components.
COOLING FLOW
Operation within the continuous ratings does not require any additional cooling.

For operating conditions above “continuous”, up to the “intermittent” ratings, additional cooling oil may be required. This can be introduced through the spare crankcase drain holes, or in special cases through the valve spool end cap. Consult Kawasaki about such applications.

MOTOR CASING PRESSURE
With the standard shaft seal fitted, the motor casing pressure should not exceed 3,5 bar (50 psi). On installations with long drain lines a relief valve is recommended to prevent over-pressurizing the seal.

Notes:
1. The casing pressure at all times must not exceed either the motor inlet or outlet pressure.
2. High pressure shaft seals are available to special order for casing pressures of:
   - Continuous: 10 bar (150 psi)
   - Intermittent: 15 bar (225 psi)
3. Check installation dimensions (page 9) for maximum crankcase drain fitting depth.

6. HYDRAULIC FLUIDS
Dependent on motor (see Model Code position 1) suitable fluids include:
- Antiwear hydraulic oils.
- Phosphate esters (HFD fluids)
- Water glycols (HFC fluids)
- 60/40% water-in-oil emulsions (HFB fluids)
- 5/95% oil-in-water emulsions (HFA fluids)

■ Reduced pressure and speed limits, see page 4.

Viscosity limits when using any fluid except oil-in-water (5/95) emulsions are:
Max. off load .......... 2000 cSt (9270 SUS)
Max. on load ........... 150 cSt (695 SUS)
Optimum .................. 50 cSt (232 SUS)
Minimum .................. 25 cSt (119 SUS)

PETROLEUM OIL RECOMMENDATIONS
The fluid should be a good hydraulic grade, non-detergent petroleum oil. It should contain anti-oxidant, anti-foam and demulsifying additives. It must contain antiwear or EP additives. Automatic transmission fluids and motor oils are not recommended.

7. TEMPERATURE LIMITS
Ambient min. .................. -30°C (-22°F)
Ambient max. .................. +70°C (158°F)

Max. operating temperature range

<table>
<thead>
<tr>
<th>Petroleum oil</th>
<th>Water-containing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min.</td>
<td>-20°C (-4°F)</td>
</tr>
<tr>
<td>Max.*</td>
<td>+80°C (175°F)</td>
</tr>
</tbody>
</table>

* To obtain optimum service life from both fluid and hydraulic system components 65°C (150°F) normally is the maximum temperature except for water-containing fluids.

8. FILTRATION
Full flow filtration (open circuit) or full boost flow filtration (closed circuit) to ensure system cleanliness of ISO 4406/1986 code 18/14 or cleaner.

9. NOISE LEVELS
The airborne noise level is less than 66.7 dB(A) DIN (70 dB(A) NFPA) throughout the “continuous” operating envelope.

Where noise is a critical factor, installation resonances can be reduced by isolating the motor by elastomeric means from the structure and the return line installation. Potential return line resonances originating from liquid borne noise can be further attenuated by providing a return line back pressure of 2 to 5 bar (30 to 70 psi).

10. POLAR MOMENT OF INERTIA
Typical data

<table>
<thead>
<tr>
<th>Displacement kg m²</th>
<th>lb in²</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>0.044</td>
</tr>
<tr>
<td>30</td>
<td>0.041</td>
</tr>
</tbody>
</table>

11. MASS
Approx. all models: 150 kg (330 lb)

12. INSTALLATION DATA
GENERAL
- Spigot
  The motor should be located by the mounting spigot on a flat, robust surface using correctly sized bolts. The diametral clearance between the motor spigot and the mounting must not exceed 0,15 mm (0.006”). If the application incurs shock loading, frequent reversing or high speed running, then high tensile bolts should be used, including one fitted bolt.

- Bolt torque
  The recommended torque wrench settings for the mounting bolts are:
  M18 .................. 312±14 Nm (230±10 lbf ft)
  5/8 UNF ............ 265±14 Nm (195±10 lbf ft)

- Shaft coupling
  Where the motor is solidly coupled to a shaft having independent bearings the shafts must be aligned to within 0,13 mm (0.005”) TIR.

CRANKCASE DRAIN
The recommended minimum pipe size for drain line lengths up to approx. 5m (15 ft) is 12.0 mm 1/2” bore. For longer drains, increase pipe bore to keep motor casing pressure within specified limits.

Crankcase drain port G1/4” (BSPF). Connect this port into main drain line downstream of a 0.35 bar (5 psi) check valve to ensure good bearing lubrication. Piping arrangement must not allow syphoning from the motorcase. Where this arrangement is not practical, please consult Kawasaki.

Piping (from any drain port) must be taken above level of motorcase to ensure good bearing lubrication. The arrangement must not allow syphoning from the motorcase.
START-UP
Fill the crankcase with system fluid. Where practical, a short period (30 minutes) of “running in” should be carried out with the motor set to its high displacement (pressure to port Y, or to port B of the size 03 pilot valve).

13. INSTALLATION DIMENSIONS IN MM (INCHES)

HMC045 MOTOR WITH TYPE “F3”/“FM3” (1 1/4” SAE) MAIN PORTS CONNECTION

See additional views for:
Displacement control connections, shaft types, alternative main port connections for 3” valve, and all port connections with 2 1/4” valve

- Suitable for M18 or 5/8” bolts. See “Installation Data”.
- Port connection details

<table>
<thead>
<tr>
<th>Model code</th>
<th>Flange</th>
<th>Bolt</th>
<th>Pressure gauge connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3</td>
<td>1 1/4” SAE code 61 4-bolt flange</td>
<td>7/16”-14 UNC-28 x 27.0 (1.06) deep</td>
<td>9/16”-18 UNF-2B, SAE J475</td>
</tr>
<tr>
<td>FM3</td>
<td>1 1/4” SAE code 61 4-bolt flange</td>
<td>M12-6H x P1.75 x 27.0 (1.06) deep</td>
<td>9/16” 9BSPF</td>
</tr>
<tr>
<td>SO3</td>
<td>Staffa 3” 6-bolt flange, see separate view on next page</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F2</td>
<td>1” SAE code 61 4-bolt flange (Imperial), see separate view on next page</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM2</td>
<td>1” SAE code 61 4-bolt flange (Metric), see separate view on next page</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See “ Shaft types” on page 11
3" VALVE HOUSING WITH 6-BOLT FLANGE, “SO3” IN MODEL CODE POSITION 6

Flow direction for shaft rotation shown on main drawing on page 9. Reverse flow for opposite direction of shaft rotation.

Displacement selector valve is not supplied with the motor; specify and order separately.

1" SAE 4-BOLT FLANGE, “F2”/“FM2” IN MODEL CODE POSITION 6

Flow direction for shaft rotation shown on main drawing on page 9. Reverse flow for opposite direction of shaft rotation.

Displacement selector valve is not supplied with the motor; specify and order separately.

Flange bolt tappings

<table>
<thead>
<tr>
<th>Model code</th>
<th>Bolt tappings</th>
</tr>
</thead>
<tbody>
<tr>
<td>F2</td>
<td>1/2&quot;-16 UNC-2B x 22.0 (0.875) deep</td>
</tr>
<tr>
<td>FM2</td>
<td>M10 x p1.5 x 22.0 (0.875) deep</td>
</tr>
</tbody>
</table>

Flow direction for shaft rotation shown on main drawing on page 9. Reverse flow for opposite direction of shaft rotation.

DISPLACEMENT CONTROL CONNECTIONS, MODEL CODE POSITION 7

Type X
G1/4" (BSPF) tapped ports X and Y
Displacement selection (via remotely located valve on motor):
High displacement: P to Y; X to T
Low displacement: P to X; Y to T

Types C, CS, C1 and C2
Mounting interface for directional control valve on motor:
High displacement: P to B; A to T
Low displacement: P to A; B to T

Displacement selector valve is not supplied with the motor; specify and order separately.
SHAFT TYPE “P”, MODEL CODE POSITION 3
Cylindrical shaft with key

Key supplied:
14,046/14,028 (0.5530/0.5523) wide
x 9,037/8,961 (0.3558/0.3526) thick

SHAFT TYPE “S”, MODEL CODE POSITION 3
Cylindrical shaft with 17 splines to BS 3550-1963

SHAFT TYPE “Z”, MODEL CODE POSITION 3
Cylindrical shaft to DIN 5480

SHAFT TYPE “Q”, MODEL CODE POSITION 3
Internally splined to BS 3550; 21 splines

Note: The type “Q” shaft will transmit the maximum torques given on page 3. However, customers should ensure that their own mating shaft will transmit the torque required in their application.
Staffa hydraulic motors are manufactured to the highest quality standards in a Kawasaki ISO 9001 certified facility. Certification No. 891150