FLIGHT WORKS INC.
MICRO GEAR PUMP
USER'S GUIDE

MN-006

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1 TABLE OF CONTENTS

1. SCOPE

This document provides procedures and directions for storage, handling, installation, verification and operations of a Flight Works micro gear pump.

2 REFERENCE DOCUMENTS

Brushless Pump Control Instructions, Flight Works, Inc., https://www.flightworksinc.com/downloads.html.

3 UNDERSTANDING YOUR PUMP

3.1 DRIVE CONFIGURATION

Flight Works micro gear pumps come in one of four drive configurations. One can determine drive configuration based on pump part number (see Table 1) and reference the appropriate sections of the user guide.

Table 1, Drive Configurations

Drive Type	Example Part Number
Coreless Direct Drive (**-Cnn**)	2212-**C05**-O
Brushless Direct Drive (**-Xnn**)	2212-**X01**-O
Coreless Magnetic Drive (**-MnnCnn**)	2212-**M04C05**-O
Brushless Magnetic Drive (**-MnnXnn**)	2212-**M04X01**-O

3.2 PUMP FLUID COMPATIBILITY

Flight Works micro gear pumps feature configurations and materials to be compatible with a wide range of fluids and applications. One can determine material configuration and fluid compatibility based on pump part number suffix/-# (see Table 2). For other configurations not listed in Table 2 (X, GP, etc.), refer to the Pump Data Sheet (PDS) provided with the product.

Care should be taken to ensure the fluids used are compatible with the wetted materials listed in the Product Data Sheet for each specific dash letter. In particular, ***water should not be used in a -O pump***. In general, Flight Works, Inc. makes no warranties concerning the suitability of a pump for a specific application; as such, it is the customer's responsibility to determine the safety and technical suitability of the pump in the system being used.

Table 2, Materials, Configurations and Fluid Compatibility

Fluid Compatibility	Example Part Number
Water (**-W**)	2212-X01-W
Oil and Fuels (**-O**)	2212-X01-O
Corrosive Chemicals (**-C**)	2212-X01-C
Hydraulic fluids (**-H**)	2212-X01-H

3.3 PRODUCT CHARACTERISTICS AND PERFORMANCE

See appropriate PDS for electrical and fluid interfaces, as well as pump performance (max pressure, max differential pressure, flow rate, etc.)

4 SETUP/INSTALLATION

4.1 MOUNTING AND FLUID INTERFACES

4.1.1 MECHANICAL INTERFACE

Flight Works micro gear pumps may be mounted in any orientation. Care should be taken while mounting pumps to avoid unnecessary stress on components. Flight Works can provide mounting accessories upon customer request.

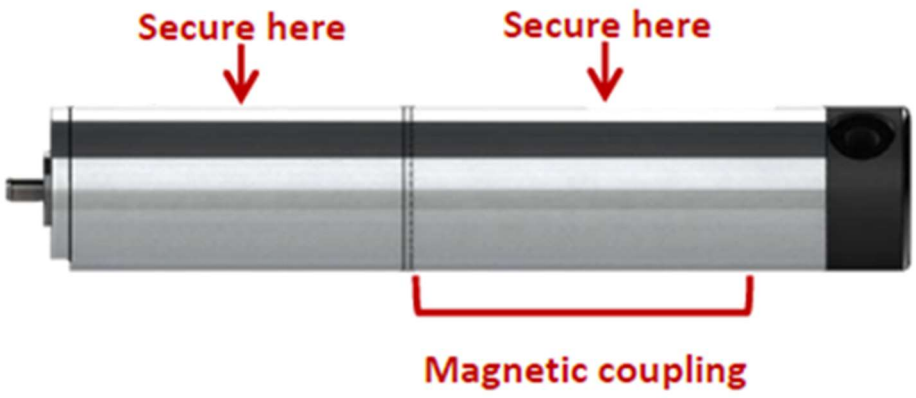

Figure 1, Example of Pump Mounting Locations for an M-Series Pump

4.1.2 SOFT TUBE INTERFACE

When mounting a pump with a soft tube interface, secure the pump from both the front and rear (see Figure 1) in order to provide maximum stability during operations. The addition of a shock-absorber (e.g., rubber pad) to the mounting surface can help protect the pump from damage or vibration. If a secure mounting is not possible, please contact Flight Works for further guidance.

4.1.3 FLANGE MOUNT

When mounting a pump with a flange mount interface, ensure that the o-rings are seated correctly in their grooves before mounting. When tightening the mounting fasteners, refer to the appropriate standard for the correct torque for the fasteners being used.

4.1.4 OTHER

For non-standard interfaces, refer to PDS or Interface Control Document as applicable.

4.2 SYSTEM REQUIREMENTS

4.2.1 FLOW DIRECTION

Flow direction is indicated by an arrow on the pump labeling. All information on the PDS is based on flow in that direction. Pumps are reversible, but performance is subject to change when running in reverse.

4.2.2 FOREIGN OBJECT DEBRIS (FOD) AND FILTERING

While assembling one's system, take care not to introduce foreign object debris (FOD) into the pump's ports or inlet lines. While installed, use a filter on the inlet of the pump to prevent issues caused by foreign particle ingestion. Flight Works recommends a filter rating of ≤25 microns. Some applications, e.g. where the flow is recirculated, may require smaller ratings and appropriate sizing.

4.3 ELECTRICAL INTERFACES AND CONTROL

Before connecting and operating a pump:

- Ensure that the power supply/controller is turned off.
- Be familiar with important information listed on the PDS. This included the nominal and max voltage, speed, and pressure, as well as a definition of the electrical interface.
- If possible, set a current limit to mitigate damage to the pump in the event of a system blockage or similar issue

4.3.1 CORELESS PUMPS

Pumps that use a coreless motor require simple positive and negative wiring and can be connected directly to a DC power supply. Speed in this type of pump is controlled by varying the voltage applied to the pump. If reversed flow is desired, the polarity of the electrical connections simply needs to be reversed.

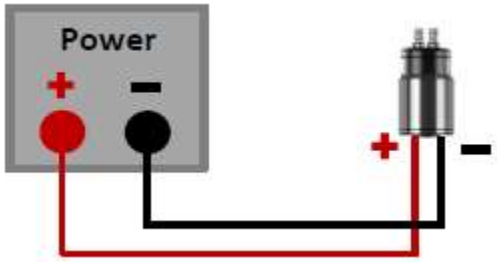

Figure 2, Connection of a Coreless Motor Pump

4.3.2 BRUSHLESS PUMPS

Pumps that use a brushless motor require a speed controller and will have either 3 wires or 8 wires.

- A pump with 3 wires requires a controller that can measure "back" EMF for speed control
- A pump with 8 wires requires a controller that can either measure "back" EMF or utilize the built-in hall-effect sensors for speed control

Pump speed, direction, and other features can be changed using the speed controller. For detailed information on brushless controller setup, see the instruction booklet in Flight Works' Customer Support web page.

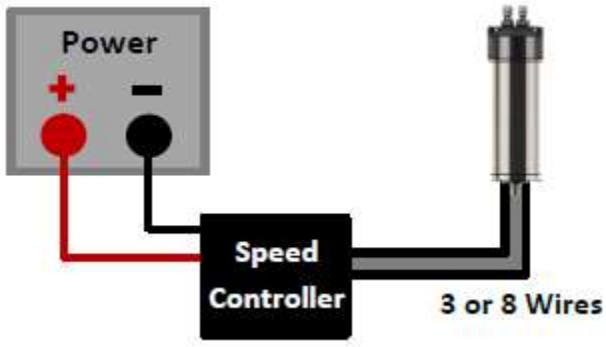

Figure 3, Connection to a Brushless Motor Pump

5 OPERATIONS

5.1 VERIFICATIONS - DRY OPERATIONS AND PRIMING

Flight Works micro gear pumps are **not designed to be operated dry** for an extended period. Dry operations of the pump should only be carried out when doing functional verification of, or for priming, the pump. Extended dry operation of the pump may result in damage or wear that reduces performance of the pump in the short term and ultimately destroys the pump in the long term.

5.1.1 DRY FUNCTIONAL VERIFICATION PROCEDURE

NOTE: This procedure is for pumps that are equipped with brushless motors OR coreless motors using a variable output power supply. If one's pump uses a coreless motor and a fixed voltage power supply, contact Flight Works for appropriate directions.

NOTE: This procedure can also be used to verify proper motor to controller connections, including proper rotation of motor shaft.

NOTE: Use of video capture is recommended so that duration of dry pump operation is as short as possible, and verification can be checked and confirmed after stopping operations

1. Use a dark marker to draw a line on the back of the motor shaft (if accessible) to assist in visual verification of operation
2. Configure brushless motor controller to operate pump at 500 RPM or less OR configure variable power supply at 0.5V-1V. If either is not possible, contact Flight Works.
3. Run Pump for <5 seconds and visually confirm rotation at back of motor shaft.
    - Irregular motion (e.g., stuttering rotation) is typical behavior for brushless motor controllers at low RPM.

5.1.2 PRIMING

Flight Works micro gear pumps are self-priming under normal operating conditions. In order to prime the pump, run it at 20% of nominal operating speed until fluid begins to flow. Once fluid is flowing through the pump, the speed can be increased slowly over 5 minutes until at nominal operational speed. If the pump speed cannot be adjusted for any reason, contact Flight Works.

5.2 NORMAL OPERATIONS

During normal operations, follow these guidelines to ensure optimal conditions and maximum operational life of one's pump:

- Where possible, use a "soft start" when turning on the pump.
    - With a coreless motor, this involves ramping from a low supply voltage to nominal.
    - With a brushless motor, this can be set in the controller.

- Monitor pump performance while operating to ensure it has been set up correctly and is performing as expected.
    - Refer to the charts on the PDS for approximate performance specifications
    - Monitor for changes in performance, current in particular
- Take care when altering the system the pump is connected to.
    - A blockage or restriction can cause a rise in differential pressure and operating current. Exceeding the max values for either of these measurements (found on PDS) may cause damage/failure of the pump.

5.2.1 FIRST TIME CORELESS OPERATIONAL PROCEDURE

1. If using a variable output power supply, ensure that it is set to its lowest point.
2. Connect the pump to a power supply according to Section 4.3.1.
3. Carry out a dry functional verification according to Section 5.1.1.
4. Mount the pump and connect the pump fluid interfaces according to Section 4 and the pump PDS.
5. Ensure that there are no unexpected restrictions in the fluid system. This may include but is not limited to closed valves, pinched lines, or capped lines.
6. Prime the pump according to Section 5.1.2.
7. Slowly increase voltage to the pump while monitoring flow and pressure to ensure nominal operation according to PDS.
8. Set voltage so that pump operates nominally and monitor performance for 5 minutes to ensure behavior is consistent.

5.2.2 FIRST TIME BRUSHLESS OPERATIONAL PROCEDURE

Refer to the brushless control operations instructions (Section 2).

NOTE: If not using a controller listed in the instructions, refer to the specific controller manual as well any time the Brushless Pump Control Instructions are referenced.

1. Connect brushless motor controller to computer and ensure it is programmed accordingly for the motor being used. Refer to Brushless Pump Control Instructions.
2. Connect the pump to the brushless motor controller according to Brushless Pump Control Instructions.
3. Connect power to the brushless motor controller.
4. Carry out a dry functional verification according to Section 5.1.1.
5. Mount the pump and connect the pump fluid interfaces according to Section 4 and the pump PDS.
6. Ensure that there are no unexpected restrictions in the fluid system. This may include but is not limited to closed valves, pinched lines, or capped lines.
7. Prime the pump according to Section 5.1.2.

8. Slowly increase the speed of the pump while monitoring flow and pressure to ensure nominal operation according to PDS.
9. Set speed so that pump operates nominally and monitor performance for 5 minutes to ensure behavior is consistent.

5.3 OPERATIONAL ENVIRONMENTS

Refer to PDS for the operational environment the pump was designed for. Unless otherwise noted, pumps are NOT designed for vibration, shock, or vacuum environments.

6 SAFETY

Flight Works micro gear pumps are capable of high-pressure operation, which does pose a safety risk if not considered during operations. In addition, there are electrical risks and temperature risks associated with the pumps and associated fluids. The following precautions can help to mitigate those risk:

- Ensure that pressure in the inlet and the outlet of the pump has been relieved before loosening connections to the pump
- Ensure that components downstream of the pump are rated to the pressures that may be seen if a blockage occurs
    - If not possible, install a relief valve downstream of the pump to ensure that an over-pressure situation can be safely managed
- Ensure that the pump is connected to its controller/power supply correctly and with the appropriate gauge of wire to handle the pump's maximum allowable current
- If the pump does not operate when power is applied, do not continue to try and operate it. This may be a sign of electrical failure. See Section 8 for troubleshooting suggestions and contact Flight Works should the problem persist.
- Be careful when handling the pump, as the motor casing can reach high temperature during prolonged operation.

7 CLEANING

The following guidelines apply when cleaning a Flight Works pump for storage or shipping:

- Water should never be run through a pump that is designed for oil or fuel operation. It will cause corrosion and failure of the pump.
- If a pump has been used for non-corrosive, non-toxic, and non-crystallizing media, the procedure detailed in Section 7.1. will be sufficient to protect the pump.
- If a pump has been used for any corrosive, toxic, or crystallizing media, it is recommended to follow the full process detailed in Section 7.2.
    - In the event of a nonoperational pump that was used for toxic media being returned to Flight Works, alert Flight Works to the details of the media before proceeding as the user is responsible for the fluids used and their potential hazards. The pump should be decontaminated prior to shipment

7.1 NITROGEN PURGING PROCEDURE

The following procedure details the process of nitrogen purging a pump:

1. Apply 10 psig of compressed nitrogen to the outlet of the pump for 2 minutes. Manipulate the pump so as to void as much fluid as possible from its inner cavities.
2. Repeat Step 1, applying the compressed nitrogen to the inlet of the pump.

7.2 FULL PUMP FLUSHING PROCEDURE

NOTE: If the fluid being pumped is not miscible with Fluid X, an additional step may need to be added that flushes the pump with a fluid that is miscible with both the operational fluid and Fluid X ***AND*** compatible with the pump. This will ensure that all residue is removed from the pump internals. Contact Flight Works for questions regarding compatibility.

Table 3, Definition of Fluid X

Type of Pump	Fluid X
Oil/Fuel	Kerosene
Water/Chemical	Deionized/Distilled Water

1. Flush system with Fluid X. Start running the pump with 0 psig back pressure at typical operating speed for 1 minute. After that, continue operating at typical operating speed and raise the back pressure to 1/3rd of the typical operational pressure. Run the pump for 5 minutes under these conditions. Discard Fluid X after cycle.
2. Repeat Step 1.

3. Flush system with Fluid X a third time. Start running the pump with 0 psig back pressure at typical operating speed for 1 minute. After that, continue operating at typical operating speed and raise the back pressure to 1/3rd of the typical operational pressure. Run the pump for 15 minutes under these conditions. Discard Fluid X after cycle.
4. Flush system with greater than 70% concentration isopropyl alcohol. Start running the pump with 0 psig back pressure at typical operating speed for 1 minute. After that, continue operating at typical operating speed and raise the back pressure to 1/3rd of the typical operational pressure. Run the pump for 5 minutes under these conditions. Discard water after cycle.
5. Repeat Step 4.
6. Flush system with greater than 70% concentration isopropyl alcohol a third time. Start running the pump with 0 psig back pressure at typical operating speed for 1 minute. After that, continue operating at typical operating speed and raise the back pressure to 1/3rd of the typical operational pressure. Run the pump for 15 minutes under these conditions. Discard water after cycle.

   OPTIONAL STEPS

   Note: Ensure that the temperature of the pump does not go above 90C at any point during the baking process. The set temperatures and durations are based on the oven that Flight Works Inc. uses in their process and may vary greatly depending on the equipment used.

7. Connect GN2 inlet of the pump and pressurize to 30 psig while running the pump at 200 rpm for 10 minutes.
8. Repeat Step 7. with GN2 connected to the outlet of the pump.
9. Bake the pump at 100°C for 30 minutes while applying a vacuum to the inlet and outlet of the pump. Ensure temperature of the pump does not go above 90C during this period.
10. Continue applying a vacuum to the inlet and outlet of the pump and lower the oven to 81.2.5°C for an additional 30 minutes (for a total of 1 hour). Ensure temperature of the pump does not go above 90C during this period.

8 TROUBLESHOOTING

This section discusses potential off-nominal conditions, explains their causes, and recommended actions for each. FAQs can be found on Flight Works' Customer Support page.

8.1 DECREASED PUMP PERFORMANCE

8.1.1 WEAR FROM EXTENDED OPERATIONS

- Explanation
  - Extended pump operations can cause decreased pump performance due to wear on surfaces and increased clearances. This will typically be displayed as gradually increasing current and decreasing flow rate and pressure at a fixed RPM or voltage.
- Recommended Actions
  - In order to counteract the effects of wear the pump should be run at a higher RPM in order to meet system requirements.
- Considerations
  - The pump must not be operated above the max RPM listed on the PDS.
  - Wear does not typically pose a safety concern as long as the pump is not overheating. If the pump motor overheats, the pump should be shut down. The pump maximum temperature can be found on the PDS.
  - If current reaches the maximum recommended, the pump should be shut down. The pump maximum current can be found on the PDS.

8.2 PUMP NOT OPERATING

8.2.1 PUMP SEIZING

- Explanation
  - Foreign debris or failure of pump components can cause flow and rotation to be stopped due to obstruction of the pump gears.
- Recommended Actions
  - If a pump has seized, it should be immediately shut down to avoid overheating and unnecessary damage.
  - Pump should be returned to Flight Works for inspection ***without*** being opened. Returning the pump without opening it will give Flight Works the best chances of addressing the root cause of the failure. Pump should be cleaned according to Section 7 before being returned for Flight Works.

- Considerations
  - In the case of a magnetic drive pump the magnets will de-couple. Generally, the motor will continue running but at a much lower current. The recommended action following this failure is to immediately shut down the motor to prevent demagnetization of the coupling due to continuous cycling and possible overheating.

8.3 PUMP DECOUPLING WITHOUT SEIZING

- Explanation
  - This failure mode is only present on magnetic drive pumps (M-Series). Typically, this is caused by an external restriction leading to a high outlet pressure that exceeds the maximum torque of the magnetic coupling. In this state, the motor will continue to operate, but the flow and outlet pressure (and current) will drop.
- Recommended Actions
  - Pump should be immediately shut down to prevent damage.
  - System should be checked for any restrictions that would lead to a higher-than-expected pressure. Possible causes are clogged filters, closed valves, and kinked tubing.
- Considerations
  - Pump should return to normal operation once the obstruction is dealt with. If the pump does not return to normal operation, stop and contact Flight Works for further assistance.

8.4 PUMP ROTATING WITHOUT PRESSURE OR FLOW

- Explanation
  - This failure mode is likely resultant from an internal component failure.
- Recommended Actions
  - Stop operations and return the pump to Flight Works for refurbishment. Pump should be cleaned according to Section 7 before doing so.
- Considerations
  - In the case of a magnetic drive pump, this could be caused by decoupling. Refer to Section 8.3 for possible actions.

8.5 OTHER

If you are experiencing any other issues with a Flight Works pump, ***do not attempt to disassemble or modify the pump***. Refer to the FAQs page of Flight Works' website for useful tips and relevant information. Contact Flight Works customer support with any further questions.

9 PUMP HANDLING, PACKAGING, STORAGE, AND MAINTENANCE

9.1 HANDLING

Flight Works micro gear pumps must be handled with care and protected from drops and impacts. Drops and impacts on a pump can cause misalignment of the pump components or worse and could render a pump inoperable.

9.2 PACKAGING

All Flight Works pumps are subject to standard packaging procedures. This includes sealing them in pouches with desiccant, wrapping them in bubble wrap, inserting them into Flight Works pump boxes, then placing those pump boxes into shipping boxes filled with packing peanuts to keep the hardware secure and safe during shipping. Contact Flight Works sales for additional packaging options.

9.3 STORAGE

Extended storage of Flight Works pumps should be done in a dry, clean environment with the pump ports sealed using caps. If the pump was previously used, it should be cleaned according to Section 7.

9.4 MAINTENANCE

Flight Works strongly recommends that the customer NOT attempt to service the unit. It is best to clean the pump according to Section 7 and return to Flight Works for service.