Ferrofluidics Exclusion Seal Applications Manual

Exclusion Seal Applications Manual

This handbook is intended for users of **Ferrofluidic® Exclusion Seals** and for the designers of devices incorporating these seals. The following six sections will describe Ferrofluidic sealing technology, installation and handling of seals, and design guidelines for implementing Ferrofluidic sealing technology in your spindle.

Section 1
Introduction to Ferrofluidic Sealing Technology

What is Ferrofluid?

Ferrofluids are magnetic liquids which can be influenced by remote magnetic fields. These unique fluids are collodial suspensions of submicron sized magnetically permeable particles coated with proprietary stabilizing agents which allow the particles to remain suspended in a carrier fluid selected for the specific application.

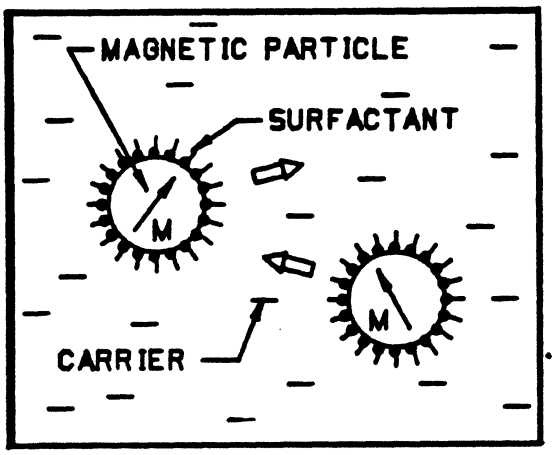


FIGURE 1
THREE COMPONENTS OF A FERROFLUID

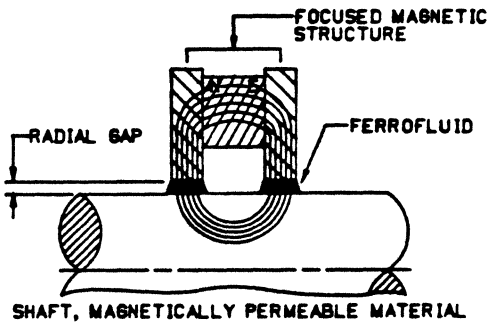
This unique combination of liquid and magnetic properties has given rise to many applications, including ore separation, cooling and damping of loudspeaker voice coils, rotary shaft damping, sealing of vacuum and hazardous gas systems, magnetic disk and tape domain detection and sealing spindle and head actuator shafts for computer disk drives. For each use, specialized ferrofluids are synthesized with properties optimized for the application. Ferrofluidics Corporation also offers electrically conductive ferrofluids for the grounding of disk drive spindles.

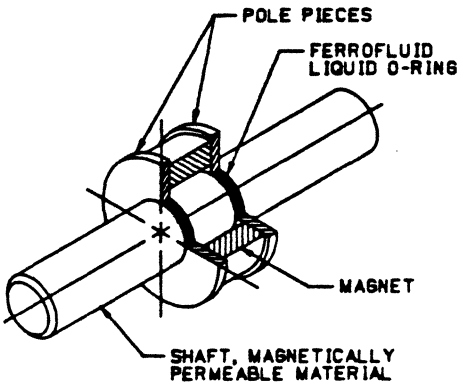
What is a Ferrofluidic Exclusion Seal?

In Ferrofluidic sealing applications, the unique ability of ferrofluids to be magnetically retained in place is utilized to provide a liquid seal through which a shaft can freely rotate. Ferrofluid is retained in place as a narrow ring resembling a liquid "o-ring" in direct contact with the shaft and the stationary seal structure. In that way, a hermetic barrier is established to completely seal the shaft with no rubbing contact.

The mechanism for retaining the ferrofluid in place is a focused magnetic field utilizing a permanent magnet. The circuit establishes a high magnetic flux density in an annular gap between the shaft and the pole piece elements of the Ferrofluidic seal. Ferrofluid is retained in this gap region forming the liquid "o-ring" described.

MODULE SEAL MAGNETIC CIRCUIT





SINGLE POLE SEAL MAGNETIC CIRCUIT

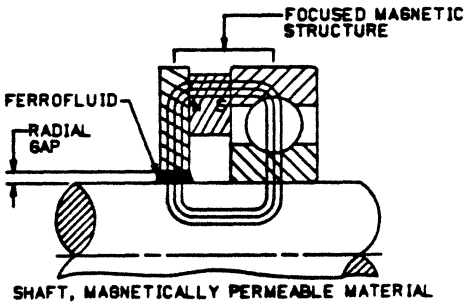


FIGURE 2

Section 2
Handling and Installation Guidelines

Preparation for Installation

As with any other component that is directly exposed to an airborne-contamination sensitive environment such as the head/disk environment of a disk drive, certain precautions are necessary to assure that the Ferrofluidic seal goes into service in a clean and functionally proper state. Ferrofluidics Corporation supplies all exclusion seals in sealed containers (usually plastic bags). The seals are clean and ready for installation directly from the bag. It is **not** necessary to clean the seal in any way. If a seal has been exposed to a dusty environment, it can be blown off with clean, dry air only. This may not, however, remove magnetic contaminants which would be magnetically attached to the seal. The best practice is to open the sealed container only in the protected environment of your assembly area and install the seal directly.

Installation

Adhesives and sealants used on or near Ferrofluidic seals must be **fully cured** before ferrofluid is introduced into the seal. The following general guidelines will serve to assist you in the selection of products compatible with Ferrofluidic seals.

1. Experience indicates that the following classes of adhesives are acceptable:
   - Cyanoacrylate products, especially those of the high viscosity type.
   - Two-part epoxy products with a high molecular weight hardener.

2. Avoid:
   - Products which cure by solvent evaporation (examples: cellulose acetate/butyrate, rubber cement).
   - Anaerobics, which cure in the absence of air; excess may cure very slowly or not at all.
   - Silicones; these products form a skin and cure very slowly inside.
   - Products which require primers or accelerators.

Production Practices

Adhesives used to retain the seal in the spindle must be fully cured to prevent uncured adhesive or accelerator from migrating to the ferrofluid. Uncured adhesives and activators in contact with ferrofluid may cause coagulation or fluid separation.

Upon request, specific candidate adhesives will be evaluated for compatibility by Ferrofluidics Corporation.

Special mounting considerations will be evaluated with your design engineer. In general, the following do's and don'ts may be useful. They are compiled from experience and encompass most of the commonly experienced field problems caused in assembly.

Do's

- Do use only the amount and type of ferrofluid recommended for your seal.
- Do make sure that all parts near the seal (especially the shaft) are clean and dry.
- Do make sure the shaft surface is free of scratches.

Don'ts

- Don't use a seal contaminated with particles, fibers, hair, lint or any liquid.
- Don't reuse a previously filled seal.
- Don't expose the seal to pressure or vacuum during cleaning of the assembled spindle.
- Don't expose the seal to liquid solvents or highly concentrated solvent vapors when cleaning the assembled spindle.
- If any chipmaking operations are performed on assembled spindles (grinding, turning, balancing), don't allow chips, dust, coolant, etc., to contaminate the seal area.

Section 3
Applying Ferrofluid to the Seal

Ferrofluid is supplied in labeled sealed containers. This label (Figure 6) identifies the fluid with respect to its type and also establishes traceability to permanent records at Ferrofluidics Corporation. Use only ferrofluid from the original container.

A microdispenser is required to accurately and safely dispense ferrofluid into the seal. Ferrofluidics Corporation recommends Dialamatic Microdispensers, manufactured by Drummond Scientific Company. They can be purchased from Ferrofluidics Corporation or directly from Drummond Scientific.

Ferrofluidics Catalog #	Drummond Catalog #	Maximum Dispensing Volume
MFD010	210	10 microliters
MFD025	225	25 microliters
MFD050	252	50 microliters
MFD100	275	100 microliters

You should use the smallest dispenser that is large enough for your seal.

To dispense the ferrofluid:

1. Adjust the dispenser to the volume of ferrofluid required according to the manufacturer's instructions.
2. Make sure the dispenser tube and plunger are clean (use the dispenser only for ferrofluid in order to avoid accidental contamination with other liquids).
3. Depress the plunger all the way. Insert the tip into the ferrofluid container and release the plunger. This fills the dispenser.
4. **VERY IMPORTANT** - Wipe excess ferrofluid from the outside of the tube with a clean, disposable wiper. Since ferrofluid is magnetic, any excess on the outside of the dispenser will be drawn into the seal. This could result in overfilling.
5. Depress the plunger in a smooth motion to dispense the fluid in the proper location. Note that the plunger extends past the end of the tube slightly. This should be taken into account when positioning the tip.

NOTE: Ferrofluid should not be used in products for which prolonged contact with skin or implantation in the human body is intended. This material is not recommended as safe and effective for such uses and Ferrofluidics Corporation assumes no liability for any such use.

Fill Procedures

There are two methods of applying ferrofluid to the seal. The one that you will use is determined by the manner in which your spindle is assembled. The amount of fluid used is different for these two methods. Both techniques are described here.

Ferrofluid Fill Procedure #50-105399 (Fig. 3)

Using this method, ferrofluid is applied to the seal before the shaft is in place. The fluid takes up its position in the sealing gaps automatically when the shaft is installed.

The seal has already been installed in the spindle housing, and any adhesive or sealant must be completely cured. Position the dispenser tip near the inner diameter of the seal. It is not necessary to touch the seal with the dispenser. If the dispenser tip is within about ⅛" (3mm) of the seal ID, the fluid will be drawn by strong magnetic attraction to the proper location. With the dispenser tip positioned properly, simply depress the plunger slowly. The fluid will jump to the seal, positioning itself predominantly at the pole piece tips.

Once the seal is filled, the ferrofluid will be retained in place by the magnetic field. It is, however, vulnerable to contamination in this condition. It is recommended to proceed with the shaft installation as soon as possible. The shaft must be installed in such a way that it does not touch the seal accidentally since this will cause fluid to be drawn out. Once the shaft has been inserted into the spindle assembly, it should be pressed into final position with a **smooth, continuous motion.** Inserting the shaft completes the formation of the seal by completing the seal's magnetic circuit.

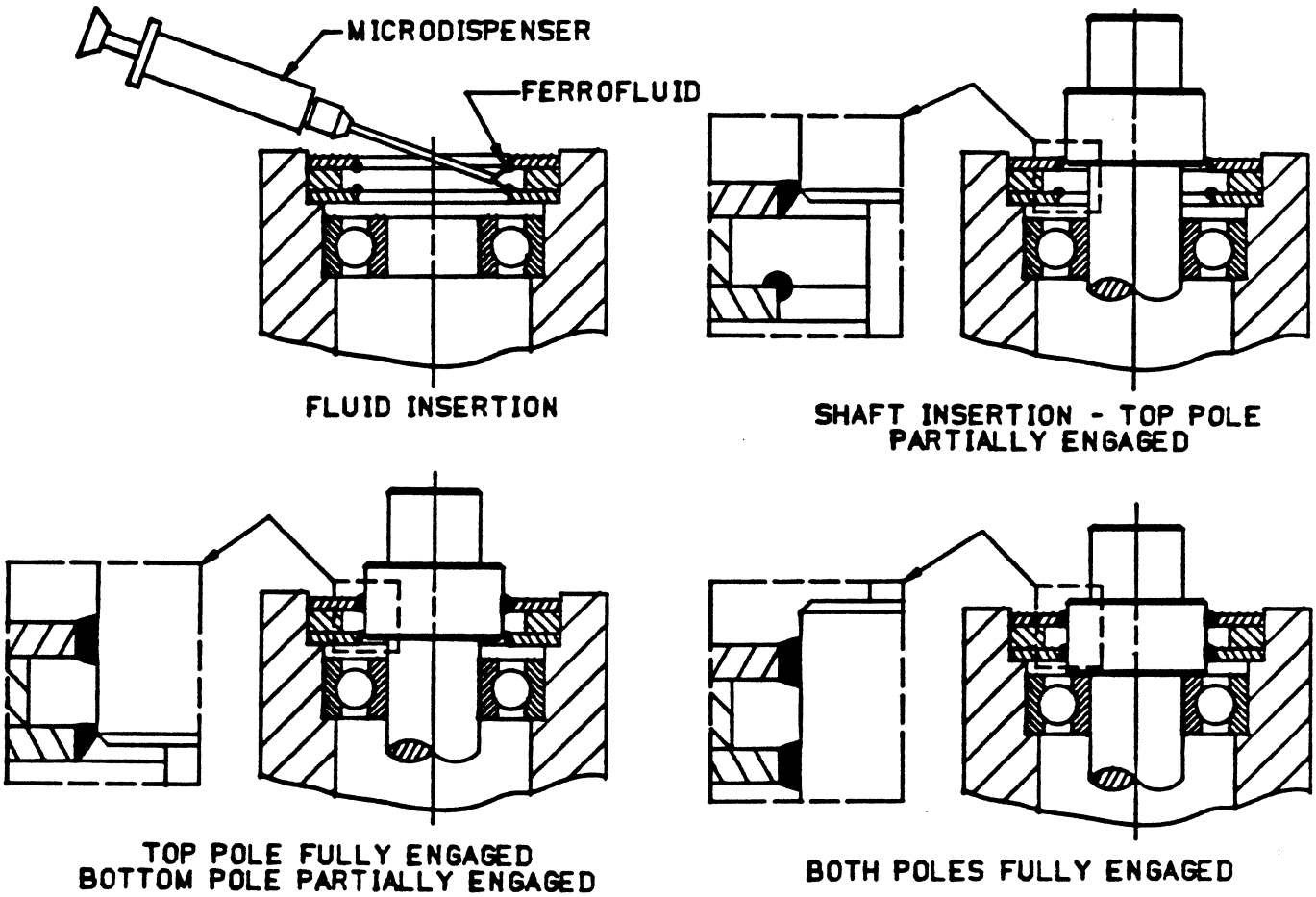

MICRODISPENSER
FERROFLUID
FLUID INSERTION
SHAFT INSERTION - TOP POLE
PARTIALLY ENGAGED
TOP POLE FULLY ENGAGED
BOTTOM POLE PARTIALLY ENGAGED
BOTH POLES FULLY ENGAGED

FIGURE 3

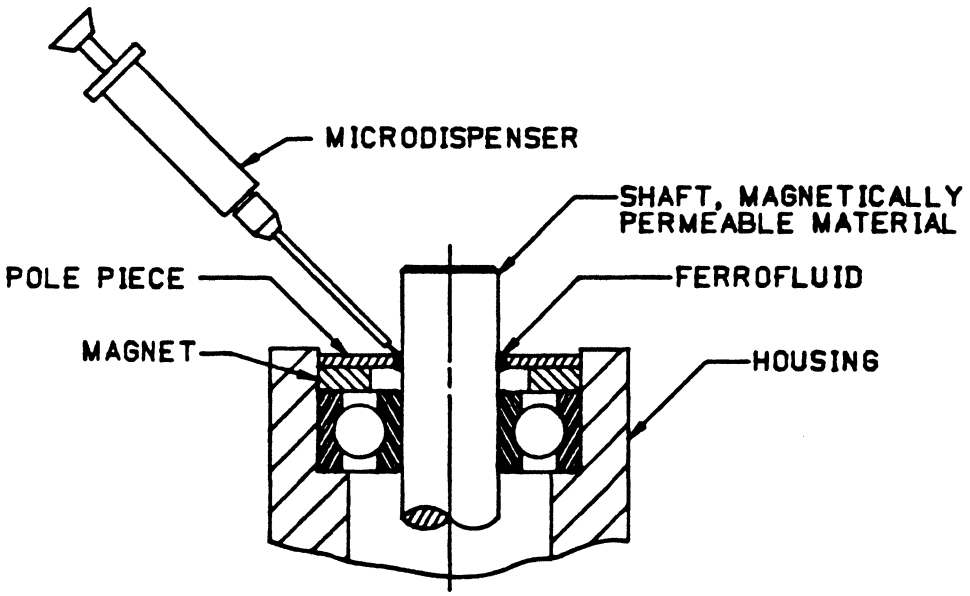


FIGURE 4

Ferrofluid Fill Procedure #50-105497 (Fig. 4)

In this procedure, ferrofluid is applied to the seal after the shaft is already in place. Ferrofluid is dispensed directly into the radial gap between the exposed (top) pole piece and the shaft.

Position the dispenser tip near but not touching the top pole piece/shaft interface. Depress the plunger in a smooth, uniform motion. The fluid is drawn magnetically to the gap. The dispenser tip may, therefore, be some distance, ⅛" (3mm) or more, away from the gap. In positioning the tip, take into account that the plunger projects some distance past the end of the tube. The dispenser should not touch the seal or the shaft.

You will note that the ferrofluid will remain in the area where it was first injected momentarily before distributing itself uniformly about the shaft.

The seal can be filled either in the static or dynamic condition up to the full design speed of the spindle.

Please note that no attempt is made to charge the bottom seal gap when this procedure is used. Only the exposed gap is used for sealing.

General Comments About Filling

The application of ferrofluid to the seal is a simple but critical step in spindle assembly. It should be documented carefully and carried out by trained people. A Ferrofluidics Corporation engineer is available to help you establish procedures and set proper guidelines.

In all cases, use only the amount of ferrofluid specified on the specification control drawing for each type of seal. The fluid quantity should be controlled in a range of the specified volume to a tolerance of +10%, -0. For example, the range of tolerance for a 40 microliter fill specification is between 40 and 44 microliters.

The adjustment of the microdispenser should be checked frequently to assure proper calibration. The dispenser should also be carefully maintained according to the manufacturer's instructions.

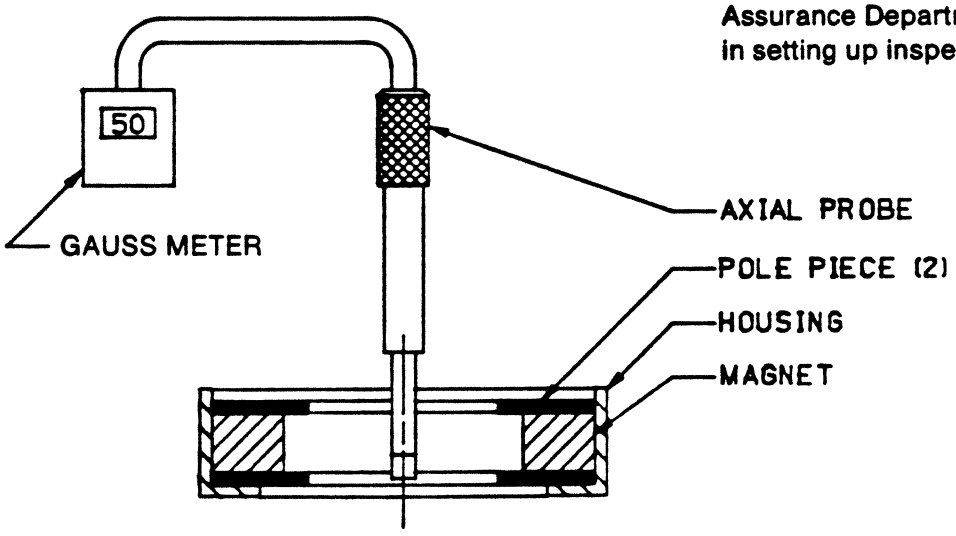
Section 4
Inspecting Ferrofluidic Exclusion Seals

Dimensional inspection of Ferrofluidic exclusion seals should be carried out with reference to the Specification Control Drawing.

The state of magnetization of the seal can be measured with any accurate gauss meter. Since different measurement techniques and different meters will give different results, it is important to select a method that gives repeatable results. One such method is detailed below (Fig. 5). If this method is used, the acceptable magnetic field reading for your seal can be provided by Ferrofluidics Corporation.

Place the seal on a flat surface. Align the gauss meter probe vertically along the centerline of the seal. Move the probe down until the highest measurement is found.

FIGURE 5



Static Seal

Seal leakage (leakage of air through the interface of the mechanical elements of the seal) is controlled by Ferrofluidics in products where the seal assembly is supplied in a housing. (Note that the Ferrofluidic seal between the shaft and pole piece is hermetic. The subject of this discussion is the passage of air through the joint between the pole piece and housing.)

Unless otherwise specified, Ferrofluidics considers a seal acceptable if it will support a pressure of 6" (150mm) H_2O in a volume 1 cubic inch for one minute with no more than 0.2" (5mm) H_2O pressure loss. This is consistent with industry practices.

Since unhoused seals are customarily bonded directly into the customer's spindle, no static leak test is practical at Ferrofluidics. In this case, the customer is responsible for eliminating static leaks.

General Comments On Inspection

Care should be taken to assure that the inspection of seals does not result in contamination. **Recleaning of seals with liquids or solvents is not advised.** Note that magnetic particles are strongly attracted to the seals.

Ferrofluidics Corporation's Engineering and Quality Assurance Departments are available to assist you in setting up inspection methods and fixturing.

Inspecting Ferrofluid

Ferrofluid is always supplied in a sealed container with a specification label attached. Measurement by the customer of the chemical and magnetic properties is difficult and unnecessary. All ferrofluid is manufactured, stored and dispensed under strict controls. Customer inspection is normally limited to noting the information on the label as shown below.

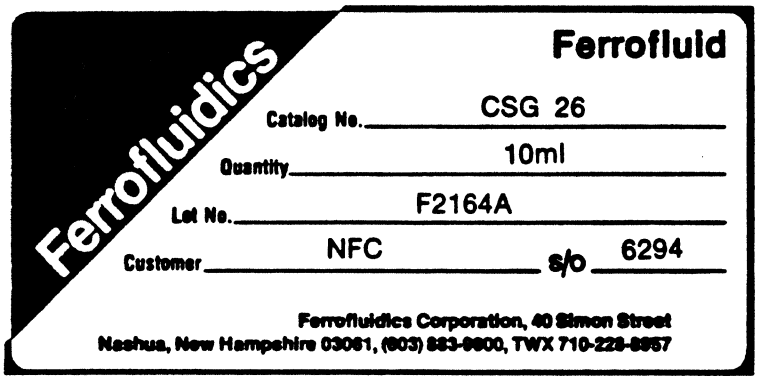


FIGURE 6

1. Catalog Number: This should match the type designated for your seal.
2. Quantity: This should be sufficient to fill the number of seals supplied.
3. Lot Number: This number is traceable to a permanent record of the date of manufacture and all measured properties of the ferrofluid. Also, a sample of each lot of ferrofluid is retained permanently for future analysis and for comparison with any returned fluid.
4. Customer Name: This information is permanently retained so that Ferrofluidics Corporation can identify all customers who have received fluid from a given lot.
5. Sales Order Number: This identifies the Ferrofluidics Corporation order for the seals with which the fluid was shipped.

It is advisable to make the ferrofluid lot number a part of your permanent records. Any suspected ferrofluid-related field problems can then be analyzed with the help of Ferrofluidics Corporation's records and retained samples.

Ferrofluid should not be transferred to another container. This would invalidate lot traceability and introduce contamination.

Section 5
Designing Your Product To Use Ferrofluidic Exclusion Seals

(Refer to Sample "Exclusion Seal Information Sheet," Page No. 6-2)

Trouble-free implementation of Ferrofluidic sealing technology is facilitated by close cooperation between Ferrofluidics Corporation's Engineering Department and the customer's spindle design personnel **early** in the design cycle. Factors that must be considered in spindle design include:

- Pressure capacity (in testing and in service).
- Operating and nonoperating temperature.
- Spindle life.
- Shock and vibration specifications.
- Shaft speed.
- Shaft size and finish.
- Space required to fit the seal into the spindle.
- Method of attaching the seal to the housing (Fig. 7).
- Material selection for shaft and housing.
- Provisions for applying ferrofluid to the seal.
- Machining, cleaning or testing of assembled spindle.
- Provisions for spindle rework if needed.

The following guidelines will be useful to spindle designers:

- Shaft size tolerance: nominal +.000", -.001" (.025mm).
- Shaft finish: 30 microinches (0.8 micrometers) AA or better, circumferential, lay free from axial scratches or pitting.
- Shaft material: magnetically permeable, corrosion resistant, usually well-passivated 400 series stainless steel.
- Shaft length dedicated to the seal should provide at least .040" (1mm) of shaft extension above the top pole piece in the direction of the disk hub and at least .030" (.8mm) below the bottom pole piece in the direction of the adjacent bearing (Fig. 8).
- Housing material (for seals mounted directly into housing): any nonmagnetic material.
- Use bearings with noncontacting shields. Sealed bearings may cause an unexpected pressure buildup of trapped air between the Ferrofluidic seal and the bearing during shaft insertion.

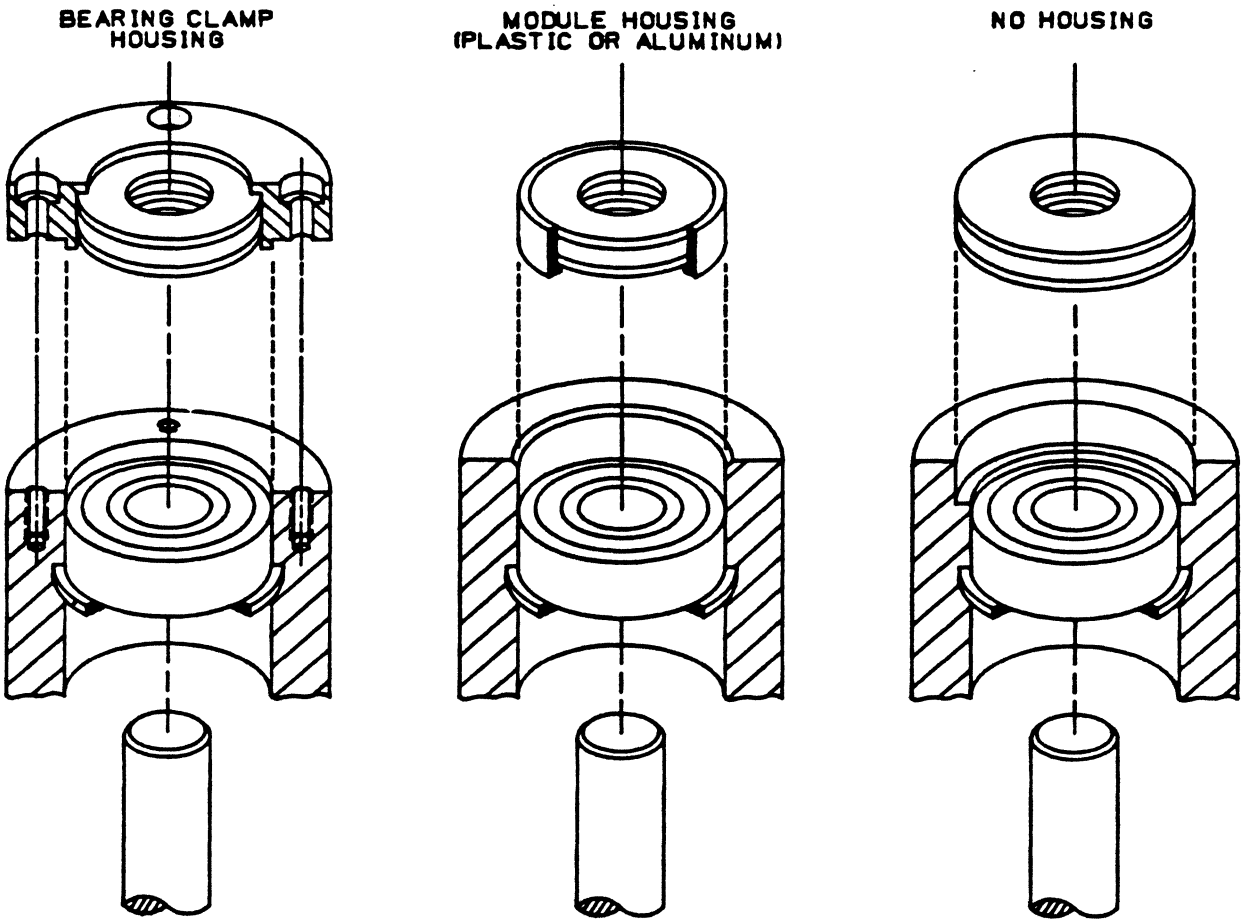


FIGURE 7

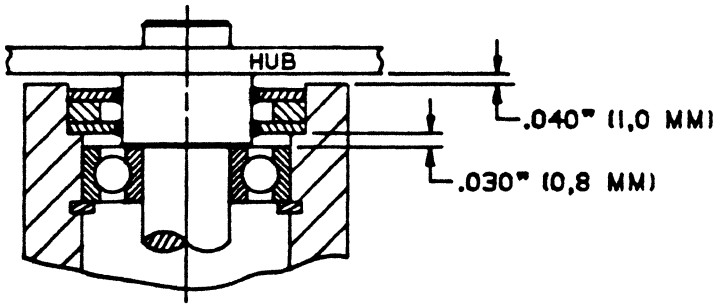


FIGURE 8

Section 6
Questions and Answers

Q. Does the evaporation of ferrofluid from the seal contribute to contamination of the disk?

A. Ferrofluids used in the seal have extremely low evaporation rates. For example, at 60°C, a typical evaporation rate is about 10^{-10} gm/cm^2 - sec. This means that only 0.0001 microgram of material leaves one square centimeter of the surface area of the seal in one second. This amount, first of all, is extremely small, and secondly the probability of this material reaching the disk area is negligible. Thus, ferrofluid carrier vapor does not introduce any contamination.

Q. What will happen if the ferrofluid carrier vapor does manage to reach the disk area?

A. The carrier vapor is a synthetic lubricant and is nonmagnetic in nature. Its presence on the disk causes no problems. The length of a typical organic carrier molecule is about 40 Å, whereas the head-to-disk separation is typically 5000 - 6000 Å. A head crash is unlikely. Furthermore, industry sources indicate that the presence of cutting oil on the magnetic disk does not lead to either a soft or hard error.

Q. Can the magnetic particles in the fluid harm the disk?

A. The magnetic particles in ferrofluid stay within the magnetic circuit (far removed from the disk) throughout the life of the seal.

Q. What happens if the ferrofluid somehow manages to deposit on the disk?

A. The quantity of ferrofluid on the disk, first of all, has to be very small since the seals normally carry inventory of ferrofluid in the microliters range. The magnetic particle size (approximately 100 Å) is much smaller than typical head-to-disk separation (5000 - 6000 Å) suggesting a low probability of a head crash caused by ferrofluid. Furthermore, since the particles are coated with thick layers of nonmagnetic surfactant, the magnetic field from the particle most likely will not interfere with the media (soft error).

Q. If, for some reason, a small portion of ferrofluid leaves the seal (splash), how is the performance of the seal affected?

A. Since the seal is designed to have reserved pressure capacity as well as reserved life, the loss of a small amount of fluid does not generally deteriorate the performance of the seal.

Q. What are some possible causes of ferrofluid migration or splash?

A.

1. Overfill from excess fluid clinging to the dispenser, or incorrect setting of micro-dispenser.
2. Two-pole fill quantity applied instead of the required quantity for a one-pole piece seal.
3. More ferrofluid added to assembly as a cure for possible QC problems.
4. Reuse of Ferrofluidic seal containing some fluid residue.
5. The radial gap where ferrofluid is retained is more eccentric than specified.
6. Splashing of ferrofluid onto the underside of the disk hub when rapidly inserting the shaft through the seal and bearing. The chamber between the seal and the bearings becomes pressurized, thus bursting the seal.
7. Air trapped in the cavity on the bearing side of the seal may result in a pressure differential that could cause bursting of the seal. Spindle should be properly vented.
8. Incorrect insertion of ferrofluid results in drops of fluid on the rotor hub, or other spindle components.
9. Excessive grease in the bearing beneath the seal leading to grease migration and dilution of the ferrofluid.
10. Particulate (dust, metal chips, etc.) contamination in seal area.
11. Shaft surface finish is too rough or corroded. It must be 32 microinches (0.8 micrometers) or better.
12. Ferrofluid has become destabilized by a cleaning solvent, adhesive or adhesive accelerator.
13. Seal has become demagnetized.

Ferrofluidics
CORPORATION

EXCLUSION SEAL

INFORMATION SHEET

Company: _____

Address: _____

City: _____ State: _____ Zip: _____

Name/Title: _____ Phone: _____ Ext: _____

Operating Parameters:

Temperature: Operating _____ Speed _____ rpm Shock and Vibration: Load _____
Storage _____ Duration _____

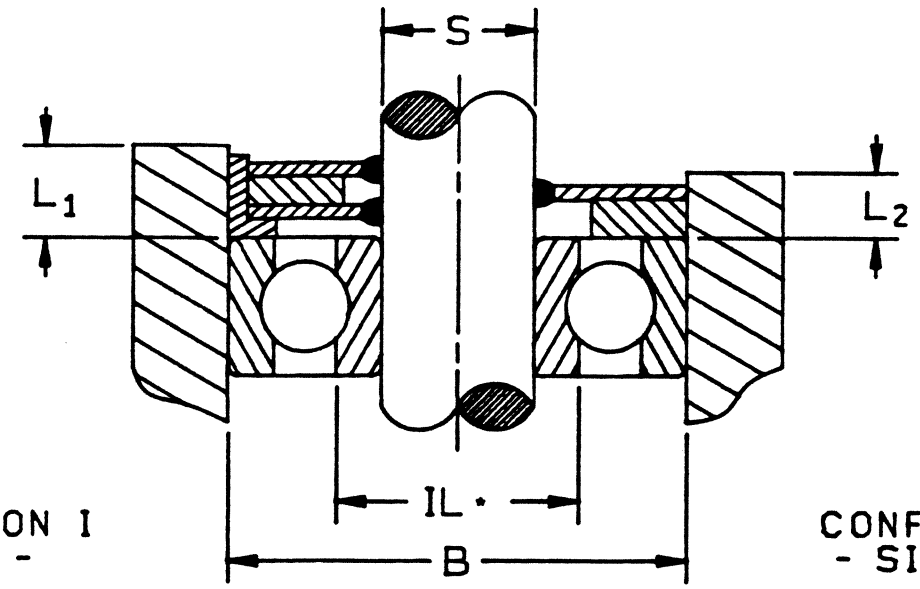
Pressure Differential: Actual _____
Test _____

Shaft: Stationary ☐ Rotating ☐ Sealing Diameter (S) _____ Material _____

Housing: Diameter (B) _____ Depth (L1, L2) _____ Material _____

Bearing: Manufacturer _____ Bore _____ O.D. _____ I.L. _____ Width _____

Type of fill to be used: Single Pole ☐ Double Pole ☐



CONFIGURATION I
- MODULE -

CONFIGURATION II
- SINGLE POLE -

* NECESSARY IF SINGLE POLE IS TO BE USED

System Information:

Type of Drive: Size _____ Capacity _____ Features _____

Source of Spindle/Motor: _____

Sealing System Used Now _____ Previously Used _____

Conductive Fluid: Yes ☐ No ☐ Present Method of Grounding _____

Price Objective _____ Targeted Spindle Cost

Quantities: Prototypes _____ Preproduction _____ Production _____

Delivery: Prototypes _____ Preproduction _____ Production _____

Production to Take Place: Domestically ☐ Off Shore ☐

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