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HOW AIR BEARINGS WORK

WHAT IS AN AIR BEARING

The Airfloat compliant air bearing supports loads on a cushion of air. It is a unique air support device, but may be compared with two other forms of air supported devices: the classical air bearing, and air cushion or "Hovercraft".

The rigid air bearing can support large loads with small unit pressures when a film of air is forced between the support surface and the ground, but because this film is only a few thousands of an inch thick, a very smooth and very flat surface is required.

Principal advantages of the rigid air bearing are its low power requirements and low noise characteristics. Disadvantages are that the bearing and the surface must be very flat, smooth and parallel.

Air cushion devices were initially of the single plenum type. A large flow of low pressure air is supplied to counteract leakage out of the air gap. Improved forms employ the skirted plenum, which helps contain the air bubble, decreasing the amount of air required.

The main advantage of the air cushion is its high ground clearance, allowing it to move over objects up to several feet in height. The main disadvantage is the great air flow required, causing very high power consumption. The load capacity is limited by the low operating pressures.

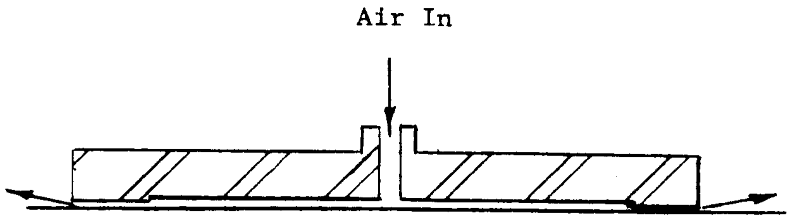
Airfloat compliant bearings combine the advantages of both the rigid air bearing and the air cushion. Its load carrying capacity is high, its power requirements are low, its noise level and dust disturbance levels are low. It can tolerate some surface imperfections and obstacles, and it is omni-directional. A comparison of the three types is shown in Figure 1-1.

Airfloat uses a flexible diaphragm beneath the load support surface. Air is pumped into the diaphragm and passes freely through the diaphragm holes and into the plenum beneath, raising the platform off the ground. The air that is forced out between the diaphragm and the ground forms a thin lubricating air film. Since the diaphragm is flexible, it can deflect as it encounters obstacles, or fill out as it passes over depressions in the surface. See Figure 1-2 for elements of a typical bearing.

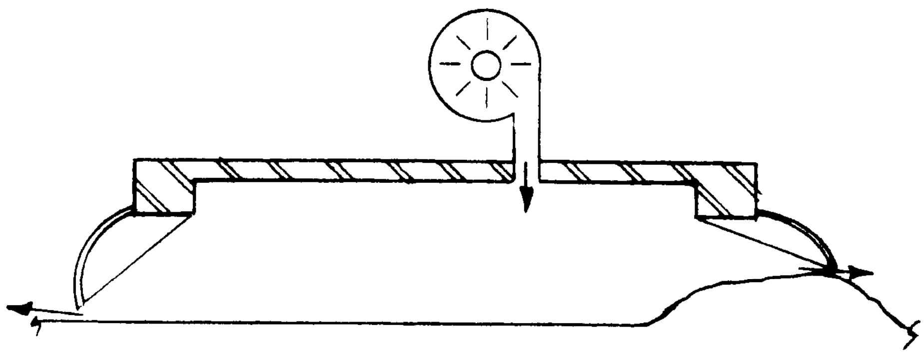
HOW IT WORKS

In an operating bearing, air flows into the space above the diaphragm and flows freely through the communicating holes, so that pressure P_1 and P_2 are very nearly equal (Figure 1-2). Air under the diaphragm tries to escape outward, under the footprint area where the clearance gap is small.

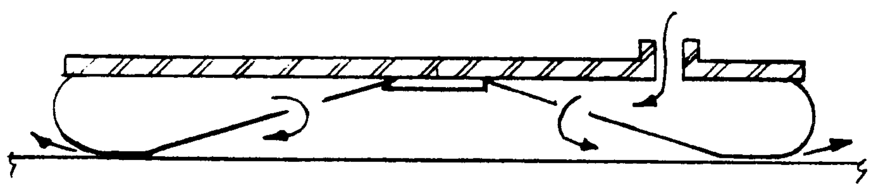
As air escapes through the small gap, velocity increases. As a result, of the Bernoulli, or venturi effect, pressure is reduced slightly, drawing the diaphragm closer to the operating surface. This results in a self-regulating clearance gap. If the operating surface is undulating



RIGID AIR BEARING



SKIRTED PLENUM
"Hovercraft"



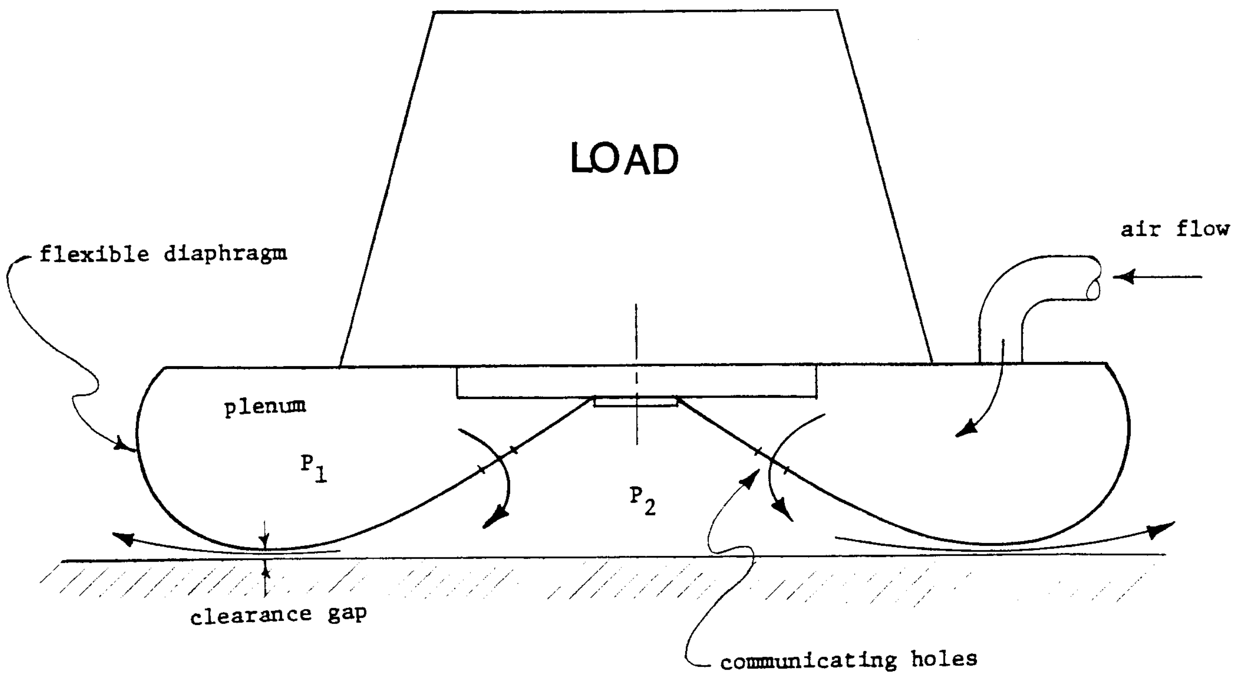
COMPLIANT AIR BEARING

COMPARISON OF AIR SUPPORT DEVICES
(APPROXIMATE)

TYPE	PRESSURE MAX. PSI	CAPACITY LBS./FT.^{2}	AIR HP PER TON*	SURFACE VARIATION
Rigid Air Bearing	5 - 100	4,000	2 - 20	.001 Inch
Compliant Air Bearings	5 - 25	2,000	½ - 4	¼ - 1 Inch (Gradual)
Air Cushion Vehicle	0.1-0.5	50	20-40	6-72 Inch (Abrupt)

*Actual values vary considerably with size of units.

FIGURE 1-1



pressure P_1 and P_2 are very nearly equal

Figure 1-2

or wavy, the diaphragm footprint will adjust to keep a small clearance gap at all points. Airfloat bearings are essentially, self-adjusting seals which maintain a very small clearance gap, which provides for a thin lubricating film of air.

Assuming sufficient air supply pressure, the pressure inside a given air bearing is determined only by the load applied, and the effective area of the bearing. It is not affected by the supply pressure. When air is supplied to a loaded bearing the pressure increases as the bearing inflates and lifts the load. At that time it acts like a relief valve. As more air is supplied, the clearance gap increases to let the excess escape, and maintain a nearly constant pressure.

$$\text{Pressure} = \frac{\text{load}}{\text{effective area}}$$

FLOOR SURFACE REQUIREMENTS

The most critical single element in a successful air bearing application is the surface the air bearing operates on. It is also the most difficult to set out practical specifications, for the unusual nature of air bearings impose some unusual floor requirements.

There is no simple way to explain or specify floor requirements. Many factors of the surface condition have an effect on bearing performance. It is necessary to understand these factors fully to make a successful and practical application of air bearings. The following sections discuss the individual aspects of the operating surface (floor).

The ideal surface would be smooth, level, flat, non-porous, and have low friction characteristics. Polished sheet metal is a good example. Commonly used floor surfaces that come very close to being ideal (when in good condition) are rubber, asphalt or vinyl floor tile, roll flooring in the non-textured types, terrazzo, and some smooth, steel-troweled concrete floors.

On an ideal surface, air bearings can carry very heavy loads with extremely low friction, (drag less than .1% of the load) and very low air consumption (under .25 CFM per foot of bearing perimeter). Under these conditions the lubricating air film is only .001-.002 inch thick.

SMOOTHNESS

The “smoothness” required of a floor suitable for air bearings is very difficult to define. Floors that look excellent by normal standards may be entirely unsuitable and other floors which are somewhat pitted and spalled may be quite acceptable for air bearing use.

Consider the several different floor surfaces described below. Note that many of the illustrations referred to are greatly magnified, and show only the footprint zone of a bearing diaphragm.

Figure 6-1 shows a perfect floor, and an air film thickness of .002 inches.
Figure 6-2 shows a new troweled concrete floor that appears very smooth to a casual observer. Most such floors have minute trails of wet grout that followed the trowel, and caused minute sharp ridges. These are thicker than the normal air film. The diaphragm touches the sharp ridges, and high drag results. This condition can be identified by the “finger tip” test described later. BAD FLOOR.

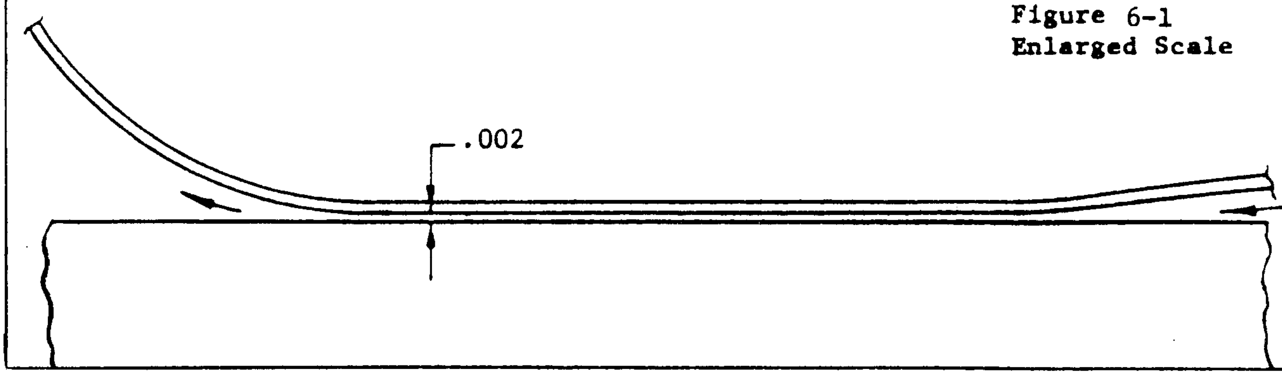


Figure 6-1
Enlarged Scale

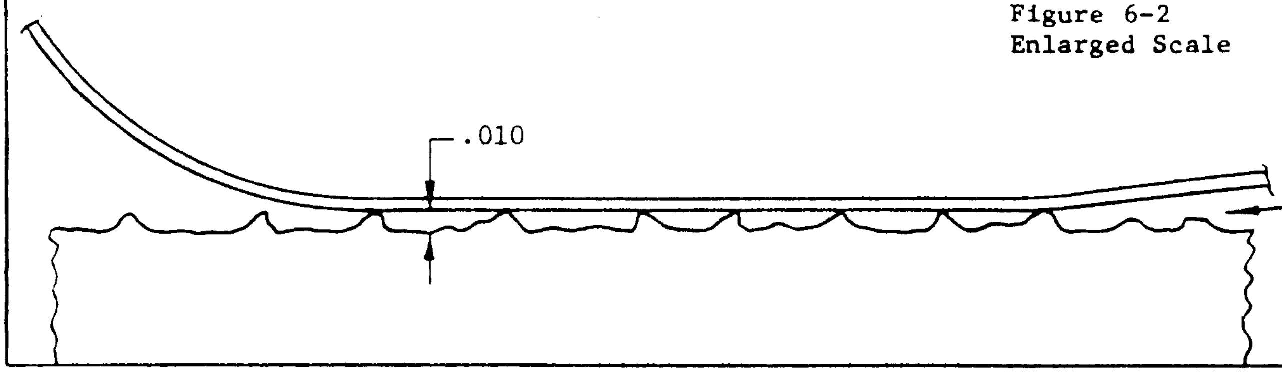


Figure 6-2
Enlarged Scale

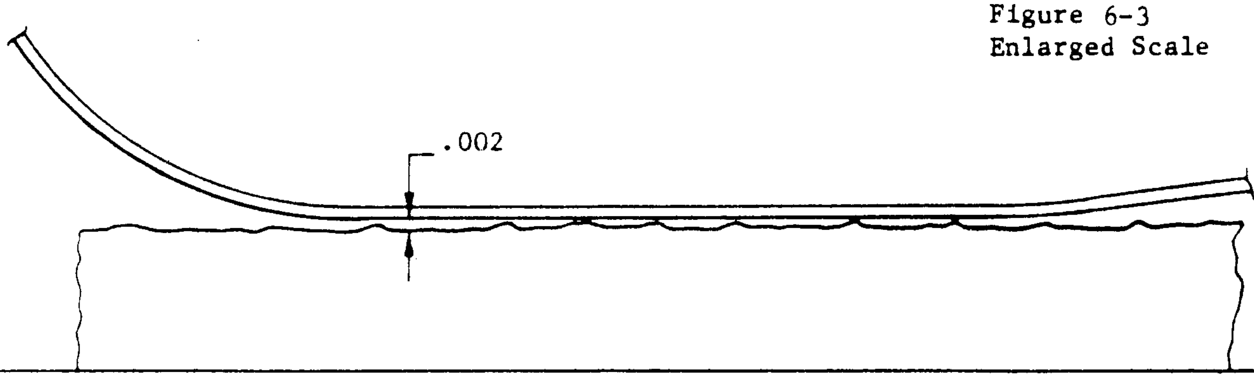


Figure 6-3
Enlarged Scale

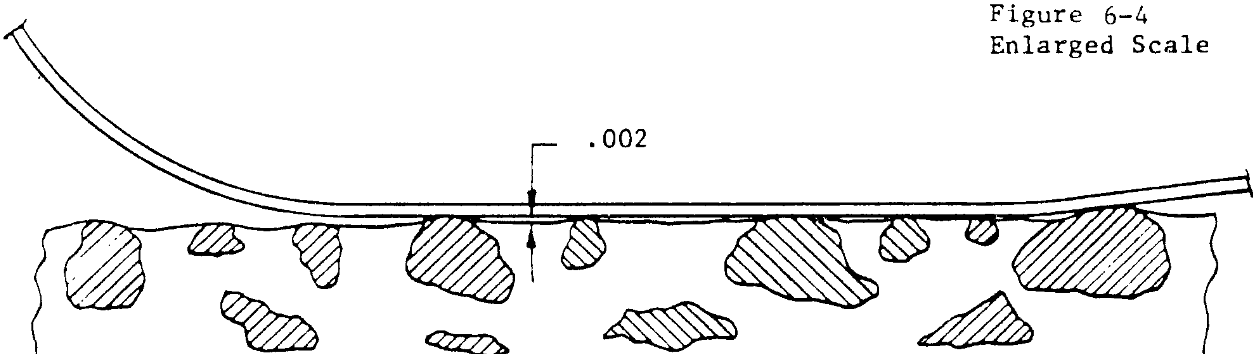


Figure 6-4
Enlarged Scale

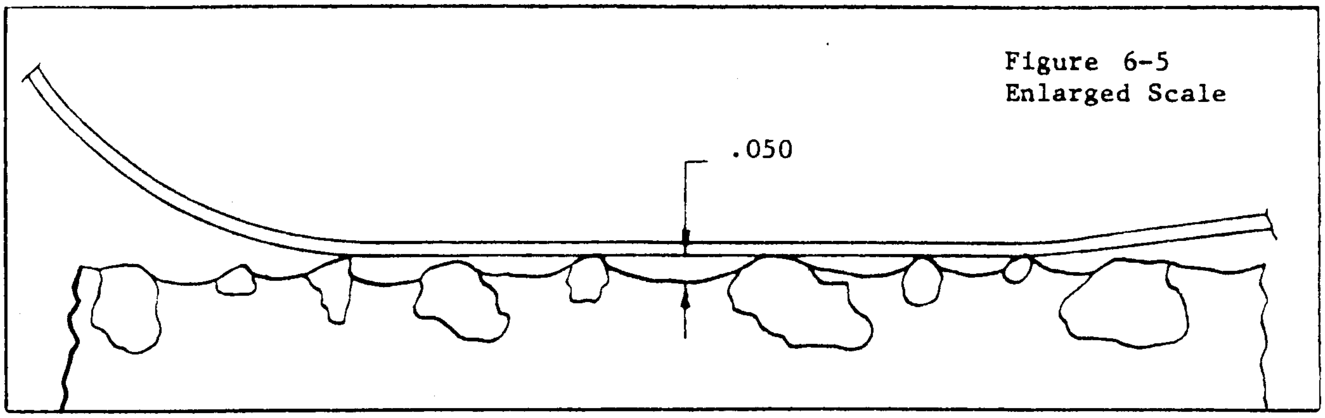


Figure 6-5
Enlarged Scale

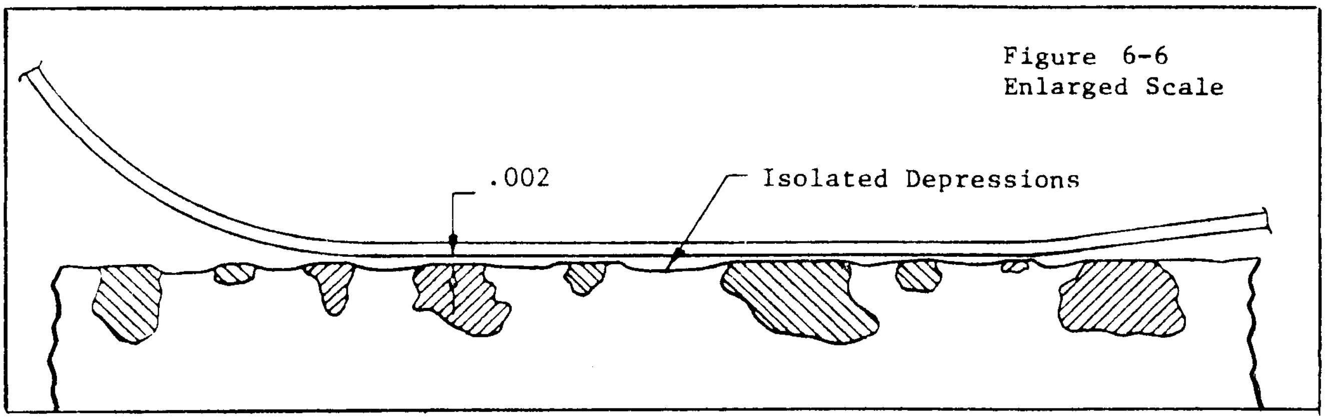


Figure 6-6
Enlarged Scale

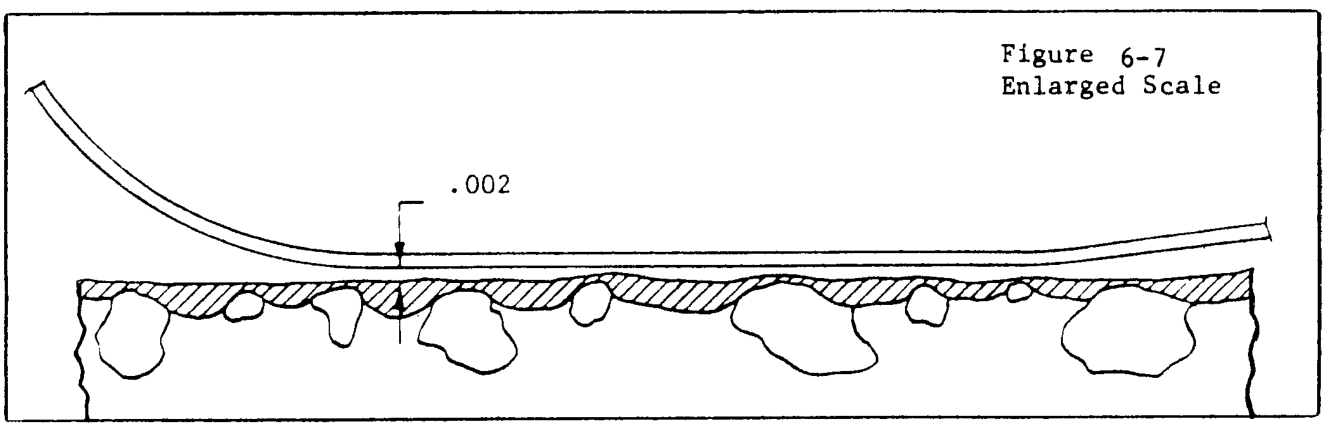


Figure 6-7
Enlarged Scale

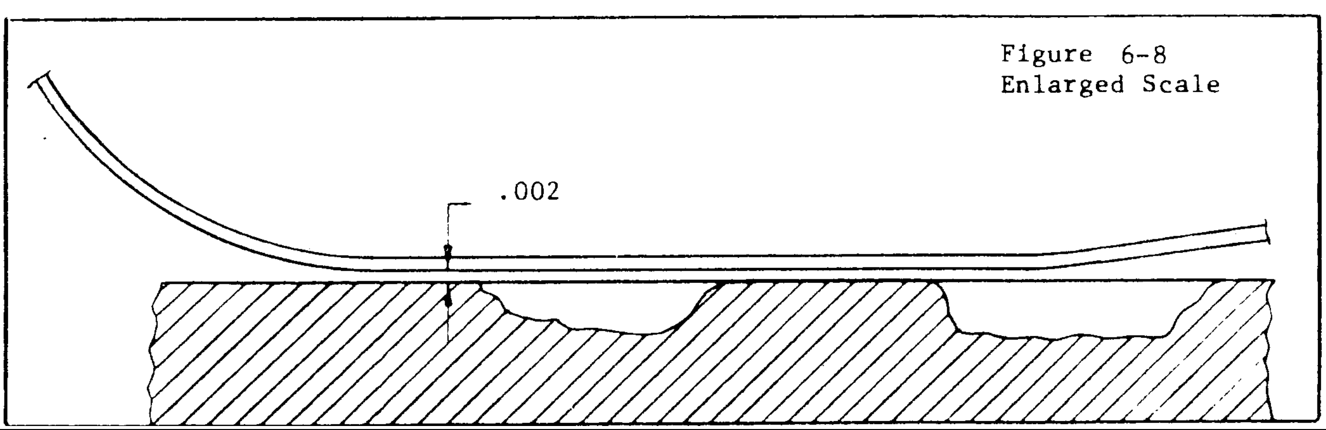


Figure 6-8
Enlarged Scale

Figure 6-3 is the same new floor, but after a week of use. Foot or wheeled traffic quickly wears down the minute ridges, to less than air film thickness. VERY GOOD FLOOR. Note: Similar effect can be gained by rubbing the new floor with emery cloth, or light grinding.
Figure 6-4 As the floor wears, mortar is worn away slightly, exposing aggregate particles. Diaphragm may touch in spots, but projections are rounded, and friction is not high. MEDIUM FLOOR.

Figure 6-5 As the floor wears further, aggregate becomes more exposed. Some scratches develop. UNUSABLE FLOOR.
Figure 6-6 The above floor can be restored by grinding the surface with a terrazzo grinder. Small depressions may remain. These are not wider than the footprint zone, and have no effect on air bearing operation. VERY GOOD FLOOR.
Figure 6-7 The same worn floor as in Figure 5 can be improved by painting or roller coating with a liquid epoxy-which fills the small depressions.
Figure 6-8 A floor once smooth, but subjected to local chipping by dropping of solid objects on it. If pitted areas are mostly isolated, and less than 1-2" in diameter, the diaphragm will control flow effectively, either on one side or the other of the pit. CAN BE USABLE FLOOR.
Figure 6-9 A smooth surface floor, but with mild gradual waviness allows the diaphragm to conform to the surface. GOOD FLOOR.
Figure 6-10 A floor with steep ridges but of the same height and spacing as in Figure 6-9. Does not allow the diaphragm to conform. BAD FLOOR.
Figure 6-11 A broomed finish concrete, like sidewalk, may cause 100 times the normal clearance gap. UNUSABLE FLOOR.
Figure 6-12 The badly worn floor as in Figure 6-5 has been covered with ½" of aggregate projects. POOR FLOOR. (To remove projections, lightly grind the epoxy or paint on a second top layer of unfilled epoxy).

Dirt particles adhering to a smooth floor can give the same effect as a very rough floor. Similarly, if dirt particles adhere, or build up on the footprint area of the diaphragm, it impairs performance as severely as similar rough projections on the floor.

In partial summary, even minute projections above the average surface impair operation. Isolated pits, grooves or depressions below a smooth surface have almost no effect.

FLOOR FRICTION CHARACTERISTICS

This refers to any property or combination of properties of the floor that affect the friction force of the diaphragm sliding over it. Theoretically there is no contact between the floor and the diaphragm. In practice, there is light contact in some areas of the diaphragm, in normal operation. The amount of drag that results from this contact depends on the friction characteristics of the floor.

As one example, imagine a flat, smooth floor covered with 500 grit abrasive paper. The height of the sharp abrasive grains would be less than the .002 inch air film expected, and in principle shouldn't cause drag. In practice, unless excess air is supplied, this surface would cause high drag. A similar condition can at times occur with a new and unused smooth concrete floor. As previously mentioned, normal use or light abrasive polishing can eliminate the minute roughness, and result in an excellent floor.

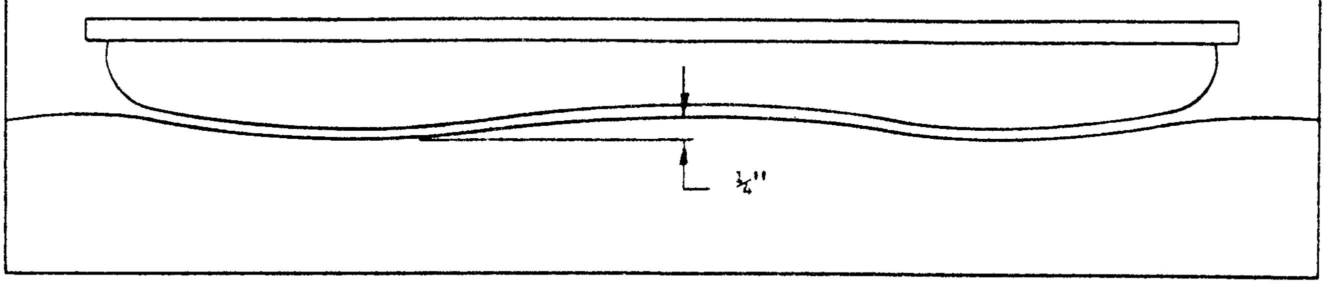


Figure 6-9
Reduced Scale

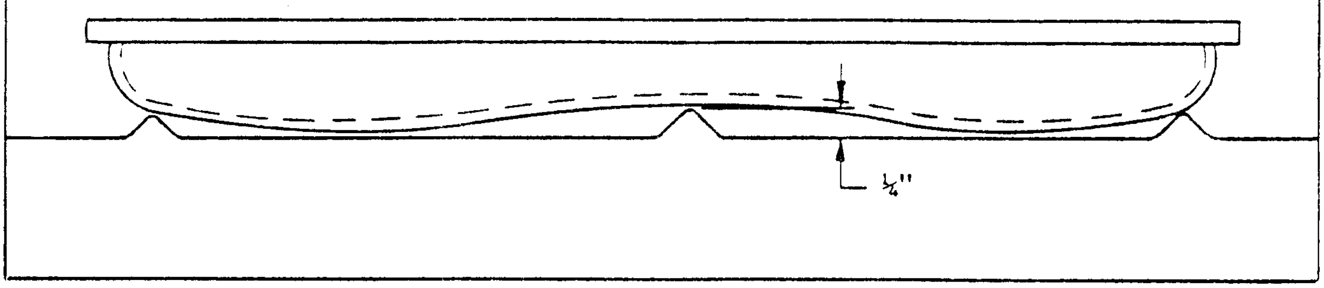


Figure 6-10
Reduced Scale

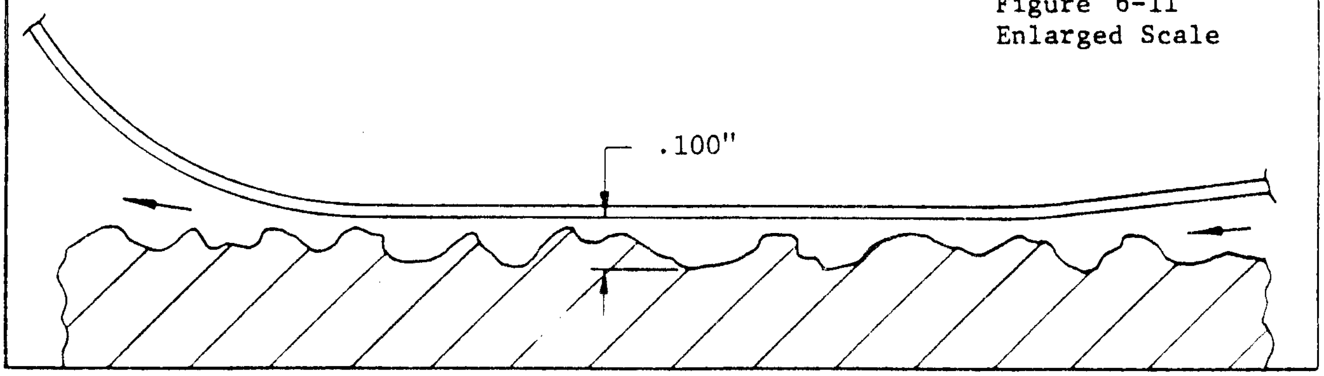


Figure 6-11
Enlarged Scale

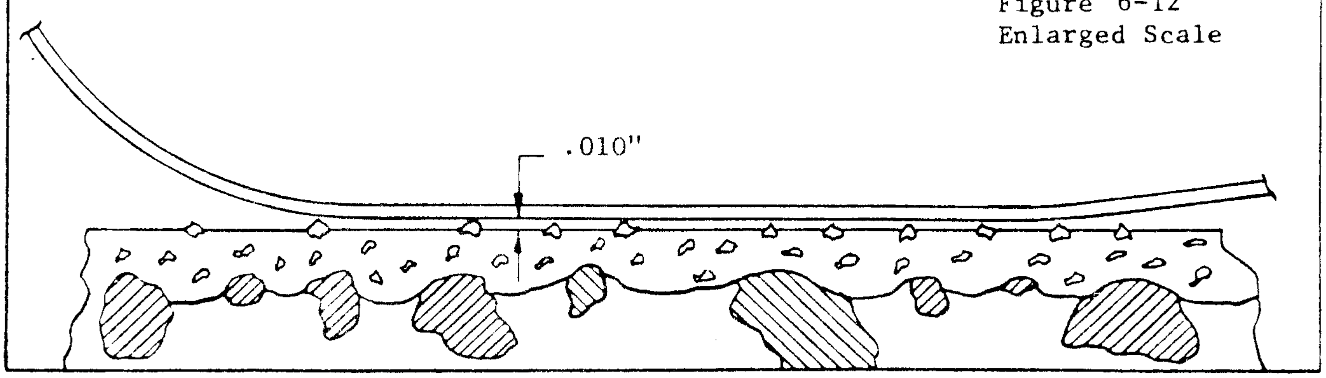


Figure 6-12
Enlarged Scale

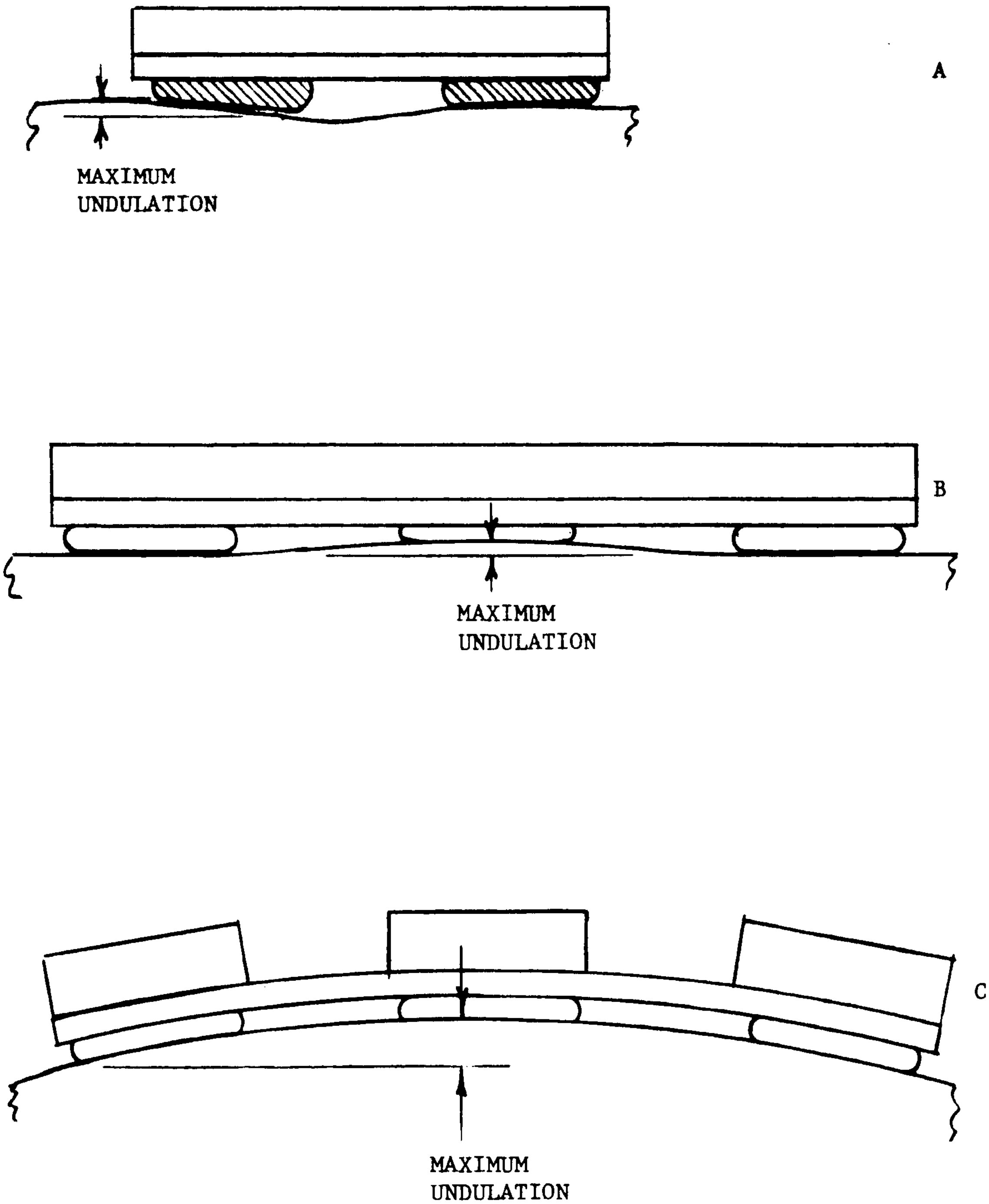

A
MAXIMUM
UNDULATION
B
MAXIMUM
UNDULATION
C
MAXIMUM
UNDULATION

FIGURE 6-13

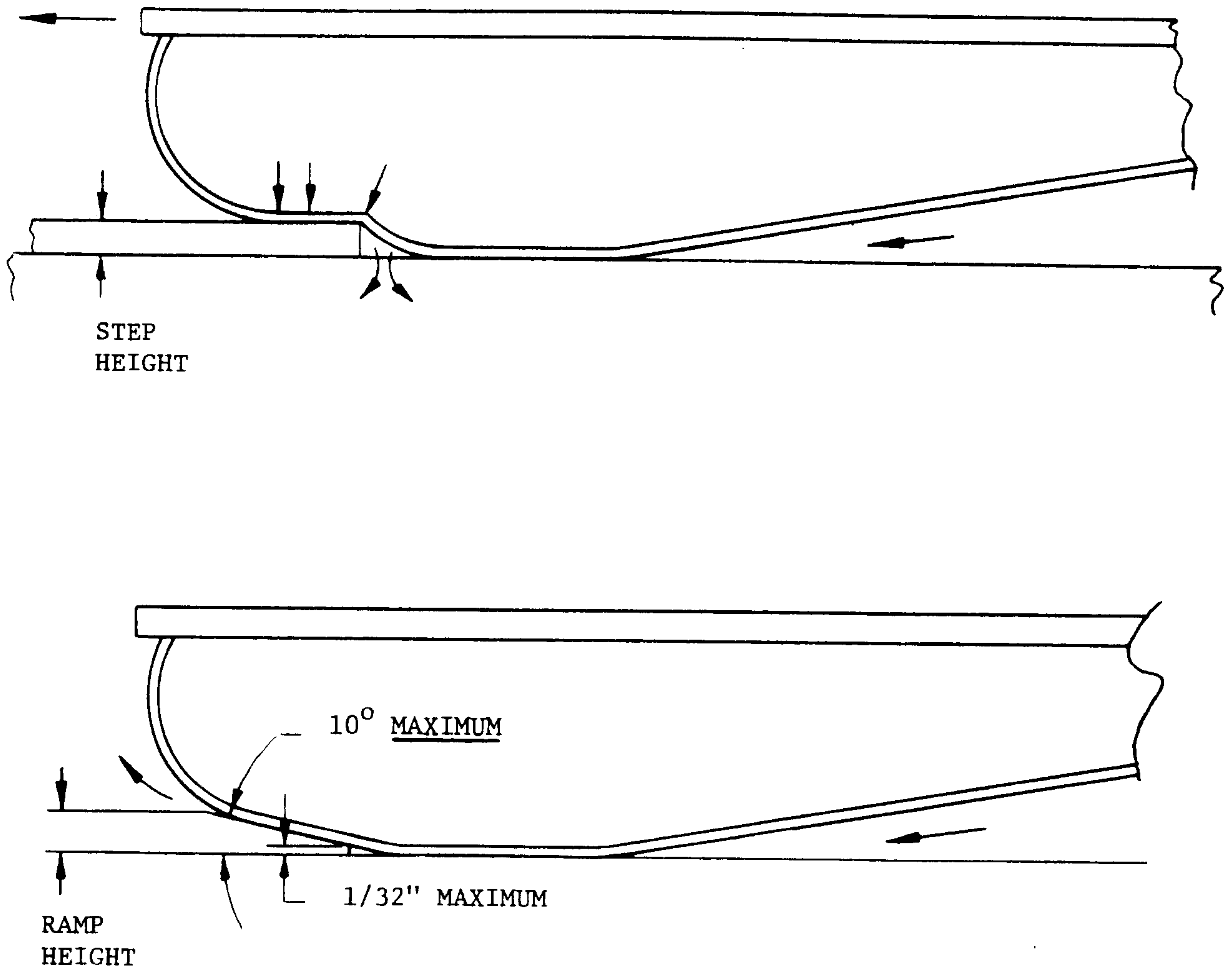
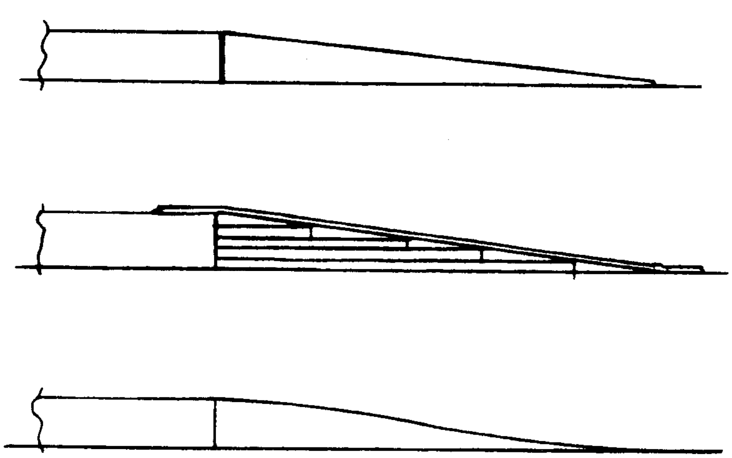


FIGURE 6-15



STEP IMPROVEMENT

1. Add a wedge-shaped ramp.

2. Add narrow shims + sheet metal or tape overlay.

3. Fillet ramp with epoxy or other floor patch material.

FIGURE 6-16

Another type of high friction surface can result from certain floor coatings that leave a smooth but slightly tacky, or high friction surface. Some low-durometer urethane coatings or sealers can give this effect, particularly when new. After a light dirt film is built up, the tackiness decreases. This can sometimes be remedied by wiping on a light coating of talc, or any talcum powder. It will last a fairly short time, but usually will be effective until normal dust and dirt takes its place.

A simple “finger” test will help measure surface friction characteristics. With the index finger at about 45^0, press down with 1-2# force, and slide it forward. If it slides easily, floor friction characteristics are probably acceptable. If it doesn’t slide well and tends to roll under, the floor condition may be a problem.

FLATNESS

One unique feature of compliant air bearings is their “compliance”, or ability to conform to undulations in the surface. This compliance is exaggerated in Figure 6-13A. Compliance increases as bearing size increases, and decreases as operating pressure increases.

As a rule of thumb, the limit of compliance is approximately 1 to 2% of the bearing diameter (somewhat greater at low pressures). This means that a 36” bearing can operate well if the surface under the bearing is .36” to .72” higher in one area than another. Thus floor waviness can be 4% of bearing diameter, across a distance equal to a bearing diameter.

This does not mean a 24’ bearing can traverse a ½” tall step. Here we are only talking about gradual undulations.

When several bearings are mounted to a rigid frame, the undulations should be limited to about 1 to 2% of bearing diameter across the entire span of bearings. Figure 6-13B. if the frame is not rigid, waviness can be much greater over the entire span. Figure 6-13C.

$$\% \text{ slope} = \frac{A}{B}$$

Force

$$F = W \times \% \text{ slope}$$

EXAMPLE:

Load	=	10,000#
Slope	=	½" in 10 ft.
% slope	=	½" ÷ 120
	=	.4%
F	=	10,000# x .004 = 40#

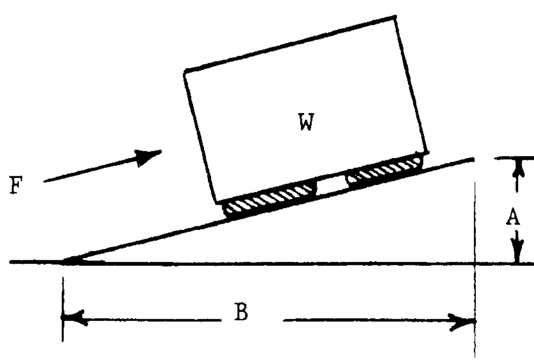


FIGURE 6-14

SLOPING FLOORS

Air bearing operation is <u>not</u> affected by a sloping floor. Moving force, however is affected. A load supported on air bearings will move by itself down a slight incline, and force is required to move it up an incline. As a result, even a slight slope, or depression in the floor will have an effect on the moving force. The force required can easily be calculated, as show in Figure 6-14.

STEPS

Air bearings have very little ability to traverse steps. For example, a 36” bearing <u>cannot</u> readily go up, on, or down from a 1/8” thick square-edge sheet. Three effects tend to prevent this. Some of the air escapes from the corners of the steps, robbing air from the bearing.

The sharp edge of the step cuts off the lubricating air film from the advancing side of the bearing, and the diaphragm “runs aground” on the sharp edge. If inertia or brute force carries the bearing some distance over on to the step, the internal pressure of the bearing forces the diaphragm down against the top of step. Since no lubricating film reaches this area, it acts like a powerful brake.

In practice, the height of a square-edge step that can be crossed depends on bearing pressure and size. Large, low-pressure bearings have greater capability than a small higher pressure bearing, but even a small square-edge step is a great obstacle. Whenever possible, steps should be modified to ramps, if only by beveling the edges. Figure 6-15.

RAMPS

While a given bearing may be unable to cross a 1/8” high step, it could cross a ½” high projection if it is ramped properly. In this case, the ramp is gradual enough not to cut off the lubricating air film, and the bearing compliance can absorb the obstruction.

If the step itself cannot be tapered, as shown in Figure 6-15, other methods can be used as shown in Figure 6-16.

When long ramps are required, they should be designed with regard to “Flatness” requirements in a preceding paragraph. In practice, long ramps whose length is equal to or greater than the bearing should be limited to 1-3% slope for most applications.

CRACKS AND EXPANSION JOINTS

Concrete floors are the most common surface on which air bearings operate. These floors are often made with expansion joints, and are subject to cracks. With many cracks, the floor on both sides of the crack is flush. However, even a nearly hairline crack can be troublesome. After several traverses with an air bearing, dirt can be blown out of the crack and air can escape through the crack to a porous gravel fill below. This way, even a small crack can leak away most of the air supplied to the bearing. Refer to a following section for repair techniques.

Expansion joints can also let air escape through the floor. They are often wide enough, and recessed sufficiently to allow much air escape out sideways from under the bearing. They also may have the two slabs shifted, so a step results. Thus unless expansion joints are properly filled they can cause a problem in three different ways.

POROSITY

Porous floor materials permit air to escape down through the floor surface itself, and leave insufficient air for bearing operation.

Floors t hat are sometimes encountered which show high porosity are hardwood plank and parquet, low density "Masonite" or particle board, and poorly painted plywood.

This porous condition is almost never encountered in good quality concrete floors, even when the surface is rather rough. Some persons have the idea that concrete floors need to have sealers applied, to eliminate porosity to air flow. Concrete sealers are often used, but their function is either to prevent unsightly oil absorption, to chemically harden he surface and prevent dusting, or for appearance reasons. There are some concrete surface "sealers" which have a heavy body, and can level minute rough areas and improve bearing performance.

FLOOR IMPROVEMENT

The appropriate methods of improving floors that are not suitable for air bearings depend on the nature of the floor defects, and also the type of air bearing equipment it must serve. A separate bulletin will be prepared on this in the future, but some general comments will be included here.

MODERATELY ROUGH FLOOR

If a floor has become rough from use, but does not have large holes or depressions, two choices may be considered. An epoxy floor coating can be applied with a brush or roller, and will tend to fill the depressions and level the surface very well. Two or more coats may be applied if necessary. Proper surface preparation is absolutely essential for good adhesion of the epoxy. Some suppliers suggest that, in addition to careful cleaning, a scarifying or mechanical abrading process is necessary to insure proper adhesion.

An alternate method we encourage where practical is to grind the surface with the large grinding machines used to prepare terrazzo floors. It is not necessary to grind to remove all pits and depressions, only to remove the high points and leave most of the surface flat and smooth. This grinding method is often relatively low cost and does not leave a coating that can peel off. The resulting terrazzo-like surface is one of the best for air bearing operation.

BADLY PITTED AND ROUGH FLOOR

A floor may be worn, rough or pitted so badly that it cannot be smoothed by grinding or applying a thin coating of liquid epoxy. An effective remedy is to use any of a number of proprietary floor coating materials that are usually mixtures of epoxy and sand aggregate. These are applied by troweling, to a minimum depth of about 1/8 inch. Some suppliers recommend that a chemical or solvent cleaning is adequate for good adhesion. We would suggest that a floor coating firm be selected that can mechanically abrade or scarify the surface after cleaning, to insure best possible adhesion.

Many, if not all of the epoxy-aggregate coating materials should be given a thin final coat of liquid epoxy "sealer" to smooth the slight roughness caused by projecting sand aggregate particles.

If you have any question about floor improvement or repair, please contact Airfloat, LLC.