Glass Beads and Reflectorization

For over sixty years Flex-O-Lite's glass beads have been used throughout the world in applications requiring improved night visibility. Their use is extremely evident in areas where safety is synonymous with visibility; such as:

1. **White and/or Yellow Lines on Highways and Airports**
2. **Barricades**
3. **Signs**
4. **Traffic Cones**
5. **Airport Runways**
6. **License Plates**
7. **Clothing**
8. **Mail Boxes**
9. **Pictures**
10. **Light Poles**
11. **House Numbers**
12. **Movie Screens, Etc.**

Some of the applications listed above require elaborate manufacturing set-ups and will not be discussed here. However, most others are very simple and offer excellent results at a minimum cost.

Why Do Beads Improve Night Visibility?

Assume two people are standing equal distance from an object and are looking at it from the same angle. (See figure 1). If person **A** shines a light on the object, one of the following four things will happen depending on the material/surface of the object.

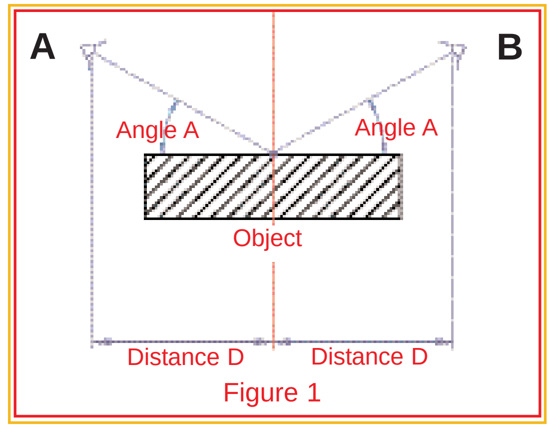
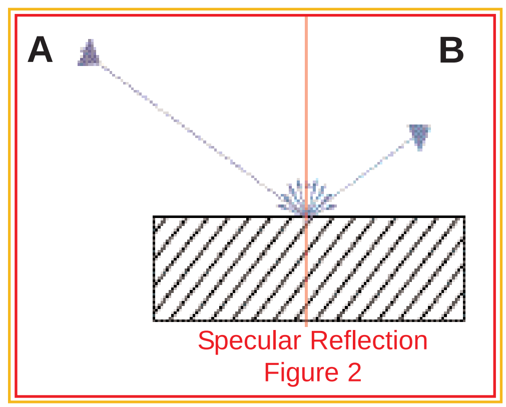


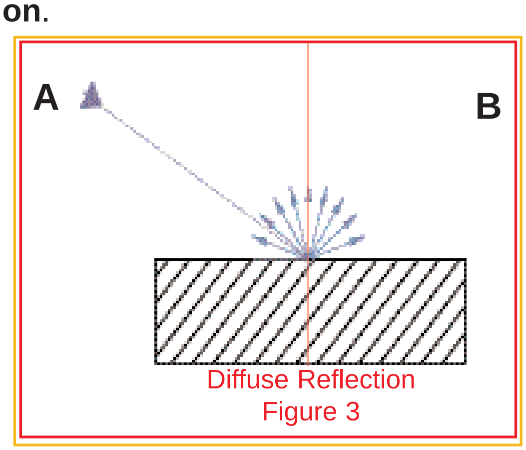
Figure 1

1. If the object was made from a very polished material, most of the light rays would be deflected toward person **B**, making it more visible to him than to person **A**. Small amounts of light would be scattered in all directions due to minute surface imperfections. (See figure 2). This condition is called **Specular Reflection**.



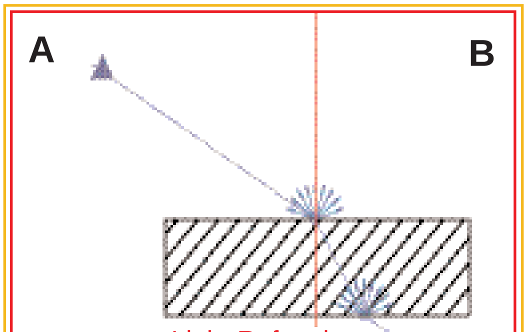
Specular Reflection
Figure 2

2. If the object had a relatively rough surface, light rays would be dispersed uniformly in all directions and both people would see it in the same way. (See figure 3). This condition is called **Diffuse Reflection**.



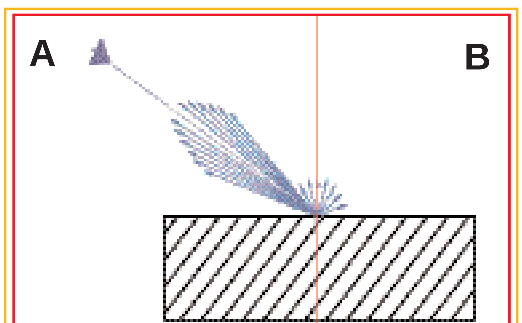
Diffuse Reflection
Figure 3

3. If the object was made from a transparent material, such as glass, most of the light would go through it. In the process, the light would change direction (bend) as it entered the object, and again as it exited. (See figure 4). This condition is called **Light Refraction**.



Light Refraction
Figure 4

4. If the surface of the object was covered with Flex-O-Lite's glass beads, most of the light would be reflected toward the light source (person **A**). Small amounts would then be scattered in all directions. (See figure 5). This condition is called **Reflex Reflectivity**, and makes the object more visible to person **A** than to person **B**.

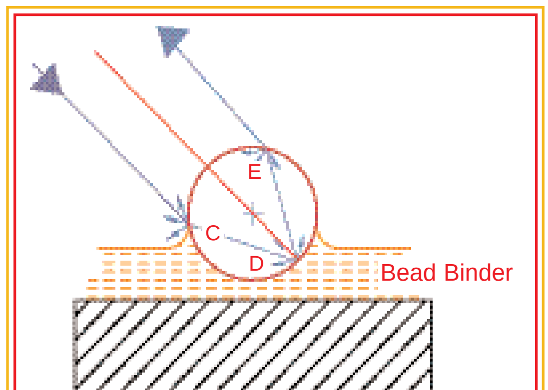


Reflex Reflectivity
Figure 5

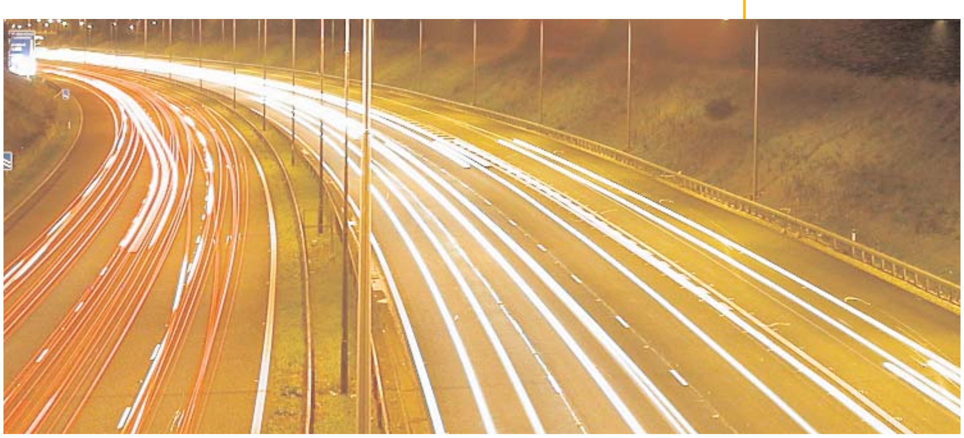
Why Do Beads Return Light to the Source?

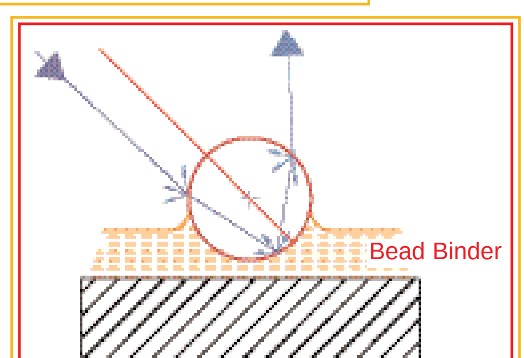
...or, what causes Reflex Reflectivity?

To achieve this, two principles are combined: Light Refraction (Fig 4) and Specular Reflection (Fig 2). A light ray enters the bead at point **C** (See figure 6) and is "bent" (Light Refraction) toward the centerline. At point **D** it encounters the high-gloss bead binder and is deflected (Specular Reflection) toward point **E**. As it leaves the sphere, the light is "bent" once again. The direction of the light ray after leaving the sphere is determined by the location of point **D**. If that point is on the centerline of the sphere, the light ray would be returned to the source (it would be parallel to the incoming ray). If point **D** is not on the centerline, the out-going ray will not be parallel with the incoming ray and would "miss" the source. (See figure 7). As the distance of point **D** from the centerline increases, so does the "miss". The location of point **D** is determined by the bead's **Index of Refraction**. Figure 6 depicts a bead having an index of refraction of approx 1.9. The bead in figure 7 has a lower index.



Surface of the Object
Figure 6





Surface of the Object
Figure 7

In A Nut-Shell
(...Predictable Results)

Using beads with the index of refraction of 1.9 will result in objects appearing very bright. (See figure 8).

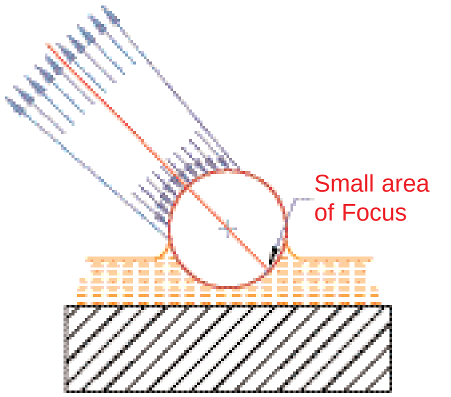


Figure 8

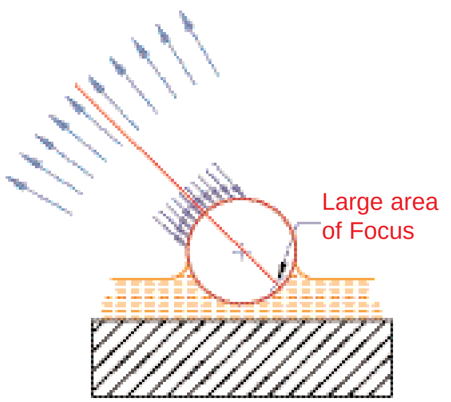


Figure 9

Objects coated with beads having a 1.5 index of refraction will not be as bright. (See figure 9).

Surfaces reflectorized with beads over light colored binders (silver, white and yellow) will have better night visibility than if they were applied over darker binders.

How Are Surfaces Reflectorized?

There are two ways to achieve this. *The most important step in either case is the selection of the bead binder.* It has to adhere to the glass and to the surface being reflectorized. (In many cases, ordinary high-gloss paint from hardware stores will perform well.)

In the first method, the **first step** *consists of the application of one coat of bead-binder.* The binder has to be applied so its dry-film-thickness is at least half of the bead diameter. Application of the binder can be achieved by any standard method: hand roller, spray, silkscreen, knife-over-roll, roller coater, or brush.

The **second step** in this process consists of an application of flotation-treated beads over the wet binder. This treatment prevents beads from sinking to the bottom. The depth to which the beads will sink depends on the type of binder and the amount of flotation treatment applied to the beads at the factory. The depth of embedment has two-fold importance: It determines how securely the binder will hold the beads and how reflective the surface will be. In general, beads embedded 40 to 50 percent of their diameter will give a very good reflectivity and have good retention (See figures 10 through 14 for various conditions).

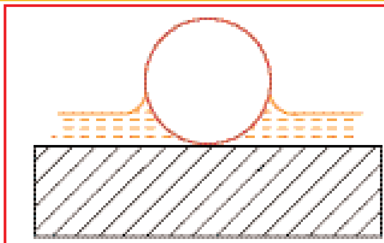


Figure 10

In figure 10 the bead has sunk to the bottom. Reflected light will have the color of the object and not of the binder.

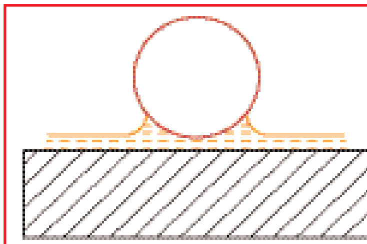


Figure 11

Figure 11 shows a bead which can easily be removed from the binder. This condition will result in a short life of the reflectorized surface.

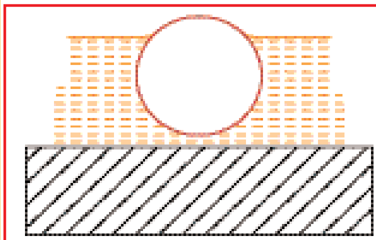


Figure 12

Figure 12 depicts a situation in which the binder is covering most of the bead and reducing the amount of light entering the sphere. It results in low reflectivity.

Figure 13 illustrates a high amount of capillary action (wicking). This condition will also reduce the amount of light entering the sphere and will result in low reflectivity.

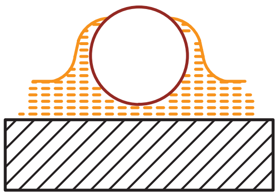


Figure 13

Figure 14 shows the optimum condition. Low capillary action combined with proper embedment will result in good reflectivity and bead retention.

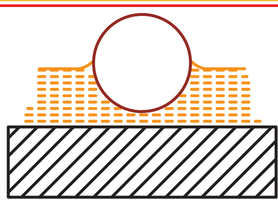


Figure 14

The **third and final step** is 'cure.' This is dependent on the type of binder used. Baked-on enamels offer better retention of the beads, but are not always practical. In those cases, air-dried binders are substituted.

The second method of reflectorization consists of five steps:
In the **first step**, a thin coat of binder is applied to the surface. The thickness is determined by the hiding (covering) ability of the binder. The goal is to provide the base color without bleed-through of the underneath surface color.

Step two is the drying of the paint (binder).

In the **third step**, the second coat of bead binder is applied. It is very important to maintain a uniform wet-film-thickness which, when dried, will result in a bead encapsulation of 40 to 50 percent of its diameter. Due to the requirement of precise and uniform binder application, a brushing method is not recommended.

The **fourth step** consists of the application of non-treated beads over the wet binder. Since the beads were not treated with a substance which makes them float, they will sink and rest on the top of the first coat of binder. (See figure 15).

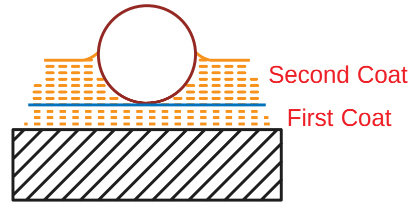


Figure 15

The **fifth and final step** is the cure cycle, which depends on the type of binder.

Differences Between The Two Methods:

The first method is used when it is not possible to apply the binder in the exact film thickness, due to the lack of equipment and/or shape of the object being reflectorized. It results in a slightly reduced reflectivity when compared to surfaces reflectorized with the second method. The culprit is the process by which the beads are flotation treated. Because of their small size, it is impossible to put a uniform coating on each and every bead. Consequently, some will sink deeper into the binder, which will effect reflectivity. (See figure 12).

Note:
The information in this pamphlet is intended as an introduction to reflectorization using glass beads and contains some generalizations. If additional information is needed, please contact our technical service department by calling toll-free: 800.325.9525.

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