technical bulletin: **REFLECTOR MANUFACTURING**

Lighting designers apply both art and science to determine appropriate downlighting products to meet the varying requirements of a space. It is the manufacturer's responsibility, in turn, to offer luminaires that combine high efficiency and low high-angle brightness, with aesthetic qualities that meet the designer's expectations.

Perhaps the most critical component of a high-quality performance downlighting system is the reflector. The goal of this report is to inform lighting professionals about key manufacturing processes that impact reflector quality, to promote critical and objective evaluations of alternative products and to ensure that the downlights selected will not compromise the integrity of their lighting designs.

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Gotham is one of very few downlighting manufacturers that produces its own reflectors. We have assembled the most experienced reflector manufacturing team in the U.S. — highly skilled professionals whose exposure to various reflector manufacturing techniques has resulted in the creation of a unique Gotham manufacturing philosophy. We are committed to the goal of continually improving downlighting reflector quality.

REFLECTOR MANUFACTURING PROCESS OVERVIEW

There are two major steps in the reflector manufacturing process: fabrication and finishing.

Fabrication is the process of forming a flat aluminum sheet into the shape and design developed by mechanical and optical engineers. For downlighting reflectors, this shaping is typically performed with one of two processes, spinning or hydroforming.

After shaping, raw parts are polished. Since polished parts are easily scratched, the final step of the process, finishing, adds an anodized coating to protect this sensitive surface.

SPINNING

Most Gotham reflectors are created by spinning. With spinning, a tool the shape of the desired reflector, called a chuck, is connected to the axle of a lathe. An aluminum blank is attached to the end of this tool and locked in place. The lathe is then spun at a high speed as rollers slowly work and push the aluminum into the shape of the reflector in a series of slow-spin passes (Fig. 1).

With downlighting reflectors, quality is determined by the absence of imperfections and consistency from one reflector to the next. The most common spinning imperfections are described in Table 1.

Hand-spinning

In the past, most spinning was done by hand; operators formed

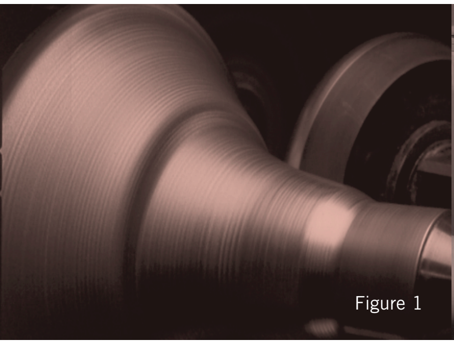
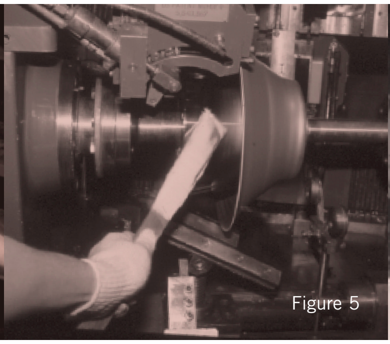


Figure 1



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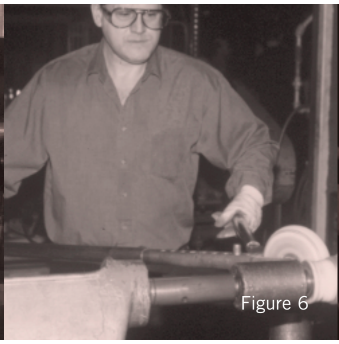


Figure 6

Figure 7

Table 1

IMPERFECTION	DESCRIPTION	SYMPTOM	CAUSE
Spin Lines (Fig.2)	Horizontal indentations that follow reflector curve parallel to ceiling.	Light reflects off indentations attracting undue attention and increasing high angle brightness.	Material is spun too quickly with insufficient burnishing (smoothing) process.
Material Separation (Fig.3)	In areas requiring tight radii (flanges), the material appears to be more diffuse than the rest of the reflector.	Decreased optical control. Lower efficiency and increased brightness at high angles.	Wrong radius on spin chuck. Material is spun too quickly.
Inconsistent Aluminum Thickness	Reflector feels too thin and is easily bent.	Part is easily damaged before or during installation. If not corrected, the damage will cause high-angle brightness and will complicate installation.	Reflector is spun too quickly.
Pitting (Fig.4)	Small imperfections on smooth sections of the reflector.	Non-uniform reflector appearance. The imperfection is brighter than its surroundings and is potentially distracting.	Scratches on blank before fabrication. Accelerated spin cycle causes the aluminum grain to separate.

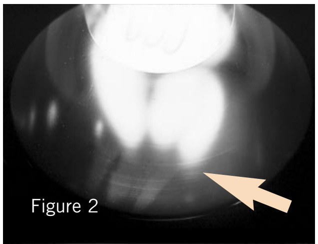


Figure 2

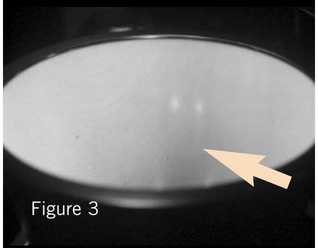


Figure 3

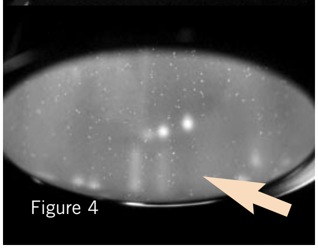


Figure 4

aluminum blanks on a spinning tool or chuck, with manually controlled rollers (Fig. 5 and 6). Hand-spinning is very difficult to do consistently well. It requires an artisan's touch to successfully produce a quality part. Hand-spinning can produce good reflectors, but human error makes it difficult to produce them free of imperfections time after time.

Computer-Controlled Spinning

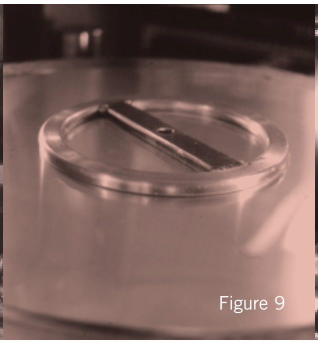
Gotham reflectors are spun on state-of-the-art, computer controlled spinning machines (Fig. 7). These machines are programmed to spin a reflector onto a spin chuck with a precise, optimized process for each reflector. Spinning programs are created by experienced programmers who understand how aluminum flows onto a spinning tool. In fact, before programming the spinning machine, the programmer will hand-spin a new reflector design to understand its nuances. This hands-on experience allows the programmer to fine-tune the automated process until a production part of consistent quality is created.

Hydroforming is an extremely precise process. To form a reflector correctly, the pressure of the bladder must be within a tight range. If there is too much pressure, the blank is sheared. If there is too little, the part does not form correctly and wrinkles. As with auto-spinning, the variables for the Gotham reflector hydroform process are optimized before a part goes into production. Reflector hydroforming is somewhat unique. Of the 300 machines (pictured below) worldwide that produce hydroformed parts, four reside at Gotham.

POLISHING/BUFFING

After fabrication, a reflector has a rough, non-specular appearance. A microscopic cross section of the reflector surface reveals a series of peaks and valleys (Fig. 11). In the polishing or buffing process, buffing wheels are used to polish the reflector surface knocking down and smoothing the peaks (Fig. 12). Gotham semi-automatic buffing machines and extremely experienced hand-buffers ensure high quality polishing of every reflector (Fig. 13).


Figure 8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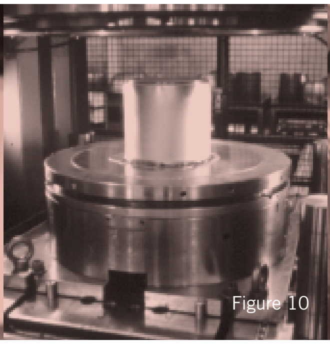
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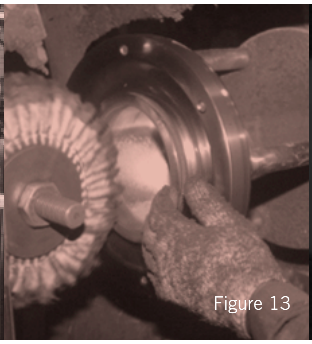
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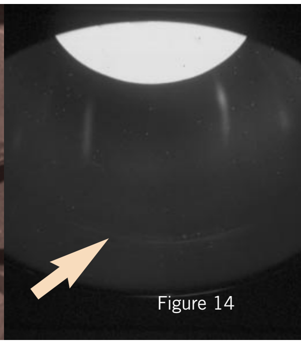


Figure 14

To create a spinning tool, or chuck, Gotham's optical engineers first create a computer-generated contour defined by literally thousands of calculated points. The distance between two points is no greater than 1/10,000 of an inch. The curve is then transferred electronically to a highly specialized computer-controlled machine that cuts the spin chuck to conform precisely to the optical engineers computer-generated curve.

Automation guarantees consistent aluminum gauge and ensures that a reflector produced yesterday is identical to one produced today. Imperfections, such as spin lines, material separation and pitting, are also eliminated. In short, Gotham state-of-the-art computer-controlled spinners eliminate the imperfections typically found in reflectors produced by traditional hand-spinning techniques or other auto-spin machines.

HYDROFORMING

Not all Gotham reflectors are produced by spinning. Some are created by a process called hydroforming. In this process, an aluminum blank is placed on top of a tool that is shaped like the desired reflector (Fig. 8). A rubber diaphragm is lowered onto the pressurized blank and forms the aluminum around the tool (Fig. 9). A ram then pushes the tool and blank into the bladder to finish the operation (Fig. 10).

Table 2 details the most common buffing problems.

Figure 11

Figure 12

Table 2

IMPERFECTION	Buffing Scratches (Fig.14)
DESCRIPTION	Large quantity of thin, horizontal scratches all over smooth sections of the reflector.
SYMPTOM	Breaks up the uniform appearance of the reflector. In extreme case, the scratches increase overall reflector brightness at high angles.
CAUSE	Reflector buffed too long, resulting in deeply scratched aluminum surface.

FINISHING (ANODIZING)

Finishing is a seven-step process that results in a durable, protective coating for the fabricated and polished reflectors. It is the most difficult reflector manufacturing process to master. Finishing imperfections are more difficult to detect than fabrication imperfections and result in significant degradation of fixture performance (Table 3). The Gotham seven-step finishing process is outlined below:

1. Cleaning The shaped aluminum reflector is first dipped in a series of tanks to clean and remove any debris from fabrication to prepare it for the rest of the process.

2. Bright Dip Reflectors are then dipped in a phosphoric/nitric solution, which further lowers the surface peaks on the aluminum material. This further increases the specularity of the reflector (Fig. 17).

5. Rinsing Once anodized, reflectors are dipped into a series of rinse tanks to prepare for the sealing process.

6. Sealing To complete the finishing process, the pores of the aluminum oxide film must be sealed. If the pores are not sealed, they act like receptacles collecting outside particles and holding them permanently. The seal is created by placing the reflectors into a tank of hot water. Heat causes the sides of the pores to contract, thus sealing the aluminum surface from contamination.

7. Clean/Dry Reflectors are cleaned and dried and are ready for inspection and shipment.

Beyond this seven-step process, the key to an exceptional finish is to understand and control these critical variables:

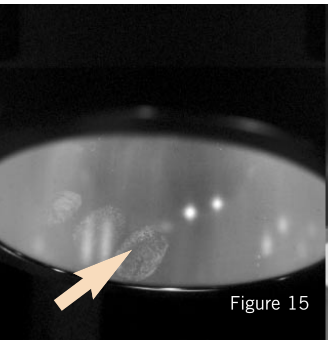
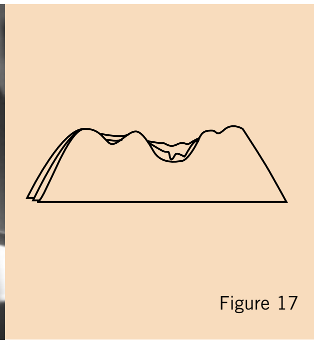


Figure 15


Figure 16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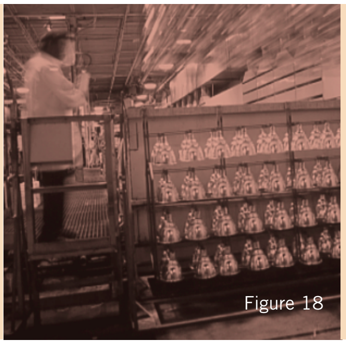
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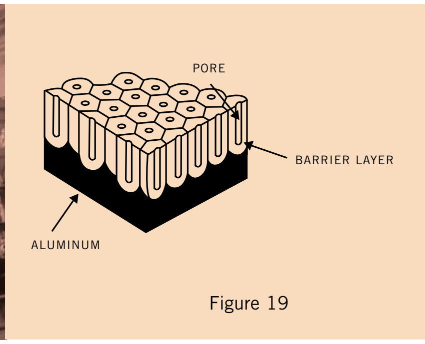

Figure 19

3. Cleaning Next, reflectors are dipped in a series of tanks to clean residue from the bright dip process in preparation for anodizing.

4. Anodizing After cleaning, reflectors are placed in a sulfuric solution of water and subjected to an electric current (Fig. 18). The current causes a controlled, crystalline oxidation that results in the formation of an aluminum oxide film on the aluminum surface. Microscopically, the film is seen as a series of pores (Fig. 19).

Time The amount of time a reflector spends in each of the above seven steps can drastically affect the appearance of a reflector. If a reflector is left in any tank for the wrong amount of time, it may lose specularity, weaken, become milky or lack appropriate protection. Many years of experience have enabled Gotham to determine exactly how much time each reflector needs to spend in each tank to produce a certain finish. Automation ensures that the process specifications are strictly followed, so all reflectors produced are identical and perfect.

Table 3

IMPERFECTION	DESCRIPTION	SYMPTOM	CAUSE
Poor Seal (Fig.15)	Fingerprints cannot be cleaned off reflector.	Fingerpoints glow, draw unwanted attention and make the reflector look dirty.	The pores of the aluminum oxide film did not close properly during sealing.
Insufficient Coating Thickness	Aluminum Oxide coating does not meet minimum requirements.	Part scratches more easily and is susceptible to corrosion.	Reflectors were not left in the anodize tank for the required amount of time.
Racking Mark (Fig. 16)	Small blemish that looks like a scratch, dent or pit.	Non-uniform reflector appearance. The imperfection is brighter than its surroundings and is potentially distracting.	Point of contact between reflector and transportation rack is not well hidden.

FINISHING (ANODIZING) CONT.

Chemical Mixture The chemical mixture in each tank is critical. If any variable (pH, specific gravity, temperature, etc.) is not within an optimum range, the quality of the reflector will suffer. Each immersion tank is computer monitored to ensure all critical variables are maintained (Fig. 20). If the chemical composition of any tank falls outside acceptable tolerances, operators are immediately alerted and corrections made.

Contamination Cleaning is a critical part of finishing. Reflectors must be designed so that no chemicals are allowed to collect and be carried from one tank to another. A rolled edge of a reflector (Fig. 21) is an example of this type of reflector design. At Gotham, design and process engineers work closely together to ensure that all reflector designs can be easily cleaned during the finishing process. A system with no contamination ensures well-sealed quality parts.

Racking Reflectors move through the anodization tanks in groups attached to racks. The connection between the reflector and rack is critical. If a connection is poor, inconsistent anodizing occurs. The location where the rack attaches to the reflector is also critical since a noticeable mark is left on the reflector at that point. Gotham racking is ingeniously designed to hold reflectors solidly at a point of contact where the unavoidable mark is hidden from view.

Figure 20

Figure 21

CONCLUSION

It is recommended that a sample of any downlight from any manufacturer be evaluated by the outlined quality standards. Doing so will ensure that the specified downlights will accomplish what the designer intends. In addition, quality specifications should always be included in a downlighting fixture specification. For example: Finish – Specular Clear Low Iridescence. No spin lines. Complete seal. No pitting. No buffing scratches. Coating thickness greater than .20 mils.

As a final check, production reflectors in the ceiling should be evaluated with the same thoroughness. Gotham has elevated the specification-quality reflector manufacturing process to a new standard. Evaluation of downlighting performance as described within this document will ensure that specified downlighting equipment can successfully transform the lighting design from concept to reality.

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