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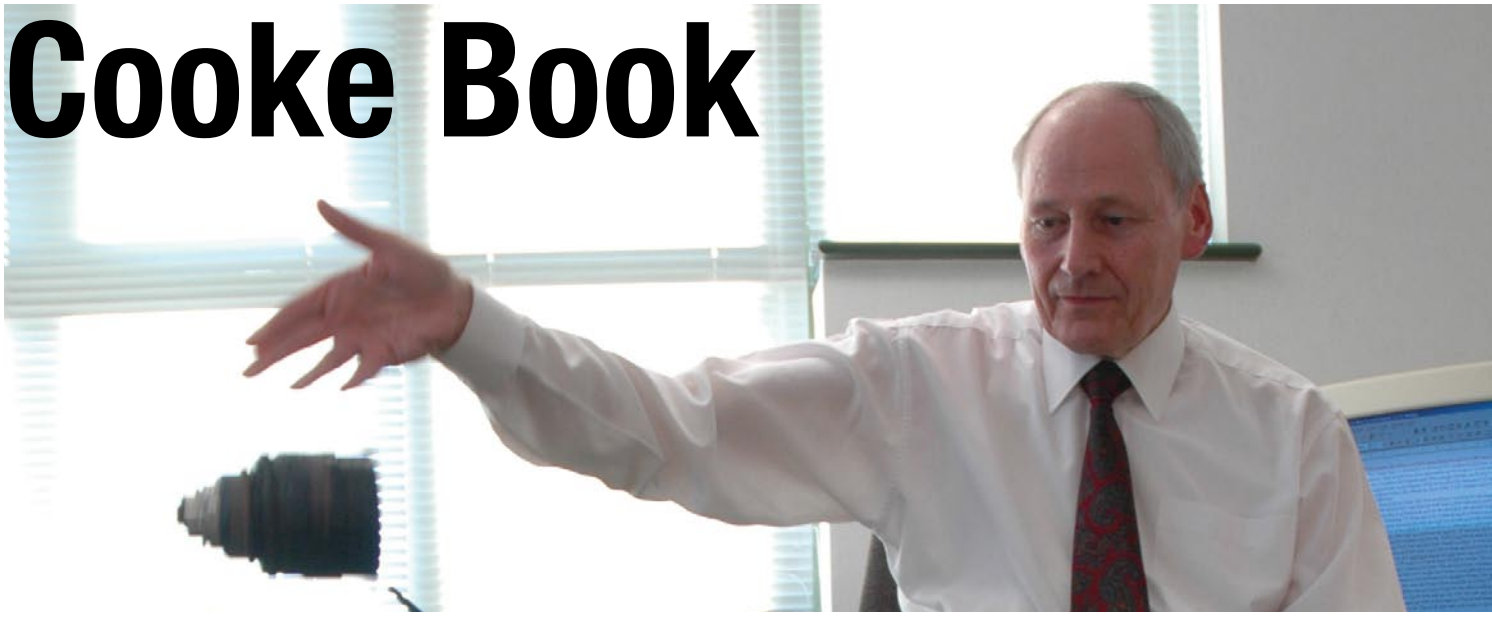
FILM AND DIGITAL TIMES

The Newsletter of Art, Technique and Technology for Film, Video and Digital Production

Cooke Book



David Nettleton, Cooke Chief Engineer, demonstrates the robustness of a Cooke S4/i. Although the lens survived, you should not attempt. May void warranty.

We're on the outskirts of Leicester, two hours north of London. The Cooke factory has relocated from the Dickensian industrial revolutionary ancestral home I remembered to this modern facility on the outskirts of town.

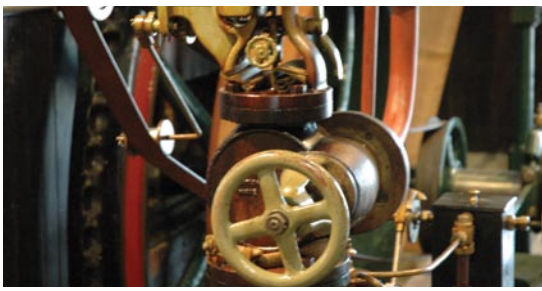
Inside the factory, there are film posters everywhere. Every square inch of available wall space is festooned with posters of major motion pictures: *Da Vinci Code, Harry Potter—Goblet of Fire, Prisoner of Azkeban, Kingdom of Heaven, Cinderella Man, Casino Royale, Brokeback Mountain, Munich, The Interpreter, Jarhead, Apocalypse Now, Chocolat,* and more.

It is clear the people who work here love movies—especially ones supplied with Cooke lenses. Pat Webb *(above)* saw 250 films this year in movie theaters. He has worked at Cooke for 42 years, and is the materials controller, tracking the arrival and deployment of countless parts.

Lens design is all about math. It's about funneling what you see down a little hole in your camera. Stuffing a 24 mile swath of Moroccan desert in *Babel* onto a 24mm x 18mm piece of plastic requires a different set of calculations than the 10' wide stacked telephoto astronaut hero shot in the *Right Stuff.* A flat piece of glass will pass light (the image) straight through. But, look through a raindrop on your window and see how the curved surface does interesting things.

It became clear after many centuries of peering through raindrops and other curved surfaces that the way light behaved could be described in mathematical formulas.

Cut to Leicester, England. In 1885, brothers William and Thomas Smithies Taylor moved to Leicester to set up a business as "Manufacturers of Optical Instruments" in Slate Street.



Cooke, cont'd

This was the Silicon Valley of the Industrial Revolution, where an abundance of coal to power the steam engines that ran the mills fueled the development of railroads, the dimpled golf ball, a knitting industry that supplied most of the world's socks and, of course, camera lenses.

The Taylor brothers were mechanical geniuses, having opened their first workshop in North London while still at school. They built their own lathe and concentrated on optical engineering.

In 1881, the Taylors built magic lanterns from brass and mahogany, with lenses ground by hand from solid glass blocks. It was actually two projectors, one above the other, illuminated by separate "limelight" burners. They were used alternately on the same screen to provide dissolves and transitions between slides—something Powerpoint still does.

An original Taylor magic lantern is on display at the Snibston Technology museum, not far from Leicester.

In 1887 William Hobson was taken on as sales manager, and the firm was named Taylor, Taylor & Hobson. The first Cooke lens was made in 1894, after T. Cooke & Sons of York (makers of telescopes) offered Taylor, Taylor & Hobson the manufacturing rights to a Triplett (3-section) photographic lens that solved the problem of edge softness.

Speed-ramp through the next 100 years: almost all feature films made in Hollywood during the first half of the 20th century were shot using Cooke lenses. Major innovations included the 1921 Speed Pancros (f2.0), and the first production zoom lens (circa 1936).

The Taylor brothers died in 1937 and 1938—the company was renamed Taylor-Hobson. In 1945, it became a subsidiary of the Rank Organization, with the familiar gong logo. Its founder, J. Arthur Rank (later Lord) was the British Mogul and Methodist who began by producing religious films and wound up controlling half the theatres in England and most of the production studios.

But, as Rank's fortunes dwindled (familiar story—mergers, diversification into real estate and the Hard Rock Cafe) Cooke lenses became a neglected division of the company. By the 1990s, there were reports that "the place was so run down that sea-gull feathers would float through holes in the roof."

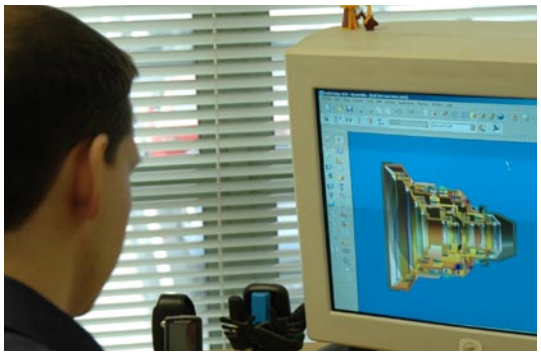
Enter Les Zellan. The Wall Street Journal wrote, "In 1998 an American wearing jeans, a bright yellow shirt and a 20-year-old red tie, with a beard and a short business plan, rescued the company."

Lens making for motion picture cameras is as much an art as a science. What makes it especially interesting is the need to focus smoothly on actors and things that move during the shot, and the exquisite tolerances needed to prevent any differences between actual eye focus and focus marks on the lens barrel.

Lenses begin as clear, bubble-free, scientific glass. This comes from Schott in Germany and Ohara in Japan. Over 70 different types of glass are used, with different refractive and chemical compositions. To save time, stress on the glass and waste, they are supplied already molded close to the required shape, with about 1mm excess. The outer surfaces are rough; you can't see through this glass. Only when ground and polished with very fine abrasive (cerium oxide) will it appear clear—just as toothpaste makes scratched Plexiglas look clear again.

Grinding with modern CNC (Computer Numerically Controlled) machines, and also on the same machines used 90 years ago, puts precise curves in the glass.

Cooke's Tour: The Adventure Continues



History Review

We've heard about the history of Cooke, founded in 1886 by the Taylor brothers, "Manufacturers of Optical Instruments" and inventors of the dimpled golf ball.

Located in a modern building on the outskirts of Leicester, England, the Cooke factory today employs over 65 highly skilled craftsmen and women. While other optical companies around the world make lenses for many purposes, Cooke still specializes in lenses for the motion picture industry.

So, let's get started and build some lenses. It only takes about 40 hours from start to finish to assemble a Cooke S4/i.

How to Build a Lens

Grinding globs of glass into fine optical-mechanical instruments is a highly guarded, highly skilled industry matched in secrecy only by that other high-end grinding business: diamonds.

This Cooke's tour was the first time a mortal cinematographer was allowed unrestricted access with a camera into the inner sanctum and holy of holies of lens creation.

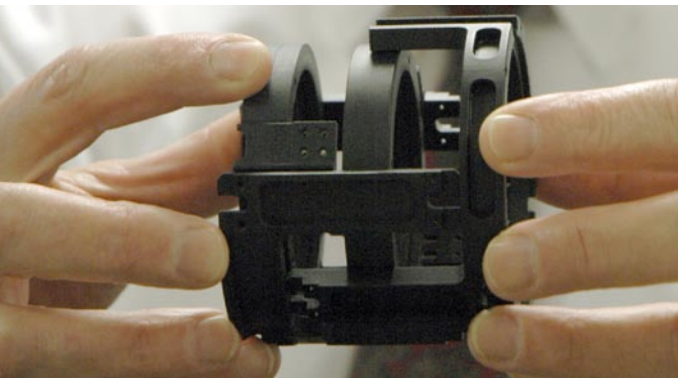
Lens design is mostly math, physics and formulas. Venerable Taylor Hobsons and Speed Panchros began as long lines of numbers pencilled into voluminous notebooks, still on display and often referred to in the Cooke design offices. Now they use computers. Paul Nettleton uses 3D CAD, middle left.

In a switch on stereotypical generational behavior, it's the dad, David Nettleton who mischievously bounces S4/i lenses off the floor to prove lens resilience. As we've said before, although the lens survived, you should not attempt. May void warranty.

Cooke, cont'd

"The safe-house is north," says the driver. We have driven through fog and rain to a row house on the outskirts of Leicester. The driver knocks three times. It could have been a scene from John le Carré. No, more J. K. Rowling. The street looked like Privet Drive in Little Whinging, with wizards lurking in the shadows, streetlights flickering.

We're in Mountsorrel, a village on the outskirts of Leicester, where wizards and designers stay when working at the Cooke factory just down the road. Lots of late night arrivals and departures have inspired imaginative neighbors weaned on Smiley and 007 to call it "the Safe-House." Its real name is "The Gatehouse." Guy Genin is the "G" of ZGC, Inc. Guy is on one of his frequent trips to the factory. Guy services most of the Cooke lenses in the US at ZGC in New Jersey, and was my gracious factory, tour and restaurant guide for three days.



Lens theory 101 in one sentence: glass elements are moved toward or away from the image plane to achieve focus.

Lenses are made of groups of polished glass disks—called elements. Each element is ground according to exact specifications: for curvature, spacing, arrangement, thickness and diameter.

To move the glass, metal carriers hold the elements and move them with great precision, smoothly and in exact alignment with the focus scales engraved on the outer barrel. Oh yes, and they must endure the abuse of life in production, extremes in temperature, being dropped, left out in the rain, and all kinds of other horrors that make any designer cringe.

The mechanical part of the optical-mechanical-electronic trinity is an array of precision machined barrels that move the internal elements in exact harmony with scribed focus and aperture marks on the outside.

Recently, with the introduction of smart lens technology, electronics have been added to the mix in the form of the /i-Lens system. Sensors provide continuous updates on distance, f-stop, and focal length.

A famous British industrialist said, "If you can't measure it, you can't make it." So, there is as much measuring as grinding, polishing and fitting at Cooke. Oh yes, and coating. All glass surfaces reflect 4% of the light passing through. If your lens had 22 elements, with 44 surfaces, not much light would get through.

Cooke lens coatings reduce refections to .1%. A brew of silicon and titanium, hardened with magnesium fluoride coats each element. It is 1 nanometer thick, which is 1 millionth of a millimeter. Your whiskers will grow longer than that in 1 second after the swipe of your razor.

Cooke, cont'd

The glass is selected and precisely pre-edged to an exact diameter on a CNC machine. This diameter will be held through the process until final edging is done.

The Computer Numerically Controlled machine grinds both sides, establishes the optical center, curves and thickness. CNC machines are also used to make aspheric lens elements, which we'll see a little later.

With a CNC machine, you can grind one element at a time in about 15 minutes. It's been compared to a microwave that can heat up your dinner one plate at a time.

When they invite more cinematographers to dinner and need more dinner plates, they use D-type polishers, designed and built in 1913 and still capable of precisely polishing 120 elements on 6 spindles in 8 hours.

Here's Dave Stevens, managing director (left), to whom we are most grateful for his encyclopedic knowledge of facts and figures, history and science, and above all, nanometers per second tonsorial growth rates.

The glass elements are held onto the base of the polisher with a sticky, black pitch. The top "cone" randomly orbits the glass, slowly polishing with a serium oxide sludge.

Polish is periodically added with a brush.

There are numerous shapes on hand for polishing the elements that go into Cooke lenses. Here we see many elements being worked on at the same time.

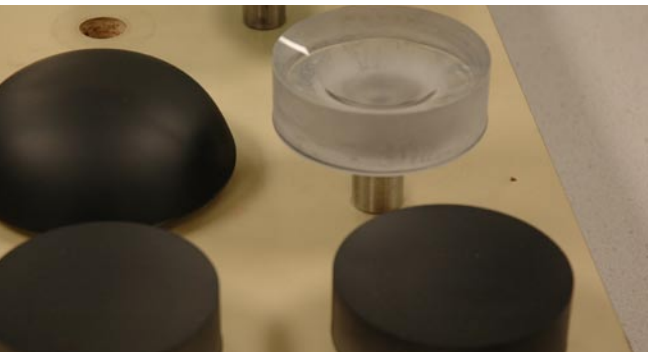
The shapes define curvature of the lenses, as defined by the mathematical formalae that have been established.

Despite the speed of CNC polishing and grinding, perhaps it is the traditional handmade craftsmanship of the D-type polishing that gives Cooke lenses their unique characteristics, which are often described in terms usually reserved for tasting fine wines: roundness, fullness, smooth and delicate fall-off.

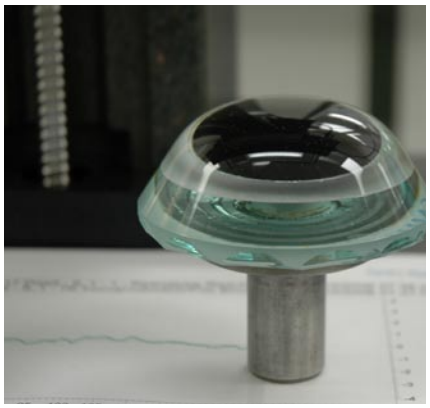
Cooke, cont'd

Over 5000 test glass gauges are available to enable almost any size element to be made at the designers' discretion.

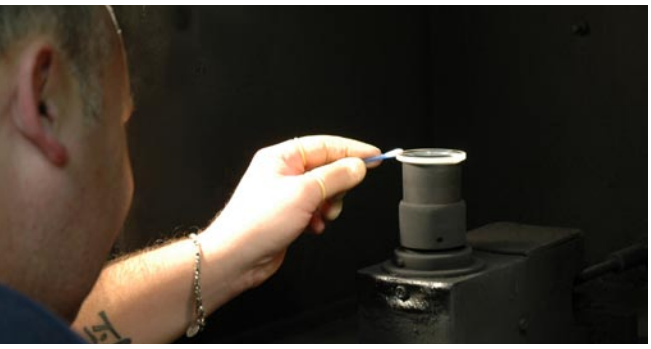
Mick Maher (right), one of the skilled polishers, smoothing the elements prior to polishing.



Spherical lenses have consistent curves. To make an aspherical lens element, imagine slicing a volleyball in half, and glueing it onto the top of a Frisbee—but on a much smaller scale. Because the outer edge of the lens has a different geometry, the element can be smaller and lighter, with less edge distortion. The Cooke CXX 15-40mm zoom and SK4 6mm use aspheric elements.

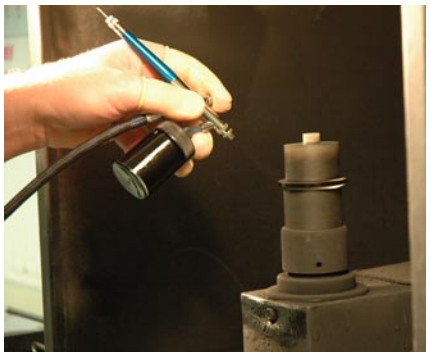


After coating, Brian Crow (right) does the final grinding of the edges and remeasuring. He grinds the diameters slightly undersized from the final tolerances to accommodate the next step: edge blacking.



The edges of each element are sprayed with a specially formulated black epoxy paint.

If the edges were left clear, light would bounce around between the elements, the metal housing and create reflections, flare and ghosting. Spraying with the airbrush is a very delicate process, done with great care.



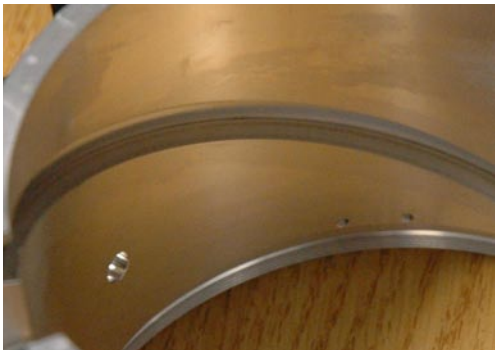
It's time to put all the pieces and parts together. Barrie Billington (left) is the assembly manager, shown here in the assembly room.

They call it the "fitting room," a term that reminded me of bespoke suit makers and custom shirt fitters in Jermyn Street.

Cooke, cont'd

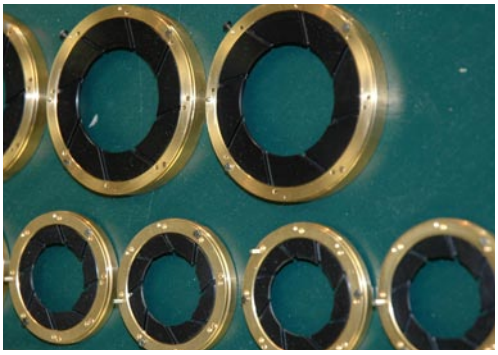
There are between 10 to 14 elements and 60 mechanical parts in an average Cooke S4 /i lens.

The lens barrels are machined from aluminum tubes and then anodized.



Element assemblies ride on two sets of precision bearings inside the barrel, precisely guided by the famous Cooke cams (left), which are essentially "channels" or freeway on-ramps in which the cam followers (right) travel.

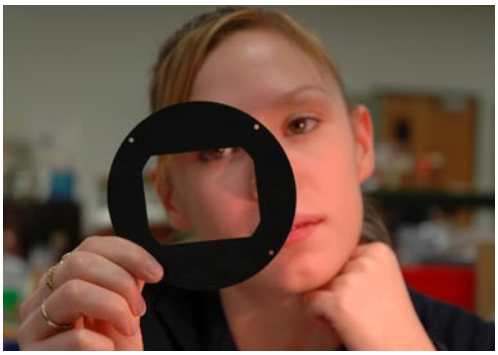
The cam and cam-follower present much less friction than threaded lens barrels. The threads require grease to provide smoothness.



Cooke S4/i lenses work smoothly in temperatures from -25° C to 55° C.

The cam-follower is made of Delrin, which is very durable and does not need lubrication.

Next, add an iris, (left and right).



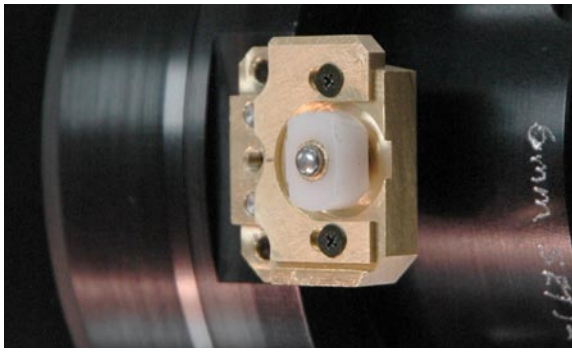
Apprentice Simone Ryan (left) selects a front element mask.

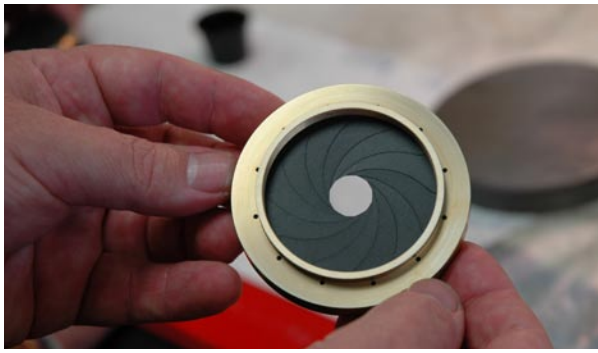
This one is fitted to a 35mm format S4 lens when shooting in Super16 format to prevent internal barrel flare by blocking extraneous light from the wider, unused "diameter."

Once the lens is assembled, like a Russian doll, it is taken apart again—totally stripped down.

The next steps involve carefully cleaning all the elements and parts again.

All the individual parts of each lens are kept together until reassembled.





Cooke, cont'd

The optical elements are "washed," and the entire lens is carefully put back together in a totally dust-free clean room.

I asked Adam Woolley (right) what's the best cleaner for lens elements when they are smudged.

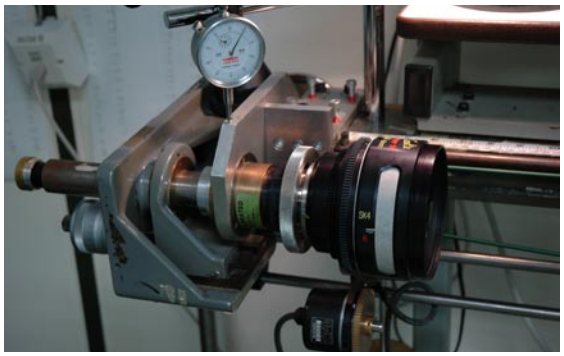
He likes acetone on a cotton ball.

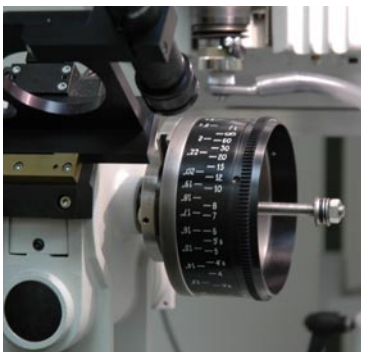
Apparently the epoxy edge blacking and the coatings are hard enough to withstand acetone. I cannot vouch for any other lenses until I check with their manufacturers.

Focus is checked for each increment of critical focus.

Focus scales are then engraved according to the computer data entered for each lens.

/i lenses are checked by computer without readouts of all information and metadata that will be used during production.





In 1667, Francis Smethwick ground the first high-quality aspheric lenses and presented them to the Royal Society in London—documented in his paper "An Account of the Invention of Grinding Optick and Burning-Glasses, of a Figure Not-Spherical, Produced before the Royal Society."

340 years later, the craftsmen and women at Cooke Optics are carrying on the tradition of fine optics.

There. That wasn't so difficult to build, was it? "Minor" assembly required.

Here's a finished Cooke S4/i 150mm lens, ready to go out into the real world of production.