ASTRONOMER

Union between the particles results not from fusion but from surface cohesion. The irregular particles touch one another only at their corners. Elsewhere air spaces remain.

Puderbaugh finds that the main secret of success with the sintered lap is to supply enough heat to produce sintering without melting. Sintered pitch has peculiar characteristics. Some that he kept for months in a refrigerator had not consolidated.

In any case, the Puderbaugh lap is radically different from the fused lap. It was first experimented with more than two years ago, and its fortunes have been watched ever since by this department. It appears to be sound. John M. Holeman of Richland now reports that "more and more local users have tried it and like it very well. They have nothing but good to say for it. Easy to make. Holds figure."

TO ELIMINATE five of Russell Porter's "seven devils" of pitch, Kenneth Falor of Bay City, Mich., simmers pure rosin until the froth and bubbles, which form in large numbers and need close watching, subside. He then adds high-grade no-detergent automobile oil of SAE 30 or 40 to obtain the desired temper. This mixture keeps its temper almost indefinitely despite frequent melting. For his inspiration Falor credits the 200-inch telescope job. He finds advantage in dropping the test samples on metal instead of glass; the metal conducts their heat away much faster than glass and saves much waiting.

IN THE PAST many amateur telescope makers have independently discovered that mirrors may be ground and polished without the conventional handle, and have reported their apostasy with quite unnecessary apology. In a debate on handles *v.* no handles much could be said on both sides. The correct way is the one you like best.

If a handle is preferred, it is likely to receive much use. A good one is thus worth while. Provided it does not cover too much of the mirror, its correct design is again the one you like best. The handle shown in the drawing on page 62, pitched to a 6-inch mirror, is a somewhat aristocratic transparent handle made by Holeman. The shaft was turned from a rod of Lucite. It is screwed to a Lucite disk ⅜-inch thick and 2½ inches in diameter to receive the thrust of the hands.

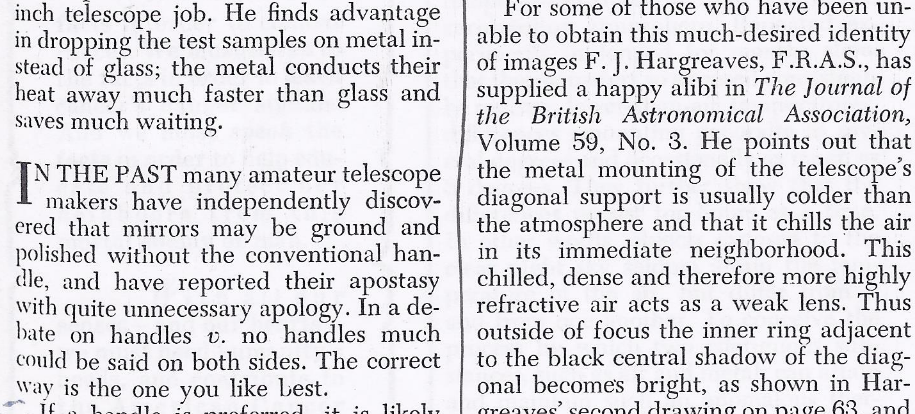
With less trouble a short button may be used as a pickup handle as in the second illustration, redrawn from a little booklet by T. J. Mulligan of 1 Airthwaite, Kendal, Westmorland, England, entitled *Making a Telescope Reflector*. With A. J. S. McMillan of 5 Oakfield Road, Bristol, Somerset, England, Mulligan is attempting to revive the telescope-making hobby in Britain by supplying mirror-making kits there.

The thermal shield shown above the Mulligan handle is devised not by Mulligan but by the editor of this department, and has been used for many years without causing any of the scratches that armchair theorists asserted it would create. It can easily be lifted to inspect the lap through the mirror.

AMATEUR telescope makers have often been disappointed because their mirrors would not pass that part of the diffraction-ring test described in *Amateur Telescope Making* in the final paragraph on page 434. This states that in a perfect mirror the out-of-focus images of a star should be alike at equal distances inside and outside focus. If there are differences the nature of these differences gives useful information about the aberrations.

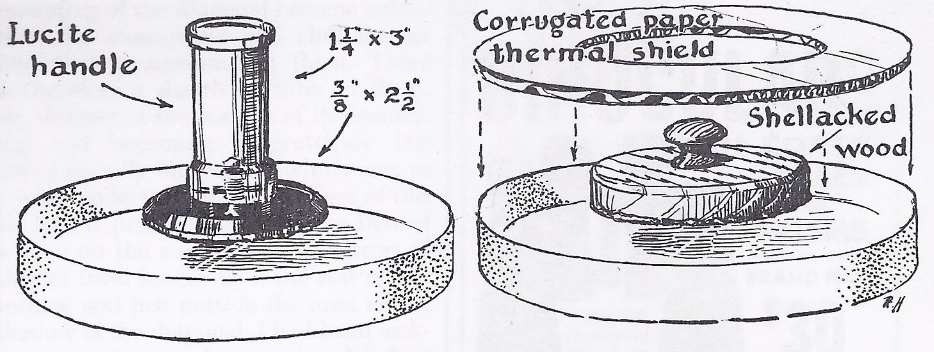
For some of those who have been unable to obtain this much-desired identity of images F. J. Hargreaves, F.R.A.S., has supplied a happy alibi in *The Journal of the British Astronomical Association*, Volume 59, No. 3. He points out that the metal mounting of the telescope's diagonal support is usually colder than the atmosphere and that it chills the air in its immediate neighborhood. This chilled, dense and therefore more highly refractive air acts as a weak lens. Thus outside of focus the inner ring adjacent to the black central shadow of the diagonal becomes bright, as shown in Hargreaves' second drawing on page 63, and has a hairy or spiky inner fringe.

If there is aberration in the mirror the bright ring is absent on one or the



Left: the Draper lap. Right: the Brashear-Croston lap

June 1950 Scientific American.



Left: Lucite mirror handle. Right: button handle

other side of focus. The "air lens" surrounding the cold metal diagonal support has exactly the same effect, and many mirror makers may have blamed their workmanship because of it.

It remains to be explained why the metal parts of a telescope should be colder than the atmosphere. We would expect this if a telescope had just been brought into the open air from a cold cellar. But even if the telescope starts with its metal parts at exactly air temperature they will be found after a time to have a lower temperature, provided the night is clear. How can we account for this?

In this department in January, 1944, F. N. Hibbard, a U. S. Weather Bureau meteorological physicist and an amateur telescope maker, explained this phenomenon. "It is not generally known, outside the Weather Service," he stated, "that various substances or materials exposed in the open air under a clear night attain temperatures different from that of the surrounding atmosphere. Repeated experiments prolonged for months show that thermometers so exposed consistently register lower-than-air temperatures, differences amounting generally to several degrees and occasionally as much as 8 degrees. They further show that the differences persist for hours at a time. In other words, objects exposed to the clear night sky seldom attain the temperature of the air, but differ from it and from one another. To conceive the process by which two contiguous substances, such as air and metal, can attain and maintain such an anomalous thermal condition for hours together is difficult. It depends, however, principally upon the individual absorption and radiation properties of the substance."

Others have given more than Hibbard's hint of the explanation. All bodies simultaneously radiate and receive heat in amounts depending on their temperatures. The telescope tube radiates to cold interstellar space at a rate so much greater than space radiates to the telescope that the radiation is practically all in the outward direction. This constant radiant heat leak explains why the telescope does not warm up to air temperature—unless clouds cut off the leak, in which event they also cut off the observing.

In his *Meteorology* the late Professor Willis I. Milham, an astronomer-meteorologist, discussed this effect, which hampers meteorologists by causing thermometers to give readings from 1 to 7 or 8 degrees too low on clear nights. Meteorologists reduce this error by placing their thermometers in shelters having diagonal sloping slats like Venetian blinds that admit the air but obstruct radiation to the sky. In an article in *Monthly Weather Review,* a publication of the U. S. Weather Bureau, for July, 1905, Professor Milham described long, painstaking experiments which proved that night after night two matched thermometers only 20 feet apart registered 3, 4 and sometimes more degrees difference. One was exposed to the clear sky; the other was within an unheated, unprotected but radiation-stopping thermometer shelter.

The metal-chilling effect of radiated heat has a direct relation to the selection of materials and forms for telescope tubes. Hibbard and J. C. Vaughan, a Virginia telescope maker, tested telescope tubes of different materials for two years. They found that:

In a solid metal tube the chilled air that constantly drained down next to the metal produced irregular refraction of light and resulted in poor images.

Lining the tube with cork, asbestos or paper improved this performance somewhat.

Holes bored in the upper part of the tube to cause air drainage there admitted cool air that streaked the image.

A solid metal tube with its central two-thirds portion removed and the ends connected only by six lengthwise angle irons did not give the expected beneficial mixing of outside and inside air. Instead, the chilled iron streaked the images. Wrapping the irons with thick black paper improved the images, but at times they were intolerable. By inserting a cardboard lining inside the skeleton tube it was proved that the chilled metal was the cause of this: the streaking vanished and the images became good. This experiment was tried over and over until the conclusion was inescapable that the metal had an entirely different temperature from that of the air, and that this difference persisted hour after hour.

In the entire two years of the tests only a single night afforded first-rate seeing with an open or skeleton tube of metal.

Hibbard and Vaughan's final experiment was to line a solid metal tube with cork a quarter-inch thick and cut a 20-square-inch hole in the tube just above the mirror. This opening, adjustable in area, ventilated and cooled the mirror and gave excellent results, especially if the hole was covered to steady the air inside just before actual observation.

After all these experiments, conducted with the understanding of underlying factors that meteorological physics affords, Hibbard stated that to build any telescope tube of aperture up to 24 inches he would use sheet metal lined with cork, balsa or Douglas fir. "The 24-inch limit," he added, "came from the late J. W. Fecker, who said he had known for many years that skeleton tubes produce troublesome images that decrease as that aperture is approached. At that point the tube effects are hardly noticeable, especially since telescopes that large are placed in domes.

Hargreaves' discovery that the fringed bright ring of his outside-focus image is caused by the refraction of chill dense air next to the metal diagonal support is clearly an example of this phenomenon of cooling by loss of radiant heat. He states that he had been puzzled by the bright ring and its vagaries for 13 years, during which he had tested a great many mirrors in his telescope. He knew that if spherical aberration is present the ring is absent on one side of the focus and that this absence might also indicate a narrow defective zone just outside the area of the shadow of the diagonal. Reviewing the problem carefully he was struck by the fact that "in every case when other tests had shown that a mirror is free from aberration, the inner bright ring had been absent from the image inside focus and abnormally bright outside focus, and never the other way round."

At last, one very windy night a clue presented itself. "Every time a strong gust struck the telescope the bright ring became temporarily one-sided—weaker on the windward side and stronger on the leeward side. The explanation," he continues, "is simple. The cell and mounting of the diagonal become colder than the atmosphere and chill the air immediately surrounding them. There is therefore a sheath or 'tube' of dense air, densest at the surface of the mounting and becoming progressively less dense radially outwardly, which acts as a weak collective lens. The effect of this air lens is precisely the same as that of a zone on the surface of the mirror, of shorter focal length than the rest of the surface and just outside the area of the shadow of the diagonal. I had been looking for such zones for years, and failing to find them."

Hargreaves put this diagnosis to the test by holding his hands on the mounting of the diagonal for a few seconds to warm it, taking care not to warm the diagonal also. "The immediate effect," he states, "was to reverse the appearance, the bright ring being transferred to the inside-focus image. After a few minutes the two images were exactly the same for a short time and then the original appearance returned" as the metal cooled.

"It must be borne in mind," he emphasizes, "that the abnormally bright ring *may* be due to spherical aberration or to a real defective zone on the mirror.

"In warm weather when the telescope is first opened up in the evening, the inside-focus image invariably shows a very strong bright ring round the central shadow. I now have no doubt that the effect is due to the diagonal mount being temporarily warmer than the surrounding air."

Hargreaves is a member of the recently organized firm of Cox, Hargreaves and Thomson of Kingswood, Surrey, England. All three partners began years ago as amateur telescope makers and, after much advanced experience, turned professional. Such has been the history of most professional telescope makers. The three partners retain their amateur status as astronomers. They have received a spate of work, including a 25-inch Schmidt camera, regrinding and refiguring the 30-inch mirror made 60 years ago by Common for Greenwich observatory, and a 51-inch mirror for the old Melbourne reflector in Australia.

Left: inside focus. Right: outside focus