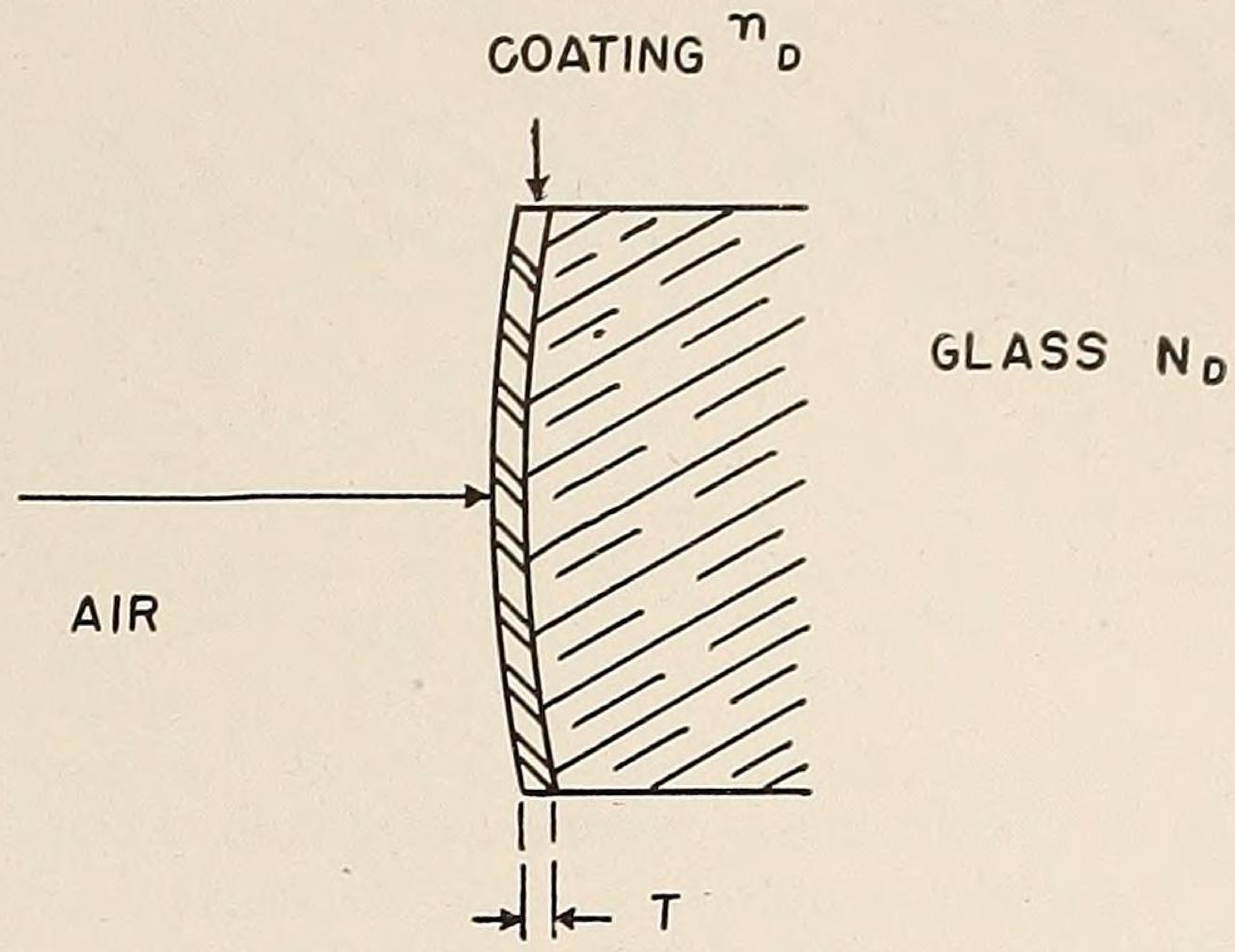
LENS COATING



• Fig 1. Conditions for the elimination of reflection loss at an air glass surface; $n = \sqrt{N}$; T=¼ wave length or 0.000147 mm. or 0.0000058 in. or $\frac{1}{172,000}$ of an inch.

The first of two discussions of what it is, how it is done and what it does

ALAN A. COOK, *Optical Engineer*
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THE development of lens coating during the war was rapid, forced on us by the requirements of military instruments.

The fighting man wants to see as long as there is any light at all. His telescope or gunsight or range finder must be made as efficient as possible, because all light losses are bad if the enemy can see you at *any* time when you cannot see him.

The lens coating process has useful results, when it is applied to photographic and projection lenses, and it is time to take account of these processes and to see what they are.

What is the coating that we put on lens surfaces, to reduce light losses? Why is that particular substance used?

The lens coating is an extremely thin film of metallic fluoride; magnesium fluoride is most commonly used, because it is the most permanent when it is properly applied. Almost all United States Army and Navy specifications call for magnesium fluoride.

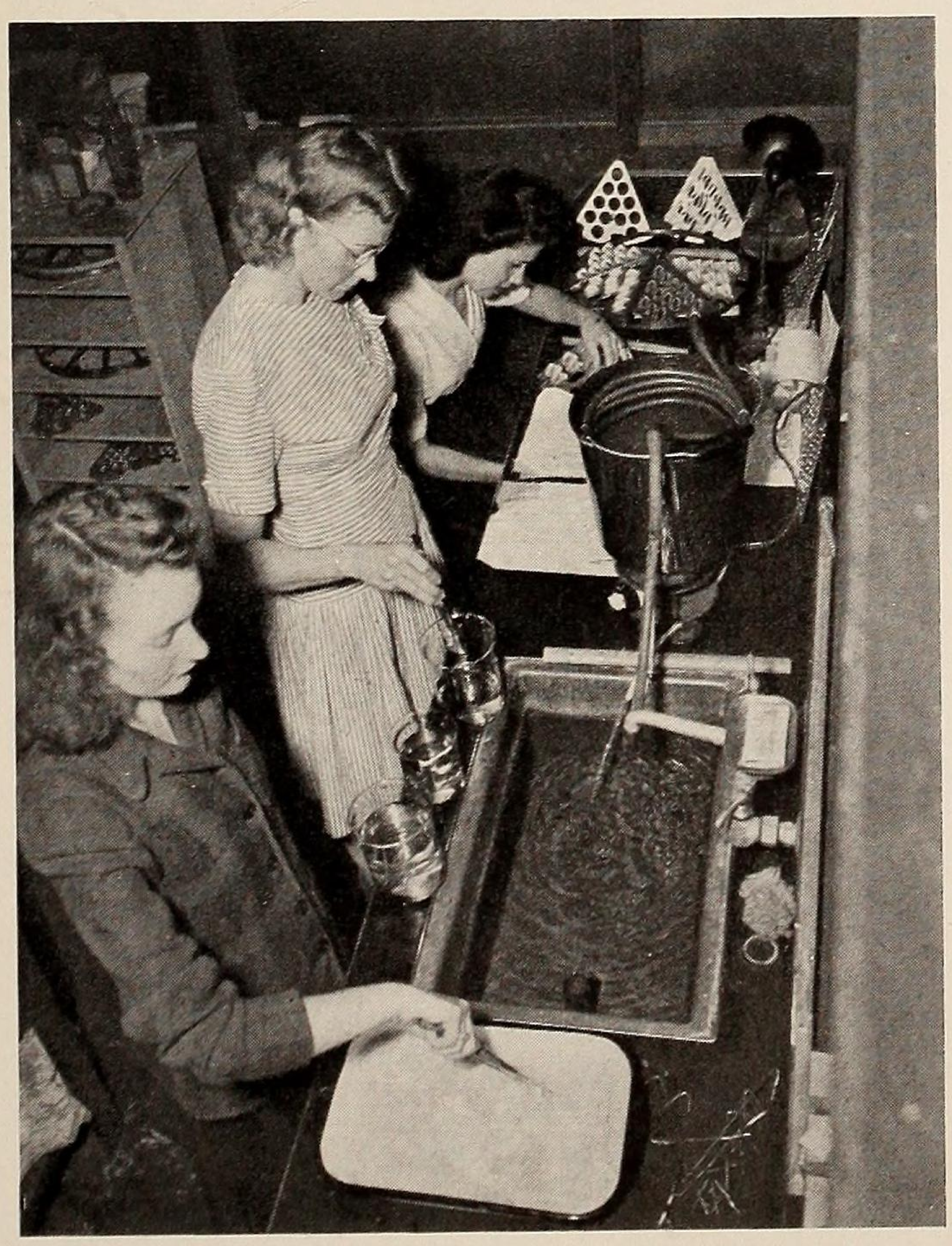
Other salts of fluorine are more efficient on many types of optical glass, but they are too soft to stand up under repeated cleaning. They may be used, however, on the inner surfaces of an objective lens, where they can be sealed within the mounts. There is a patent (see Note 1 at the end of this discussion) on double layers of coating, with a thin film of quartz on top of the fluoride, for protection, or a layer of chromium oxide under it, to make the fluoride adhere strongly to the glass.

Why is such a substance used? Why not use gelatin or plastic, or Madame Queenie's Facial Creme?

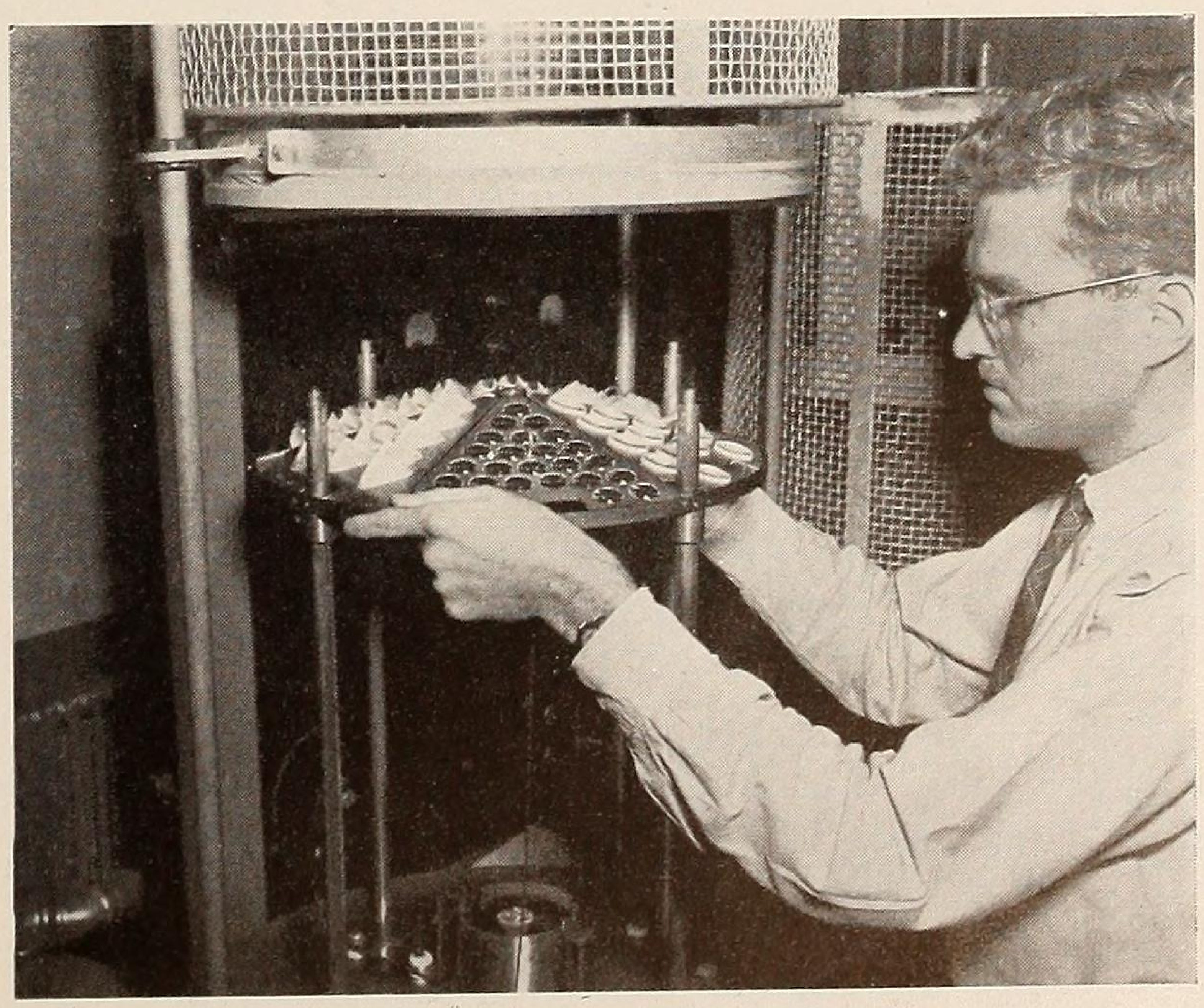
The diagram in Fig. 1 on this page gives an outline of the optical requirements. Light is a wave motion, and the law of Fresnel states that, when it travels through a boundary surface from air into glass, there is a certain and definite loss in the process of refraction through the surface. Not all the light goes through—and the part that is reflected back equals

$$\frac{(N-1)^2}{(N+1)^2}$$

where "N" is the index of refraction of the glass and "1" is the index of air. The [Continued on page 73]



• Fig. 2. The dust free, properly air conditioned laboratory of the Wollensak Optical Company makes cleaning lenses a routine.



• Fig. 3. Vacuum apparatus for lens coating in the Wollensak laboratory; technician is raising the bell jar, to load lenses for heat application.

and naturalness.

In fact, it is desirable to use some modeling light, usually placed high and to one side of the subject, in making color movies indoors. You should be sure that the modeling light is built up on a good foundation of flat basic lighting which will illuminate all parts of your subject evenly. A simple, easy to arrange and reliable lighting setup is shown in Fig. 1 on page 57. The exposure is based on the two main lights close to the camera, with little or no account taken of the side light which illuminates only a portion of the scene.

At the present time Ansco Color motion picture film for amateur use is being supplied only in the 16mm. size. For those who want to have their films duplicated in color, Ansco offers such a service.

If you have not tried color movies before, it is time to find out how satisfactory their full color naturalness can be. If you already know that, you will still be interested in trying the new Ansco Color film because of its slightly greater latitude and its very natural appearing color.

Lens coating

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situation is repeated when the light comes out into the air again.

These losses of light can be prevented by adding a thin film of material on each air glass surface. The film should have a definite thickness, one quarter of a wave length, or $\frac{1}{172,000}$ of an inch, for sodium light; it should have a definite refractive index, "n," exactly equal to the square root of "N," the index of the glass used. This precise condition produces interference in the reflected wave at the two surfaces and cancels it out completely.

We need a hard, permanent, insoluble material of an index equaling $n = 1.234$, for ordinary crown glass. Magnesium fluoride is the best substance found so far, and if any one can think of a better one to use—something which will meet *all* of these specifications—the optical industry will be very appreciative.

It is a fact, of course, that magnesium fluoride is not an ideal material. It does not reduce the reflection loss absolutely to zero. It is not so hard as glass. To meet the ideal condition, we should also need a different coating material, "n," for each kind of optical glass, "N," that we use in making photographic and projection lenses.

Furthermore, any coating can reduce the loss to zero for only a single wave length or color of light. Colors higher or lower in the spectrum will still be reflected in slight amounts; this fact accounts for the bluish purple tint observed in the surface of coated lenses, which has become their mark of identification.

The first step in the lens coating process is to get the surfaces physically and chemically clean.

That is not an easy matter, and it is particularly difficult with old lenses. When the glass parts are freshly polished, however, and there is a considerable quantity of each size, the process of cleaning becomes routine, and it can be done with ordinary solvents. Cleaning can be accomplished quite rapidly if the room is dust free and the humidity of the air is at the proper level. This operation is shown in Fig. 2 on page 59. Cemented elements should be coated as two separate elements, before they are cemented together, with the coating applied only to the side that will be the outer one.

The clean glass parts are then put on metal holders and are suspended at the top of a high bell jar (see Fig. 3 on page 59) which fits tightly on the base plate of a vacuum pump. Special, high vacuum outfits for this purpose were a military necessity; they were developed and made in quantity during the war. While the pump draws the air out of the bell jar, heat is applied to the glass surfaces by a radiant heater, mounted above the lens holder inside the jar.

When the vacuum gauge is down to almost nothing, and the lenses have reached the correct temperature, the magnesium fluoride, a solid white salt, is vaporized from the bottom of the jar. This is accomplished simply by turning a switch to light a tungsten filament, thereby applying rapid heat to the fluoride—which is in a porcelain crucible standing solidly on the base plate of the apparatus.

The evaporation time is carefully controlled. The coating is checked for thickness, as it is deposited on the lens surfaces, by observing the image of a lamp filament reflected to the inspector's eye by the actual surface of the lens that is receiving the fluoride coating. Remember that the coating must be $\frac{1}{172{,}000}$ of an inch thick—no more and no less! It sounds difficult, but the eye is very sensitive to color differences at this point; so, this method of control has been found to give consistent results. (See Note 2 at the end of this discussion.)

After the coated film reaches the proper thickness for minimum reflectance in green light, the crucible heater filament is switched off and the acquired coating is baked on the glass for a certain time. This baking process hardens the fluoride very considerably and makes it much more resistant to abrasion. The lenses can then be removed from the apparatus as soon as they are cool enough to avoid cracking, and the cycle

TABLE I

Index of refraction ND	*Normal loss* $\frac{(N-1)^2}{(N+1)^2}$	*Loss with two coated surfaces*	*Increased transmission for one coated surface*
1.500	4.0%	1.6%	2.5%
1.540	4.52%	1.4%	3.3%
1.580	5.38%	1.2%	4.4%
1.620	5.60%	0.9%	5.0%
1.650	6.02%	0.8%	5.6%
1.700	6.72%	0.6%	6.6%
1.750	7.44%	0.4%*	7.6%

*ND 1.750 not listed in U. S. Specifications, reference (2); so, the 0.4% value is an estimate.

TABLE II

Lens type	*Number of air glass surfaces*	*N D average*	*Transmission uncoated*	*Transmission coated*	*Gain, or difference in percent*
Two single or cemented *elements*— Old R. R. *f*/8.0; Double Meniscus *f*/11; 8mm. & 16mm. projectors; Dagor & Protar lenses	4	1.575	81.50%	95.29%	16.92%
Triplets of Cooke or Tessar form— 8mm. & 16mm. cameras; most hand cameras; *f*/3.5 to *f*/6.3; slide film projectors	6	1.600	72.01%	94.69%	31.50%
Lenses of 4 separate elements; Celor, Syntor, or Dogmar type; Compound Gauss lenses; *f*/3.5 to *f*/2.0	8	1.610	63.81%	92.47%	44.91%
High aperture anastigmats of recent design *f*/2.0 to *f*/1.3	8	1.625	62.69%	93.15%	48.59%

is repeated with the next batch.

What does lens coating do?

First, it reduces the light loss in an optical system and restores that light to its proper phase and direction in image formation. That is why a coated lens is faster in photography than an uncoated one. Table I on page 74 gives the results for a *single air-glass surface*, at a number of values of the refractive index that are often used.

Table II on page 74 makes a report on *average* results to be expected from certain types of lenses that are in common use. It is computed without consideration of absorption losses in the glass.

Note 1. U. S. Patent No. 2,207,656. See also John Strong, Journal Optical Society of America; Vol. 26, January, 1936, page 73.

Note 2. U. S. Army Specification No. 51-70-4B; U. S. Navy Specifications: Bureau of Ordnance, O.S. 1357; Bureau of Ships, 18-G-7-INT.

(The second, and concluding, part of this discussion will appear in an early number of MOVIE MAKERS.*)*

Winter movie games

[Continued from page 65]

handle bar mustache in the process of eating an order of spaghetti. Use closeups here, even if his reaching hands might go out of range. It is the facial expression in this scene that counts.

There will be lots of fun when, on the screen at a later date, you show Bernie attempting to wangle a date with the telephone operator, as his wife pops into the picture. Catching the shadow of the approaching wife is good technique for this shot, employing a semicloseup.

Hildur can go through the opera soprano's rôle with all the action and none of the sound. Pick the right girl for this rôle, film her in a closeup, and you have something!

If you have some fellow like Elmer in your party, a chunky, good natured chap, what better spot for him than to act out the part of a fat man wading through very deep snow? You will have to use a medium shot here.

Grace can be depended upon to do a first class job, as she attempts to give medicine to three children who don't particularly care for it. The choice of children from volunteers is quite an important feature of this scene. Use a medium shot.

Catch Gladys as a dignified woman in the process of making a snowball, with especial care to be unobserved, and then have her throw it. The right subject for this medium shot will bring guffaws in its eventual screening.

Bill can provide entertainment if you get him to portray the actions of an organ grinder with his cavorting (imaginary) monkey on a string. Film Bill as he tries to grind the organ and collect the pennies from the monkey at the same time!

LENS COATING

The last of two discussions of what it is, how it is done and what it does

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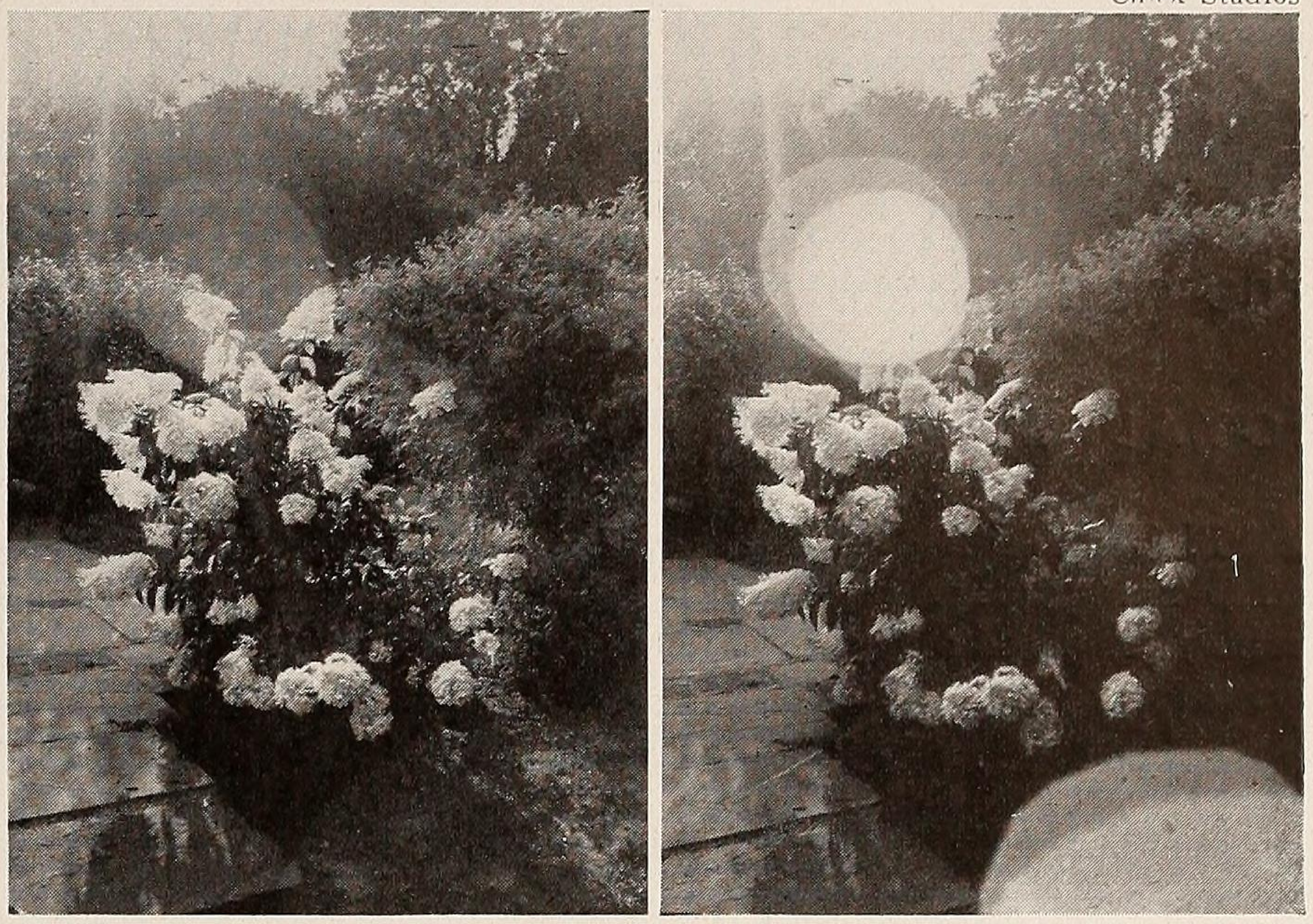
Wollensak Optical Company

Chick Studios



• **Fig. 1. Even in extreme conditions, with the sun shining directly into the camera, good results are achieved by using coated lens.**

IN THE first part of this discussion which appeared in February MOVIE MAKERS, the process of coating lenses, to reduce reflection losses, was described.

A table was offered, to show that, under average conditions, the gain in light transmission—when coating is applied to lenses—varies from 16.92%, in the case of the simple doublets, to 48.59% for modern anastigmats of high aperture.

This is not an enormous increase in light. It amounts to half a stop, about fifty percent more light, at most. It does mean that coating permits us to take better pictures under conditions of weak illumination, but that fact is not the principal advantage offered by the process of lens coating.

More important than the increased efficiency are the improvement in definition and the greater contrast which are obtained when reflected light and diffuse flare are kept out of the camera.

Coating does do these things to an astounding extent. Figs. 1 and 2 on this page illustrate the results of lens coating; the picture taken with a coated lens shows finer detail in almost all parts of the scene.

It should be emphasized that the pictures presented in Figs. 1 and 2 were made with identical lenses under conditions as nearly alike as it is possible to get them; the only difference is that one picture of the pair was made with a coated lens, the other with an uncoated one; the lenses were matched and mounted exactly like stereo camera sets, and then one of them was coated by the process that was described in the first part of this discussion. Hence, these pictures show real results.

When the scene is contrasty and the light is glaring, the different performance of coated optics is particularly noticeable. The pair of photographs in Fig. 1 gives an example of these extreme conditions. Here the sun is shining directly into the camera lens, and its ghost images produce enough flare to erase the scene entirely wherever they strike. When that same lens is coated, however, almost all of the reflected flare and stray light are eliminated and the underlying detail is revealed in the finished picture.

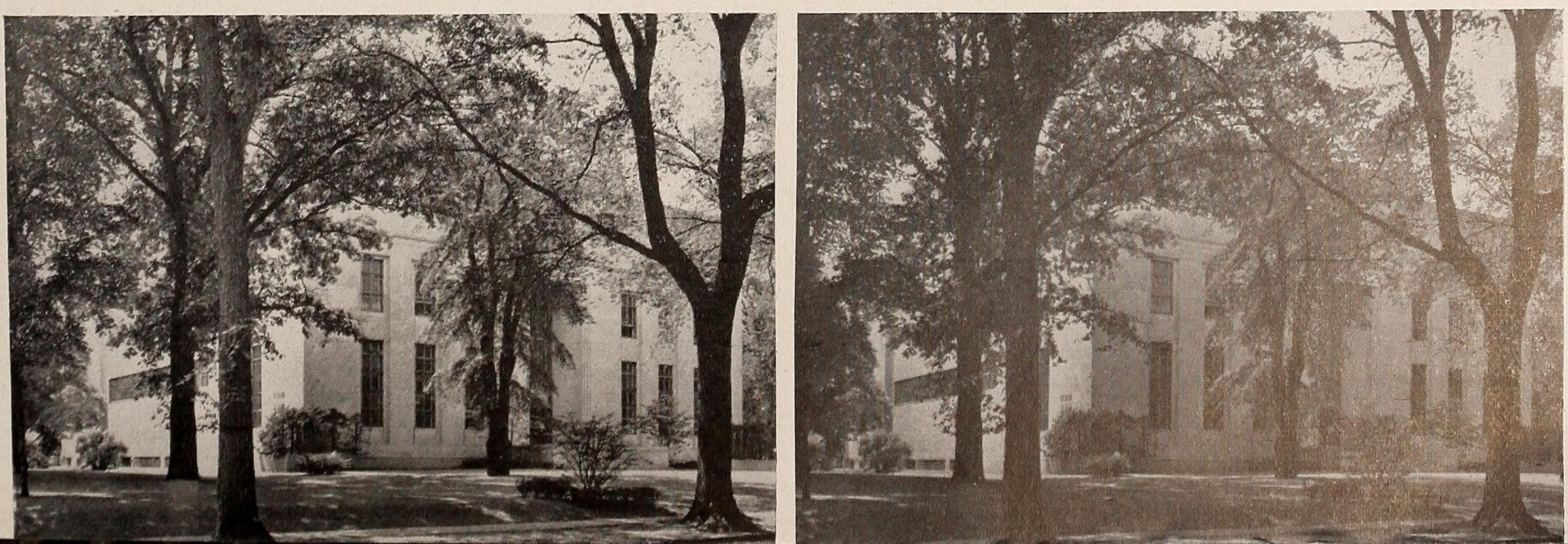
The first reports on the use of coated lenses for color photography indicate that these same two factors apply. Improved definition and the removal of flare give much better pictures with color films, too, the result being a greater purity in the rendition of color values, which adds much to the naturalness of the finished print. Accurate comparisons are not yet available, but one can already predict with some confidence that coated lenses will be a necessity for getting best results with any new color films or processes that may appear in the future.

There are two other matters that may well be included even in a short account of lens coating. The first of these is the care and cleaning of coated optics.

A coated lens should be kept as clean and free from dust as possible, just like any other optical instrument. Remember that the coating on the surfaces is not as hard as glass. Particles of dust are often very hard and can cause scratches, if they are rubbed into the surface.

Remove them, therefore, with [Continued on page 119]

• **Fig. 2. Giving finer detail in almost all aspects, a coated lens, as used in the street scene on the left, provides a marked contrast to the results on the right; note particularly the improvement in definition and absence of flare.**



feld to whom I owe so much for that bit of movie making technique which I hope to retain.

The movie makers at SCPC are shedding the olive drab. It is time for graduation, to plan some more grand strategy and to build a home. Other veterans and myself want to take our places in the film industry. For there are new movie minded communities with fresh aspirations, a more mature excitement and, hopefully, a more thinking world in which to live.

This discharge of mine is a diploma from one of the toughest, roughest and most accredited schools in the world—the United States Army. Every veteran has one, and millions plan to use theirs as I do, in finding a home, a better job and a finer happiness.

Lens coating

[Continued from page 105]

a soft clean brush as the first step in cleaning optics, and then proceed to wipe the glass surfaces clean by rubbing them gently with a soft cloth. Solvents are generally not good things to apply, because they will take the lacquer finish from the lens mounts, if allowed to come in contact with the metal at any point. Do not take a lens apart, to clean the inner surfaces, unless those surfaces are really dirty and unless you know how to do it.

The second point of interest is the question of whether old lenses can be coated.

They certainly can, because nothing is quite impossible, if one has the proper tools. The principal difficulty of the work is that each lens presents an individual task which makes the cost a matter to consider. From the brief description in the first part of this discussion, it is obvious that an old lens must be taken apart, repolished, coated, reassembled and readjusted, in order to get a first class result. One must have the proper tools. Therefore the man who made the lens is the man to do the coating.

This is not good news for the filmer who has foreign made equipment, but it is an unfortunate fact.

So, if you own a Katthauser "Bitchar" $f/1.23$, which is a pet of yours and can take a picture right through a mink coat at midnight, we can all understand why you want it coated, especially if it has fifteen elements and eleven air-glass surfaces.

We all know, too, that Katthauser sold out to Schleitz, who sold to Sseiz, who sold out to Hitler—who is now out of business. The moral is, if your lens can't go to the original manufacturer for coating, it must be done at the owner's risk. And the risk is always there, because coating is a complicated series of operations.