Portable Microscope for On-Site Analysis and Counting of Asbestos Fibers[1]

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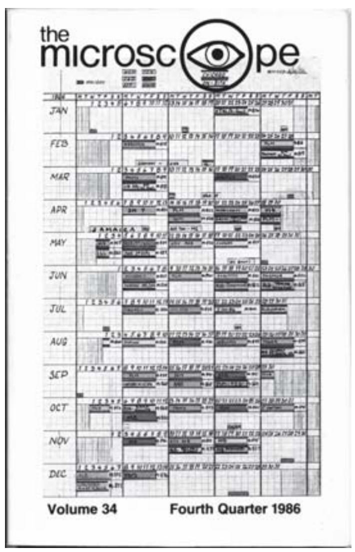
Portable polarized light microscope, asbestos identification, asbestos fiber counts, insulation, microscopy, light microscopy

ABSTRACT

Considerable interest has been expressed in the need for a portable microscope for on-site analysis and counting of asbestos fibers. The optical and mechanical requirements for such an instrument, together with design considerations, are enumerated and explained. A prototype instrument, complete with carrying case, has been assembled and is described; possibilities for mechanical and optical variations and alternatives are discussed.



INTRODUCTION

Ever since the beginning of the need for asbestos fiber analysis and counting, polarizing microscopes equipped with dispersion staining objectives and phase contrast equipment have been put into service in laboratories everywhere, and have met analytical requirements very well in this country, Canada and abroad. Recently, there has been considerable interest expressed at the national level for a portable microscope for on-site analysis and counting of asbestos fibers (1). Specifically, the Department of Defense Small Business Innovation Research Program (SBIR) published a program solicitation for FY-1986 in which it was reported that the Toxic Substances Control Act (TOSCA) prohibits the use of asbestos in new buildings, and requires that old buildings, such as schools, be inspected for asbestos. At the same time, it is recognized that inspection and analysis for asbestos is quite costly and requires considerable turnaround time. The proposed concept was to consist of developing a simplified portable, compact phase contrast and polarized light microscope (PC/PLM). The development instrument was to enable field technicians to be trained in a short time and then to analyze for asbestos according to straightforward and rapid methods. Standardization and calibration techniques were to be the means whereby the acceptability of the testing procedures would be assured and their compatibility with EPA and OSHA methods guaranteed. The method was to utilize comparisons of actual samples with photomicrographs of knowns to qualitatively and quantitatively analyze for asbestos.

The program called for a feasibility study, a prototype development phase, and a manufacturing phase. Since I knew the program objective was feasible—and had been so for half a century—and since I had already constructed a prototype instrument mostly from commercially available parts, I decided to explore the optical and mechanical requirements for such an in-

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strument, both as regards the immediate adaptation of presently available parts and equipment, and as regards design considerations for a wholly new-manufactured, specialized instrument.

THE BASIC MICROSCOPE STAND

The required microscope needs to be both polarizing and capable of phase contrast. It is possible to start with a biomedical, phase contrast microscope and convert it for polarized light work, but it is vastly easier to convert a polarizing microscope for phase contrast work, especially since only one phase contrast objective is needed, a 40X. The required microscope also needs to be generally smaller than laboratory-based instruments to meet the criterion of portability. Ideally, then, it would be easiest to start with available portable polarizing microscopes. Alas, there are none readily available. To be sure, there are smaller, laboratory-based polarizing microscopes that could be put into a carrying case, and considered portable. Examples of these include the Olympus POS, the Unitron Model MPS-3 Polarizing Microscope, and the Hacker Instruments Polarizing Microscope Series 600—all monocular polarizing instruments built on small stands. But these are not true, portable microscopes intended primarily for transporting into the field. True portable microscopes, also called "field" microscopes, or "traveling" microscopes, achieve their portability through one or more of the following: 1) deliberate reduction in dimensions of stand, base, stage, or combination, 2) collapsible body/draw tube, 3) removal of objectives, 4) usually clever or ingenious ways of hinging and folding parts of the stand or components. Also, portable microscopes are distinguished from "pocket" microscopes. Portable microscopes are small for travel, but open up or assemble into instruments comparable to laboratory-based microscopes; pocket microscopes are hand-held instruments literally capable of being carried in a coat pocket (2). Examples of portable microscopes include the early "Club" or field microscopes made by Powell and Lealand, Swift and Son, Beck, and Rousselet during the last century, and those made within the first two decades of this century by Baker (1907 "Diagnostic"), Watson and Sons, E. Leitz, Swift and Son, and Bausch & Lomb (model APS). More recently, we have seen the Unitron Model MLP Portable Medical and Laboratory Microscope, the Zeiss (Jena) Travelling Microscopes LrO, the Tiyoda Portable Microscope, Model Q, and the Leningrad Optical-Mechanical Enterprises Model MPD-1. Of all of these portable microscopes, only the last one, the Russian-made MPD-1 is a portable *polarizing* microscope. Unfortunately, it is difficult to impossible to obtain, especially in the United States. It is, however, the logical choice on which to base a prototype. It is already a well-designed, small, portable polarizing microscope, needing only dispersion staining and phase contrast objectives, and the fitting of a phase annulus and counting graticule.

Figure 1 is an illustration of the Russian-made MPD-1 portable polarizing microsope fitted with dispersion staining objective, as seen in side view. Figure 2 is the front view, showing the much-reduced base and stage dimensions whereby much of its portability is derived. As shown, this instrument is capable of all asbestos fiber identifications.

Now, if one were designing a microscope from scratch for this kind of work, how would it differ from the MPD-1? For one thing, the MPD-1 is designed as a "Quick-change," single centerable objective (at a time) instrument—a characteristic it shares with the Olympus POS, and many expensive instruments from the best manufacturers. However, the demonstrated superiority of the multi-objective nosepiece, with centering capability for each objective position, makes it the design of choice. Strictly speaking, only two objective positions are required, but three or four result in a more versatile PLM instrument.

All of the portable microscopes mentioned require an outside light source. Portable microscopes are generally made for use with natural daylight, or with small, unsophisticated illuminators not capable of supplying Köhler illumination. The fact is, for most requirements, including asbestos identification and counting, strict Köhler illumination is not necessary to achieve success, especially if an experienced analyst is using the instrument. However, to ensure optimum illumination for all workers, and for critical photomicrographic documentation, a built-in illuminator capable of Köhler illumination is a desirable feature. For versatility, the lamp should be capable of operating from 110V AC or other local voltage, automobile battery, or rechargeable battery; there should also be a simple, attachable mirror for use with natural daylight. Beyond a multiple objective nosepiece and built-in light source, not much more is needed. Binocular/trinocular attachments are available for several models of portable microscopes, but these are always optional, separate accessories that only add bulk. Other than added comfort for long-term viewing, they are not strictly needed, and on-site microscopes are seldom used very long at one time.

A newly designed modern portable microscope

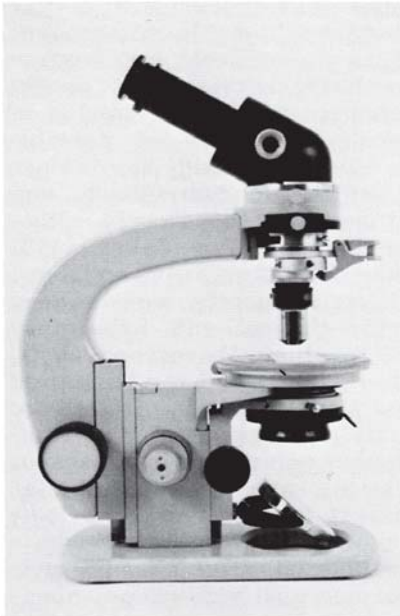

Figure 1. Side view of the Russian-made MPD-1 portable polarizing microscope, with dispersion-staining objective.

Figure 2. Front view of the MPD-1.

might also make extensive use of the newer, structurally strong composite materials to achieve weight reduction.

DISPERSION STAINING OBJECTIVE

The dispersion staining objective has been around, in one configuration or another, for several decades. Dissatisfaction with the then-current design prompted the writer to design the objective around the Abbe diffraction funnel furnished with the Zeiss Abbe Diffraction Apparatus. A prototype of the new dispersion staining objective was constructed, and presented formally at Inter/Micro 75, Cambridge, England (3). The advantages of this objective over others at the time and since include 1) the ability to easily interchange various-sized central and annular stops, 2) the ability to center stops for use in microscope without centering condensers, 3) the ability to screw objective into a rotating nosepiece without having to first remove the two objectives on either side, 4) a fourth advantage, not mentioned in the debuting article, but added in a following letter to the editor (4), was the ability to parfocalize the objective to others on the nosepiece. At the time, the new 45 mm objective adjustment distance was, at best, as common as the 37 mm adjustment length. The length of thread was calculated to work with and without its lock ring in such a way as to adjust for parfocality with either adjustment-length objective. In this writer's opinion, it is superior to any other model dispersion staining objective then or now. This objective is illustrated in Figure 3 in place for use on the MPD-1 portable polarizing microscope. Figure 4 shows the objective with its slider out and one central stop in place. This particular model objective was not put into production, because the machinists who made the prototype said that it was too difficult to make; the amount of precision required would make the objective too expensive—a conclusion this writer does not share.

Today, I would modify this objective. Since the general adaptation of the DIN Standards, there is virtually no call for the 37 mm adjustment length. The thread can, therefore, be cut for parfocality with 45 mm adjustment length objectives only. No other changes are required for use on most microscopes today.

An alternative to fixed annular stops is an iris diaphragm. Figure 5 (right) illustrates an iris diaphragm in a slider, which fits into the dispersion stainer slot, or into a general slotted intermediate piece (Figure 5, center). An objective fitted with a built-in iris diaphragm for annular stop dispersion staining (Figure 5, left) is still another alternative.

Before long, still another change in the objective

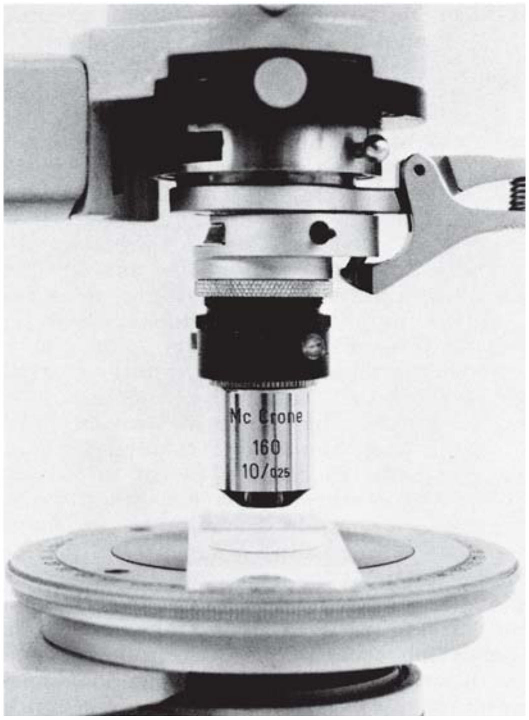

Figure 3. Dispersion staining objective in place on the MPD-1.

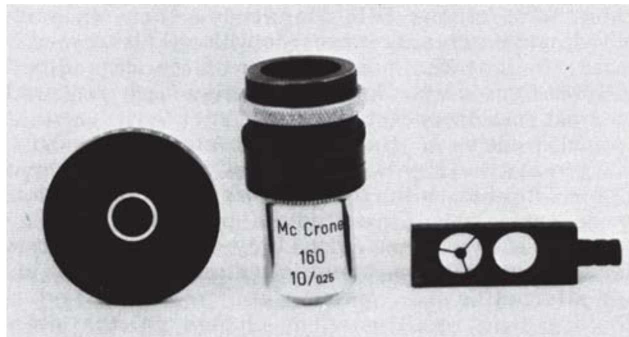

Figure 4. Dispersion staining objective with central-stop slider removed; on the left is a substage condenser annulus for use with a 40X phase objective.

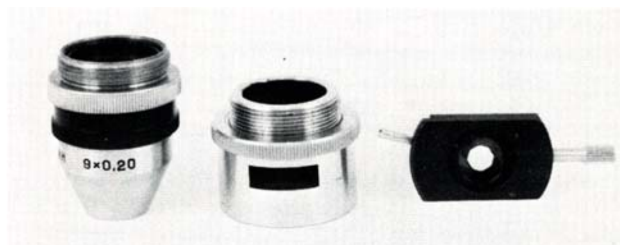

Figure 5. A 9X objective with built-in iris (left) is standard for the MPD-1. A slotted "extension" tube for the objective takes a slider as shown center and right.

will be necessary, and this will be due to the current trend toward infinity-corrected objectives. There is at least one stop-gap measure: Zeiss will shortly have available an adapter into which current 160 mm tubelength objectives can be screwed, which will convert them for use with infinity-corrected objectives. Any newly designed microscope will have to take this trend into consideration.

PHASE CONTRAST EQUIPMENT

Asbestos fiber counts made using the phase contrast technique call for the use of a 40X to 45X phase contrast objective, with a numerical aperture of 0.65 to 0.75. Generally, a phase contrast microscope is recommended, which implies a phase contrast condenser, with several phase annuli mounted in a rotating disc. This is not necessary; only a single phase annulus is required for any single 40X-45X objective. I recommend purchasing any 40X-45X/0.65-0.75 objective, and making one's own phase annulus to match the phase plate ring in the objective. There is nothing special or critical about the phase annulus; it is only a stop to allow a ring of light to illuminate the specimen. Such a phase annulus is illustrated in Figure 4, left. It can be black-painted glass or plastic. The only tricky part is to determine the i.d. and o.d. of the annulus itself, which will depend on the phase plate in the objective, the focal length of the condenser, and the location of the annulus within the condenser.

First, decide on a location for the annulus. This might be a filter holder at or near the bottom of the condenser. If not filter holder is available, a friction fit ring can be made to slip up into the condenser. Crudely, even a slide with annulus can be sticky-taped to the bottom of the condenser. When the location of the phase annulus has been decided upon, focus the 40X-45X phase objective on a specimen, set the condenser focus according to the Köhler method, and then place a transparent (metric) rule in the plane where you will place the annulus. Remove the eyepiece and observe the objective back focal plane, or introduce the Bertrand lens or phase telescope. At the objective back focal plane you will see the phase plate ring in the objective, with the image of the transparent rule superimposed. (If you do not have a transparent rule, you can make one by using a copy machine to copy an opaque rule onto a transparent sheet sold for this purpose.) Now, simply read directly in the back focal plane the inner diameter and outer diameter of the objective phase plate ring. These dimensions will indicate the i.d. and o.d. of the phase annulus required. The annulus can then be made using black paint or drawing ink on a glass or plastic disc. The completed annulus is then mounted in or under the condenser to provide the proper lighting for that objective. In the MPD-1 microscope, the annulus can be placed on top of the polarizer (not good because the polarizer acts as a neutral density filter), or it can be put in a machined bayonet-ring and substituted for the polarizer.

For a newly designed instrument, the phase annulus can be mounted in a slide-in/side-out fixture or a swing-in/swing-out filter holder of the common type.

A green or blue filter anywhere in the light path enhances contrast.

A Walton-Beckett type graticule must be custom made for each microscope. The disc diameter needed to fit the focusing eyepiece must be specified, as well as the diameter (mm) of the circular counting area (the graticule is available from Graticules, Ltd., Morely Road, Tonbridge TN9 1RN, Kent, England).

Additionally, a HSE/NPL phase contrast test slide, Mark II is required. It is available from PTR Optics Ltd., 145 Newton Street, Waltham, MA 02154.

A stage micrometer is also needed.

CARRYING CASE

Figure 6 shows the MPD-1 microscope ready for travel in its metal carrying case. A better idea for the complete instrument we are discussing would be one of the waterproof/dustproof Pelikan cases as made to military specifications. This rubber-ring sealed case would survive the consequences of almost any traveling mishap.

Olympus has announced a recently available, custom-fitted transport case for their BHT or BHTU microscope series. The case is constructed of heavy gauge molded ABS plastic, with die-cut foam insert to hold the microscope, objectives and accessories.

If a great many samples must be analyzed on-site, one might consider adding to the portable outfit a motorized rotating polarizer for speeding analysis (5).

Figure 6. MLD-1 microscope in metal carrying case.

CONCLUSION

Blue-skying the design of a specialized microscope like this and assembling a working instrument is both fun and challenging, but ultimately it is not the instrument that will perform the asbestos analyses and counts but the trained microscopist. Regardless of laboratory-based or on-site portable microscope, emphasis still needs to be placed on the training, drill and evaluation of the analysts who will use the equipment.

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