Production Engineering and Implementation of a Modular Military Binocular

W. J. Trsar, R. J. Benjamin, J. F. Casper, Optical Engineering 20(2) [1981]

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ABSTRACT

The following report reviews a technical paper that details the U.S. Army's efforts to design and produce a modular binocular for military use following WWII.

Keywords: Binocular; modular optics; opto-mechanics; production engineering.

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1. INTRODUCTION

The binocular is one several key instruments widely used in both military and non-military applications. Beginning in the 1950s, the U.S. military endeavored to re-design existing products by creating a smaller and lighter modular binocular that exceeded the optical performance of prior models. The final product was an opto-mechanical and production engineering success that demonstrated the feasibility of a modular design. The synopsis below follows the outline detailed in the original document.

2. PAPER SYNOPSIS

2.1 – Evolution of the M19

During WWII, the U.S. Armed Forces purchased close to half a million pairs of 6×30 and 7×50 binoculars[a]. These instruments were essentially commercially available units with some minor modifications for military use. The basic design of binoculars of the time used a metal enclosure to house and align an objective assembly followed by a pair of Porro prisms and an eyepiece assembly for each eye.

Use of these instruments during wartime raised issues of weight, size, mechanical reliability, and maintainability. After the end of the Korean War, studies conducted by the U.S. Army determined that neither weight nor size could be significantly reduced without a major re-design of the existing configuration. Thus, in 1956 the U.S. Army authorized development of the T14 binocular, with the intention of producing a 7×50 binocular with reduced size and weight.

At the time, it was recognized that the T14 program did not address the issues of mechanical reliability or maintenance. Multiple options were subjected to financial analysis, after which it was decided that a technical investigation would be conducted on a totally new binocular that could be maintained with minimal components and without special tools or skills.

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[a] A×B refers to the binocular's magnification (A) and objective diameter (B).

The contract to manufacture evaluation units of the new binocular was awarded to the Farrand Optical Company of Valhalla, NY. The result of the collaboration between Farrand Optical and the Frankford Arsenal[b] was the T14, a binocular that optically outperformed and, at the same time, halved the size and weight of its predecessor. The T14 would eventually become the M19, the first truly modular binocular, consisting of five, non-maintainable modules: eyepiece, objective, hinge pin, and left and right housings.

The U.S. Army evaluated the T14 design through 1959 and 1960. Field-testing exposed several flaws, which were addressed in the revised design, called the T14E1. Modularity was maintained in the T14E1, which, after minor modification, resulted in the M19, the final version of the product. Mass production of the M19 was done at Bell & Howell Company of Chicago, IL.

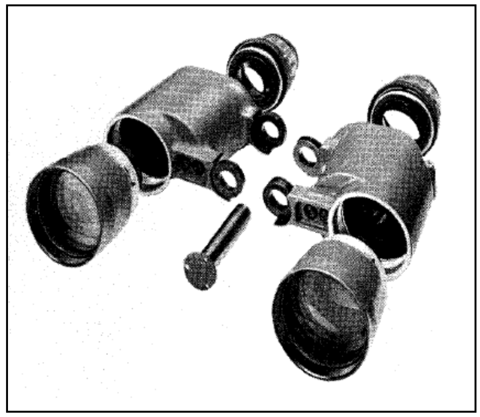

Fig. 1: M19 Modular Assembly

2.2 – Modularity of the M19

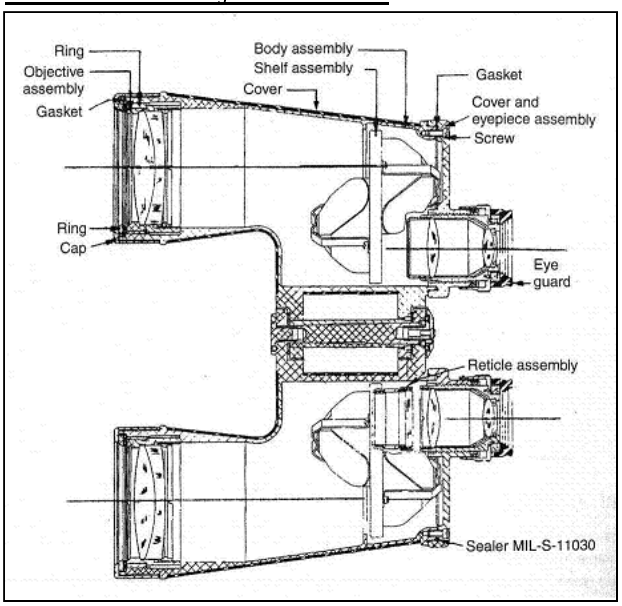

Fig. 2: Sectional View of WWII Era M17 Binocular

Modularity of the M19 was certainly its most striking aspect. To appreciate the extent to which this instrument was made modular, it is worthwhile to note that a typical WWII-era binocular was manufactured using selective assembly, was comprised of approximately 250 parts, and required more than 100 special tools for maintenance. Figure 2 shows such an instrument[1].

In contrast, the M19 was composed of a minimal number of interchangeable modules and required only two special tools, an adapter plug for a torque wrench and a spanner wrench, for assembly or disassembly.[2] This concept minimized the time and complexity required for service and maintenance.

[b] Frankford Arsenal: A U.S. Army facility in Philadelphia, PA active in design and development of military instruments. Closed in 1977.

The objective and eyepiece modules of the M19 were interchangeable among units without sacrificing performance in collimation, focus, or resolving power. The M19's aluminum body housings held the prism pairs, bonded together with a UV-curing adhesive, and fixed into place with an adhesive developed by the U.S. Army. The two prisms in each monocular were precisely aligned and seated on machined surfaces within the housing. The coating of the M19 used fused vinyl rather than paint or hand-glued vinyl. This coating offered a comfortable, easily applied, machinable surface to the exterior of the product.

The modularity of the M19 required tight tolerances for the interface dimensions between modules, achieved by a combination of precision machining, optical alignment, and mechanical fixturing. If the worst-case misalignment condition of modules had been used to establish tolerance limits, the required dimensional tolerances would have been 0.005mm, a value unacceptable for economically feasible manufacturing. Therefore, the U.S. Army performed Monte Carlo analysis to demonstrate that larger tolerance values could be used for production without suffering significant fallout at manufacturing.

2.3 - Performance Requirements

Figure 3 below defines the key performance requirements of the M19 binocular.

CHARACTERISTIC	UNITS	SPECIFICATION RANGE
Collimation	minutes of arc	
Dipvergence		+/- 15
Divergence		20 +/- 20
Resolution	seconds of arc	6 maximum
Image Tilt	minutes of arc	30 maximum
Parallax	mm	0.127 maximum
Eyepiece Focus	diopters	+/- 4

Fig. 3: Performance Requirements for M19 Binocular

The specification for collimation was the most difficult to achieve from a manufacturing point of view. Collimation in binoculars refers to the degree of parallelism, both horizontal (divergence) and vertical (dipvergence), of the output optical axes of the two monoculars.

2.4 – Production Engineering Concept

The basic approach used by Bell & Howell to produce the M19 binocular can be summarized as follows:

2.4.1 – Approach

- Modules would be produced pre-focused and collimated.
- Machining of modules would be done after assembly and sealing.
- Significant effort would be placed on tooling and machining using optical alignment in order to meet the required instrument specifications.
- Simple yet effective optical testing would be developed to qualify the opto-mechanical components.

- Studies would be performed to ensure compliance with required specifications and to improve quality.

2.4.2 – Production Flow

In its most simple form, the production flow of the M19 can be described as: Fabrication, Assembly, Machining. The components were first fabricated, after which the modules were assembled, and finally the critical surfaces were precision machined to ensure that the finished product was compliant with the required specifications. Throughout the manufacturing process, alignment and testing were performed as well.

No alignment or adjustment of the modules was performed after assembly was completed. In this way manufacturing of M19 was consistent with the modular design.

2.5 – Production Engineering Issues & Solutions

2.5.1 – Housing Module

The single-piece, aluminum, housing modules contained the reticle and Porro prisms that served to erect the image and provide a stereoscopic effect in the binocular. The U.S. Army developed and delivered a suitable adhesive used to bond the prisms to internal surfaces of the housings; however, due to the tight tolerance specifications, additional fixturing was required to maintain exact positioning of the glass components during the curing process. The housings required machining after assembly, which in turn required a complex alignment and fixturing process that was compounded by the asymmetric shape and soft coating of the housing. The detailed steps required of Bell & Howell's engineering team to meet this issue are described further in the original document.

2.5.2 – Objective Module

The objective of the M19 was an air-spaced triplet of telephoto design[3]. Similar to the housing module, the objective module required tight tolerances for several critical dimensions. After assembly, the module was sealed, locked into a fixture, and transferred to a lathe where precision machining was performed to define mounting surfaces.

2.5.3 – Eyepiece Module

Design of the M19 required that the eyepiece module be allowed to move axially for focus, while minimizing "wander", a displacement of the optical axis with respect to the mechanical axis. Facing a technical obstacle with regards to this feature, the Bell & Howell team engineered a solution that provided a spring preload, which ensured that the mating surfaces were maintained and wander was thus minimized.

3. SUMMARY

The M19 binocular provided the U.S. armed forces with a truly modular instrument suitable for use in the severe environments encountered by the military. Additionally, the M19 provided a high-quality opto-mechanical device with significantly reduced size and weight that enabled simple, rapid field-maintenance, where it mattered most. The result of this effort recalls the words of British statesman John Morley: *"Simplicity of character is no hindrance to the subtlety of intellect."*

4. COMMENTS

This paper is relevant for both students and professionals involved in optics, mechanics, process and manufacturing engineering, as well as for others who may simply take interest in how precision opto-mechanical instruments are manufactured. The discussions related to production engineering are especially useful for those interested in the extensive engineering efforts often required to produce rather simple and elegant opto-mechanical assemblies.

A similar analysis of the M19 binocular is found in the text referenced at the end of this document. Astute readers may recognize that the author (Paul R. Yoder, Jr.) spent a decade working at the Frankford Arsenal and was one of the designers of the M19. Therefore, his analysis of the product certainly warrants reading as well.

REFERENCES

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[1] Paul R. Yoder, Jr., *Opto-Mechanical Systems Design, Third Edition*, (Markel Dekker, 1986), 660.
[2] Yoder, Jr., 682.
[3] Yoder, Jr., 678.