



Savvy Optics Corp.

The scratch and dig revolution

April, 2013

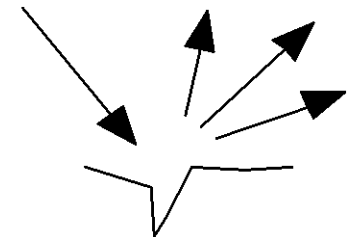
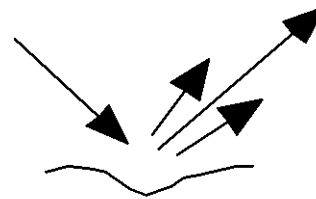
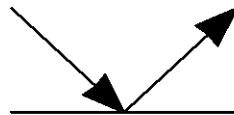
Revision 2.0

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...the scratch standard is only a cosmetic standard...the scratch standard is only a cosmetic standard...the scratch standard is...

- ▶ MIL-PRF-13830B is the de facto standard method of specifying cosmetic surface quality
 - Specification of “**visual appearance** of defects on optical parts”
 - Uses a pair of numbers, the first for scratch, the second for dig (e.g., 80-50; 40-10)
 - **Arbitrary numbers** referenced to a set of master scratches and digs
- ▶ Cannot be used to control functional defects, but more than adequate for cosmetic imperfections
- ▶ This is not a secret; Matt Young published a series of papers in the 1980's making this quite clear
- ▶ There is little correlation between the appearance or visibility of a scratch and its measured width. The *shape* of a scratch has a lot to do with its visibility.



Myths and legends¹ *... all false!*

- ▶ The scratch number was supposed to be the width in microns
- ▶ The Arsenal decreased the scratch width by a factor of 10 in the late 1970's
- ▶ The line width had to be reduced because the scratches "heal" over time
- ▶ Artifact standards calibrated in certain years can be used as a functional scratch standard

The truth is that the master scratches and the meaning of the visual appearance of, say, a #40 scratch has been unchanged since the first master scratches were made

Where did this specification come from?

- ▶ Proposed by McLeod and Sherwood in 1945
- ▶ Codified in MIL-O-13830 in 1954; revised to MIL-O-13830A in 1963
 - Referenced Drawing C7641866 for the comparison standards
 - C7641866 Rev. E (1956) has no notes on scratch width
- ▶ C7641866 revised to Rev. E-3 in 1960 to add
 - “Scratch numbers do not denote width of the scratch. The numbers indicate that the scratch has the same weight or visual appearance as the master scratch bearing the same weight number....”
- ▶ In an attempt to address a shortage of standards, C7641866 revised to Rev. H in 1974
 - Change note 2: “Scratch number denotes the width of the scratch in microns.”
 - Change note 6: “Manufacturer has the option to measure scratch width...or utilize comparison standards identical to those illustrated herein.”
- ▶ Drawing was revised 1980 to fix the error
 - Current revision is Rev R, and is again based on visual weight, and not width

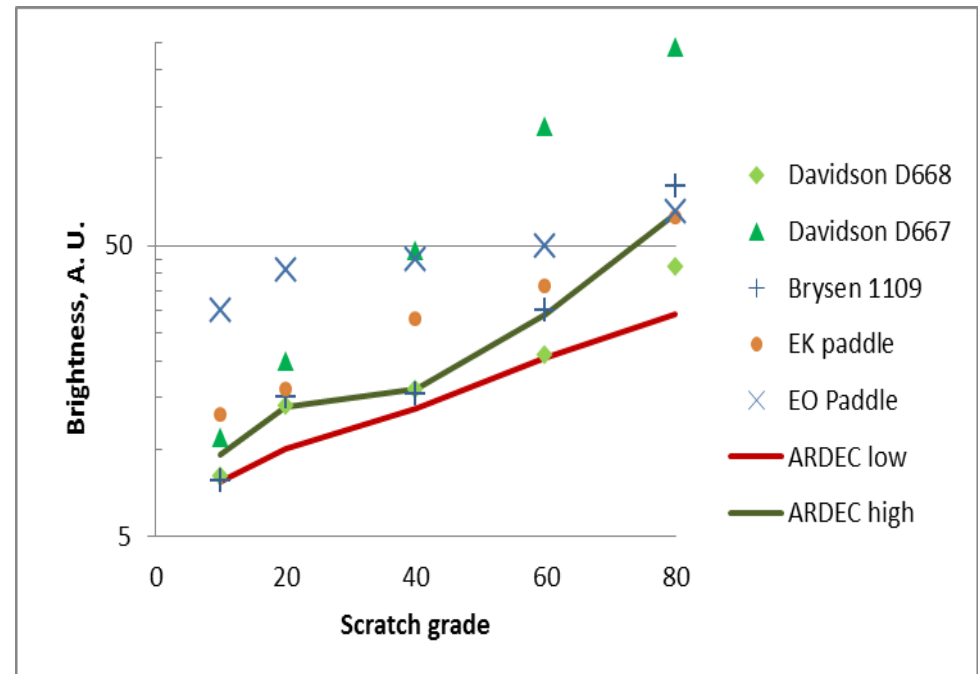
You cannot measure the width of a scratch to determine its grade. The evaluation must be done based on brightness

Is this standard still in use?

- ▶ The MIL-PRF-13830B standard for “scratch and dig” is still active, and used throughout the optics industry
 - By far the most commonly cited imperfection specification for optics
- ▶ In 2006, ANSI published American National Standard OP1.002, “surface imperfections”
 - The visibility specification is based entirely on MIL-PRF-13830B
 - References the same Military drawing, C7641866, for comparison standards
 - In 2009, a dimensional version of specification and measurement was added to the ANSI standard
- ▶ Unfortunately, only the Army has the visibility limit masters, so getting compliant comparison standards has been problematic

The problem with visibility: comparison artifacts

- ▶ Only one set of limit standards exist – Picatinny Arsenal
 - This is fine for the Army, but not the rest of us
- ▶ Can buy comparison artifacts from multiple suppliers
 - Brysen Optical (now owned by Flir Systems, Inc) makes Rev R box sets
 - Davidson Optronics (D-667) based on Rev H
 - Jenoptik Paddle – available from Thor Labs and Edmund Optics
- ▶ Manufacturers do the best they can to make the sets the same
 - Subjective verification of brightness
 - No way to correlate set to set
- ▶ *Significant differences exist from make to make*



The problem with visibility: objective versus subjective

- ▶ The trained human eye is quite good (repeatable) in making accurate side by side comparisons.
- ▶ Disagreements from inspector to inspector and shop to shop due to differences in:
 - Training
 - Interpretation
 - Illumination
 - Visibility of comparison standards.
- ▶ Better training and use of standard hardware helps
- ▶ Ultimately, it is still a subjective measurement



Photo from "taking variability out of scratch inspection," presentation to OEOSC by Ari B. Siletz

Geometry for standard reflectance visibility measurement from OP1.002:2009

- ▶ Illumination with a broad spectrum of angles
- ▶ Viewed with a small band of angles
- ▶ Part is rotated to achieve maximum visibility

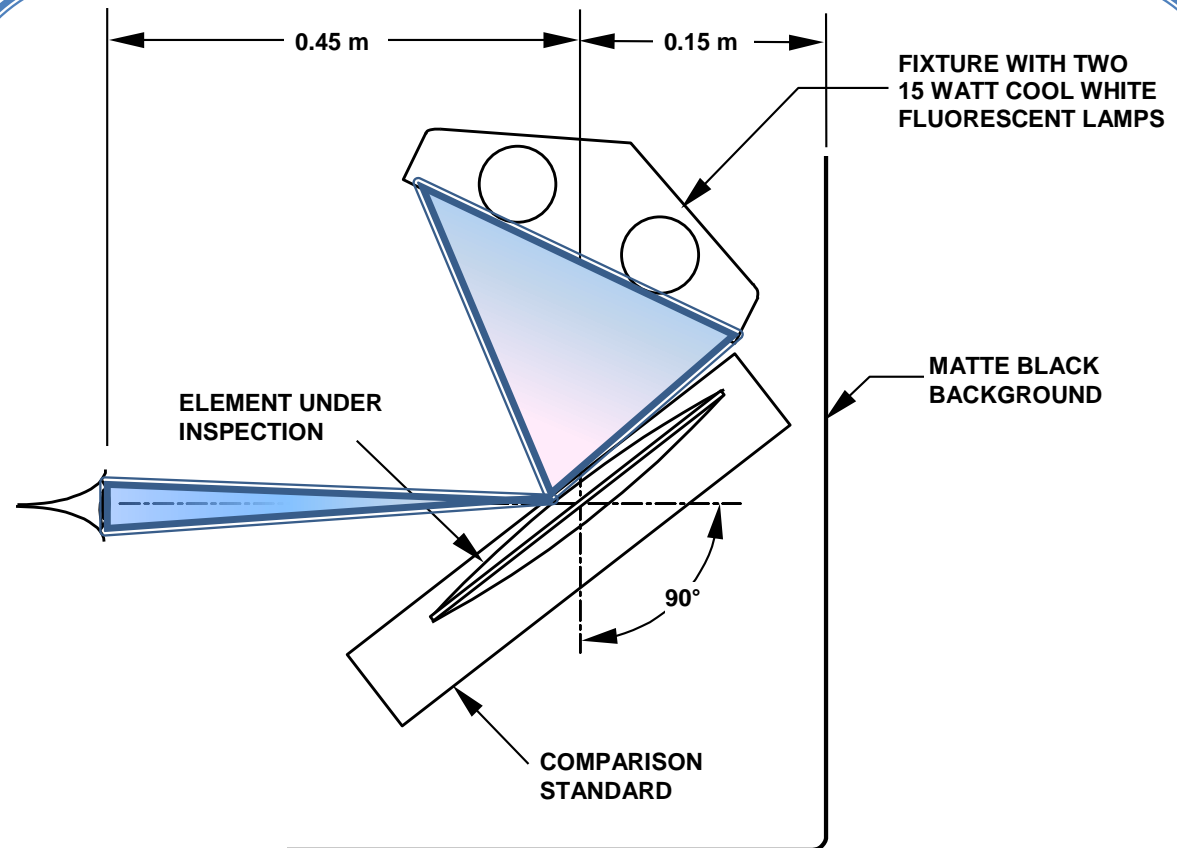


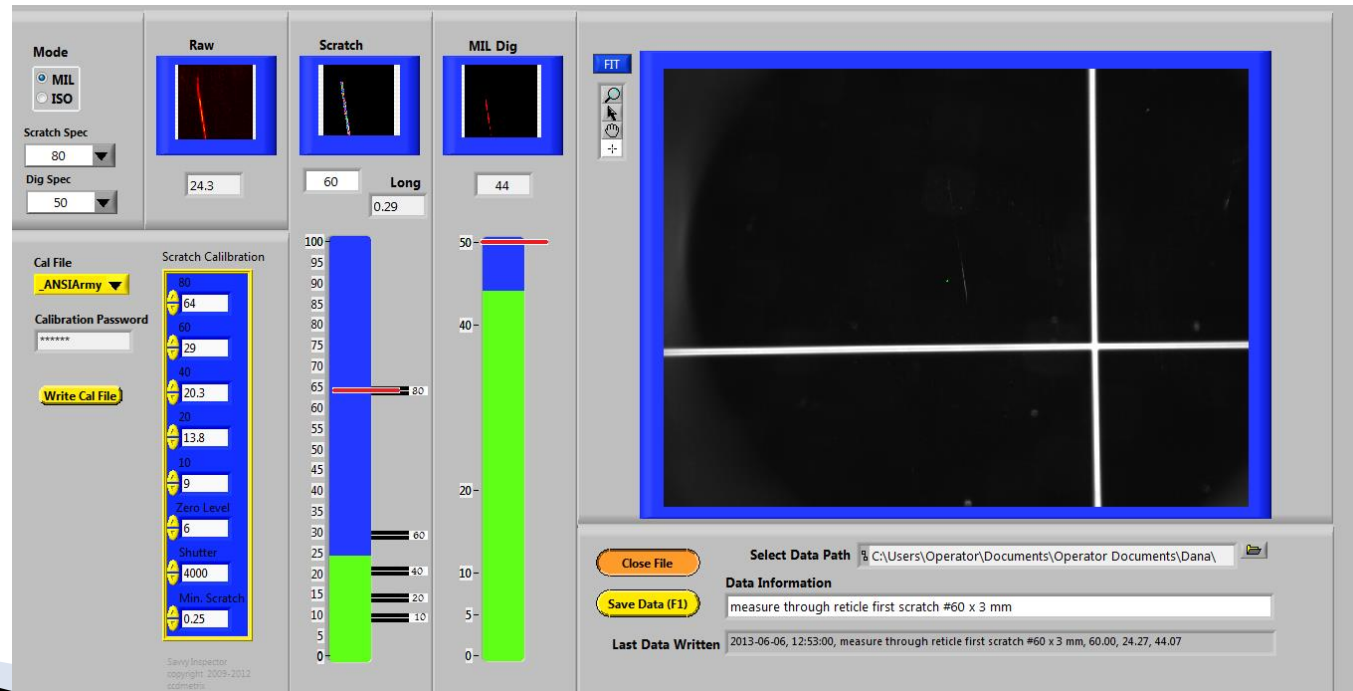
Figure 4 Reflected Light Inspection

This is just an evaluation of integrated scatter for specific angles!

Addressing the subjectivity problem: The SavvyInspector™

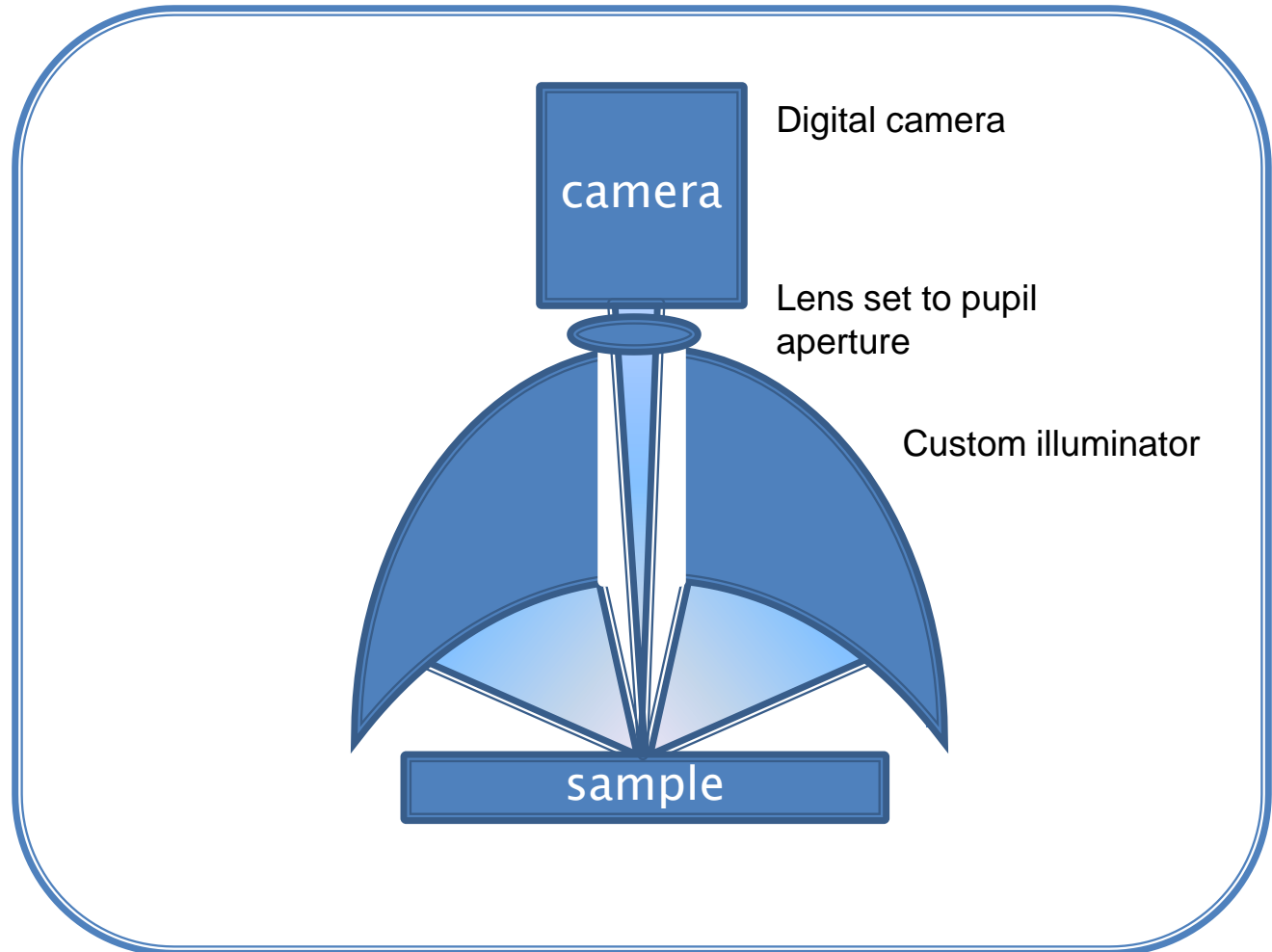


- ▶ Fixed Illumination, Magnification, and Lens Aperture
- ▶ Calibrated with any comparison set
- ▶ Completely objective measurement
- ▶ Designed to match inspection per MIL-PRF-13830B
- ▶ The best solution for flat optics inspection



SavvyInspector™ recreates the reflection visibility conditions, over 360 degrees of rotation

- ▶ Same illumination and detection angles
- ▶ Illuminates in a ring to eliminate part orientation
- ▶ Tailored brightness and integration to make #10 just visible on camera



Solving the problem of comparison artifacts

- ▶ In 2010, the Army purchased a SavvyInspector™ and converted over to objective evaluation of comparison sets.
 - Conducted repeatability and reproducibility studies
 - Created a set of inspection files based on the actual limit masters
 - Currently using the system to certify official sets
 - Re-wrote the SOP for certification of standards
- ▶ In 2012 Davidson Optronics implemented the same procedure
 - Created a new product series, D-668, to differentiate it from their existing “Rev H” based product (D-667)
 - Certified using a SavvyInspector™

For the first time, it is possible to purchase a scratch and dig comparison set that is certified to the Army limit master standards!

Savvy Optics Solutions for: Flat Optics

OK	Better	Even Better	Best
Visual comparison using traditional subjective methods and commercial standards	Visual comparison with set calibrated using objective measurement	Davidson D-668 comparison set, or Army issued set	SavvyInspector™ SIF-4 direct objective inspection
Savvy Optics contributions:			
Savvy Optics Training	Mapping and Certification with SIF4	Savvy Optics helped develop and sell	Savvy Optics co-invented - we sell and rent

Savvy Optics Solutions for: Curved Optics

OK	Better	Even Better	Best
Visual comparison using traditional subjective methods and commercial standards	Visual comparison with set calibrated using objective measurement	Davidson D-668 comparison set, or Army issued set	Not yet available: SIL system needs to be developed
Savvy Optics contributions:			
Savvy Optics Training	Mapping and Certification with SIF4	Savvy Optics helps develop and sell	Savvy Optics currently looking for development funding for SIL-4

The leaders of our industry are part
of the scratch and dig revolution



How are you solving the problem of scratch and dig?

Summary

- ▶ For flat surfaces, the best thing you can do is use a SavvyInspector™
 - Call for a quote: 860-878-0722
- ▶ For curved surfaces you have a couple of choices
 - Use a SavvyInspector™ to calibrate your own lens comparison artifacts
 - Get a set certified by Picatinny Arsenal (for Military contracts only)
 - Can buy a D-668 comparison set from Davidson Optronics or Savvy Optics Corp.
 - Call for a quote: 860-878-0722

Join the scratch and dig revolution!