

# Optics Surface Quality Solutions: The scratch and dig revolution

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### Manufacturing Processes



- If you can measure it, you can control it and improve it
- The better the measurement
  - The better the control
  - The more opportunities for improvement

#### Scratches and digs can be specified by

### Visibility or Size



Specification	Scratches	Digs
MIL-PRF-13830	Visibility (brightness) (10, 20, 40, 60 or 80)	Apparent size (5, 10, 20, 40 or 50)
ISO 10110-7	Size (width) or Visibility (10, 20, 40, 60, or 80)	Size (root area) or Apparent size (5, 10, 20, 40, or 50)
MIL-C-48497 MIF-F-48616	Size (width) (A, B, C, D, E, F or G)	Size (diameter) (A, B, C, D, E, F, G, or H)
ANSI OP1.002	Visibility (10, 20, 40, 60, 80) or Size (letter)	Size (number or letter)

#### De Facto Surface Quality Standard:

### MIL-PRF-13830



- 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
- 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.



Scratch morphology drives brightness

# Manufacturing Control: Scratch and Dig



## Surface imperfections are a significant cause of yield loss

Specified using "scratch and dig" specifications (MIL-PRF-13830B or ANSI OEOSC OP1.002)

#### Ways to improve yield loss due to scratch and dig:

- Train engineers and technicians on specifying and measuring scratch and dig
- Train manufacturing personnel on cleaning and handling of optics
- Improve inspection process to reject bad parts and accept good parts
- Review rejected parts to feedback process and/or design improvements

#### Conventional Inspection



### Skilled operator under controlled lighting conditions:

- 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.

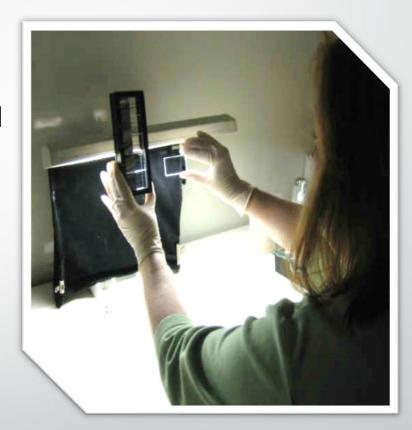


Photo from "taking variability out of scratch inspection," presentation to OEOSC by Ari B. Siletz

## Where did this specification come from?



Proposed by McLeod and Sherwood from Kodak in 1945

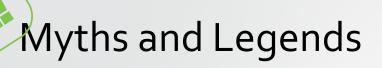
Codified in MIL-O-13830 in 1954;

Current revision is MIL-PRF-13830B

Standard is still in use throughout the industry

- Referenced Drawing C7641866 for the comparison standards
- Current revision of C7641866 is Rev R, and is still based on visual weight, and not width, size, or depth
- Army SOP for preparing comparison samples is based on SavvyInspector® technology at Picatinny Arsenal

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





- 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

#### Is this Standard Still In Use?



Yes.

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

And

- 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 2017, the ISO 10110 drawing standard was revised to add the MIL visibility specification as well

Unfortunately, only the Army has the visibility limit masters, so getting compliant comparison standards has been problematic

#### The problem with visibility:

### Comparison Artifacts

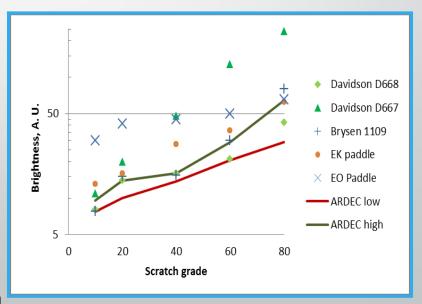


- Only one set of limit standards exist Picatinny Arsenal
  - This is fine for the Army, but not the rest of us
- Commercial equivalents aren't always equivalent
  - Davidson Optronics (D-668) uses Army SOP and SavvyInspector® for certification
  - Davidson Optronics (D-667) based on Rev H
  - Brysen Optical (suggested supplier on Army drawing)
  - Jenoptik Paddle sold by 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



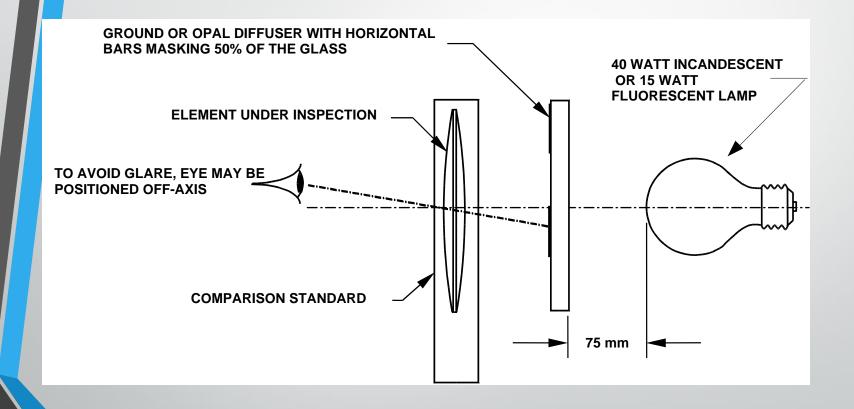
- The trained human eye is quite good (repeatable) in making accurate side by side comparisons.
- Disagreements from inspector to inspector and shop to shop due to differences in:
  - Training
  - Interpretation
  - Illumination
  - Visibility of comparison standards.
- Better training and use of standard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



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

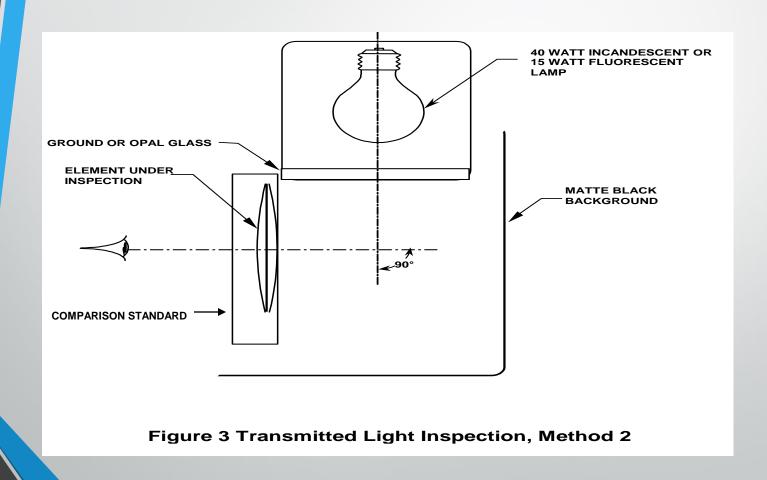
# Transmitted Light Inspection, Method 1<sup>1</sup>





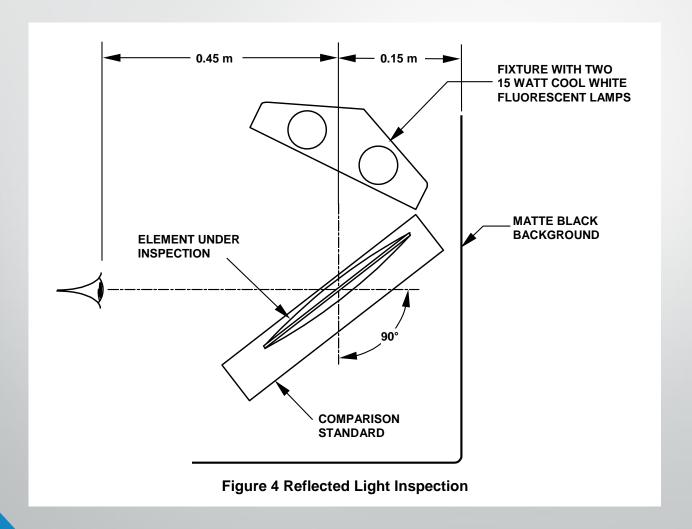
## Transmitted Light Inspection, Method 2<sup>1</sup>





# Reflected Light Inspection Setup<sup>1</sup>





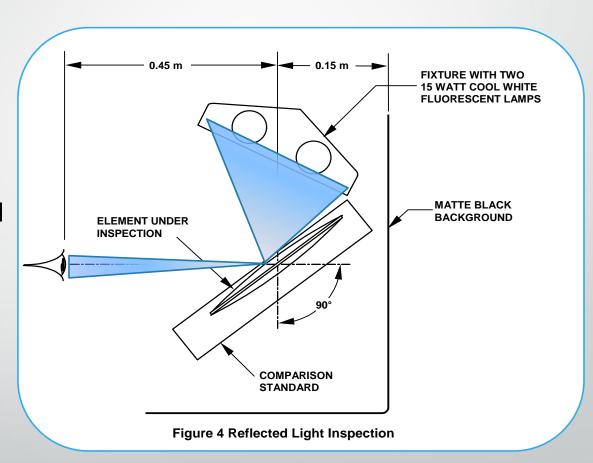
#### Reflectance Visibility Measurement

### Geometry



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



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

# Visual inspection to MIL, ANSI and ISO standards







Transmitted light method 2



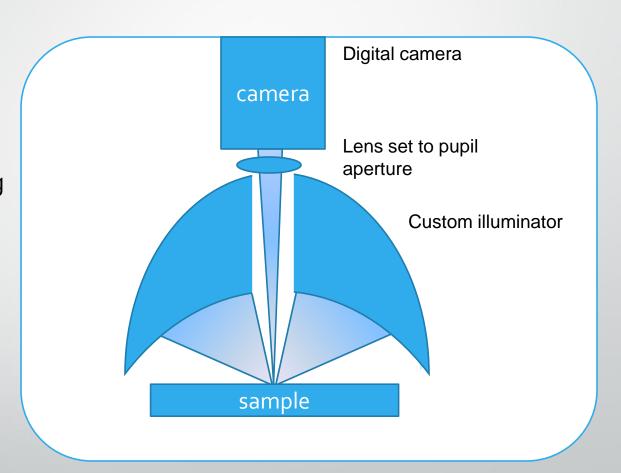
Reflected light method

#### Introducing:

### SavvyInspector®



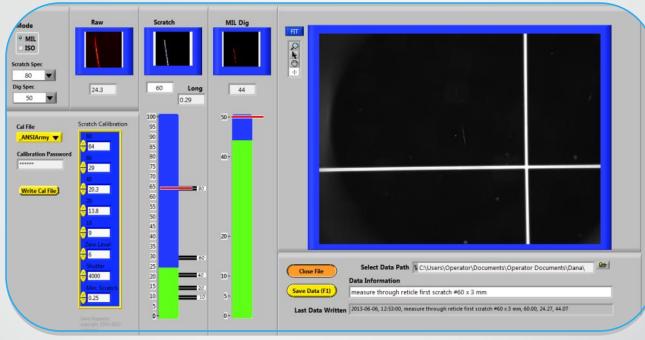
- Same illumination and detection angles
- Illuminates in a ring to eliminate part orientation
- Tailored brightness and integration to make #10 just visible on camera



**Diagram:** SavvyInspector® recreates the reflection visibility conditions of conventional inspection

### Finally Addressing the Subjectivity Problem





Calibrated with any comparison set

Completely objective measurement

The Best Solution for Surface Quality Inspection

Fixed Illumination, Magnification, and Lens Aperture

Designed to match inspection per MIL-PRF-13830B

## The SavvyInspector® Model SIF-8M





Motorized three-axis 200 x 200 x 70







- Part sizes up to 70 mm diameter
- Convex or Concave
- Up to f/2 surface slopes
- Real-time feedback
- Army traceable

Manual x, y, tip-tilt and motorized focus

### The Software is the Key



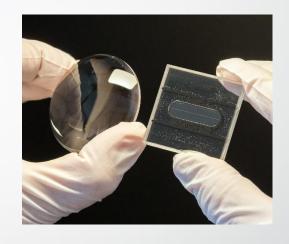


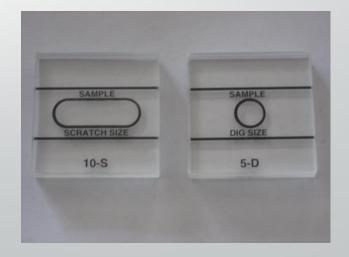
## Army-traceable Visibility Samples



- Completely re-mastered
- Certified using Army SOP
  - SavvyInspector® calibration



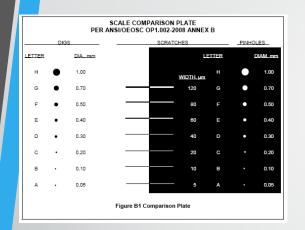


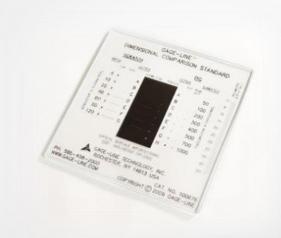


### OP 1.002 Dimensional Standard



Based on Annex B of the standard





A 10x loupe with a fixed reticle is also available

Fast, efficient



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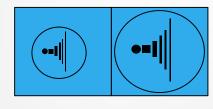
### ISO 10110-7 Comparison Standards



### POG Praezisionsoptik Gera GmbH Standards (comparison plates)



0.040

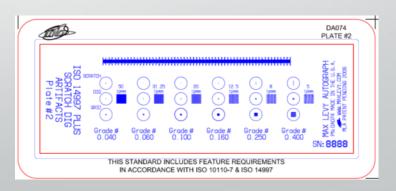


0.250 0.400

#### **Max Levy**

(both positive and negative versions of artifacts)





# Scratch and Dig Inspection Options: Flat Optics



OK	Better	Even Better	Best
Visual comparison using traditional	Visual comparison with set calibrated	Davidson D-668 comparison set, or	SavvyInspector® SIF-4 direct
subjective methods	using objective	Army issued set	objective inspection
and commercial standards	measurement		

## Solutions for: Scratch and Dig Inspection on Flat Optics



ОК	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 helps develop and sell	Savvy Optics co-invented – we sell and rent	

# Surface Imperfection: Scratch and Dig on Curved Surfaces



OK	Better	Even Better	Best
Visual comparison using traditional subjective methods and commercial	Visual comparison with set calibrated using objective measurement	Davidson D-668 comparison set, or Army issued set	Savvylnspector®  SIL-4 direct  objective  measurement
standards			

## Solutions for: Scratch and Dig Inspection on Curved Surfaces

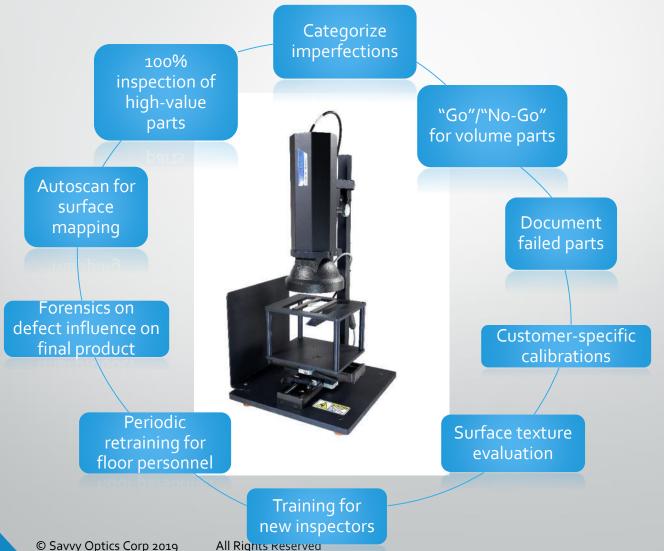


ОК	Better	Even Better	Best	
Visual comparison using traditional subjective methods and commercial standards	Visual comparison with set calibrated using objective measurement	Davidson D-668 comparison set, or Army issued set	SavvyInspector® SIL-4 direct objective measurement	
Savvy Optics contributions:				
Savvy Optics Training	Mapping and Certification with SIF4	Savvy Optics helps develop and sell	New Product by Savvy Optics Corp.	

### **Customer Applications**

of the SavvyInspector®





### Summary



Customers are using the SavvyInspector® in ways we would never have imagined to improve yield and profit

- Totally objective "gold standard"
- Very repeatable
- Easy to calibrate
- Easy to operate
- Permanent record and traceability
- Mapping and autoscan



SavvyInspector® takes the subjectivity out of the scratch inspection process



### The leaders of the industry are part of the solution







nanometrics



















































Apri

Newport.

Rubicon Technology





