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Specifying Scratch/Dig of an Optical Surface MIL-0-13830

The designation of surface will be given in the form of two numbers, i.e. 60-40. The first number specifies the maximum width of scratches on the surface in tenths of a micron.

#80	Max width equals 8 microns
#60	Max width equals 6 microns
#40	Max width equals 4 microns
#20	Max width equals 2 microns
#10	Max width equals 1 micron
#5	Max width equals 1/2 micron

The second number defines the average maximum diameter of a dig in hundredths of a millimeter.

#50	Max diameter equals .50 millimeter
#40	Max diameter equals .40 millimeter
#30	Max diameter equals .30 millimeter
#20	Max diameter equals .20 millimeter
#10	Max diameter equals .10 millimeter
#5	Max diameter equals .05 millimeter

Scratches:

A scratch is defined as any marking or tearing in the surface. A scratch is much longer in length than it is wide and is not as deep as a dig.

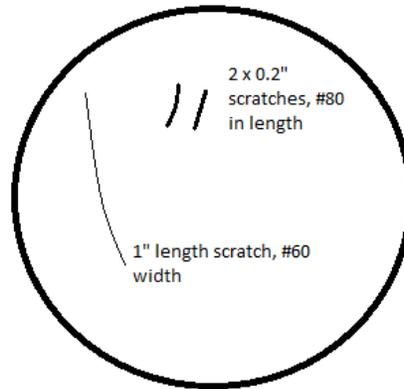
Types of Scratches:

- Block reek: a chain like scratch produced in polishing.
- Runner-cut: curved scratch caused by grinding.
- Sleek: hairline scratch.
- Crush or Rub: surface scratch of a series of smaller scratches caused by mishandling.

Implied Specifications of a Scratch:

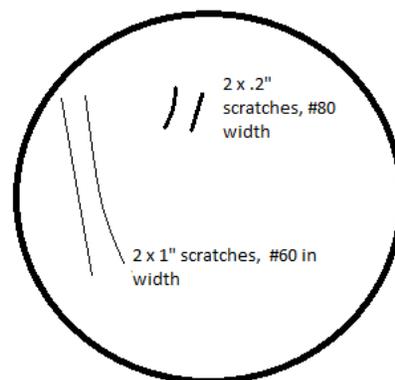
1. Circular Element: The combined length of all the scratches on a surface with the maximum specified width shall not exceed 1/4 of the diameter of the surface.

For example: Take a 2" diameter lens with 3 scratches on it. A #60 scratch of 1" length and two #80 scratches 0.20" in length. The combined length of the bigger scratches is only 0.4". This lens meets the specification.



2. An element with multiple scratches of various widths: Each scratch width number is multiplied times the ratio of their length to the diameter of the element. The sum of these values shall not exceed the maximum specified scratch number.

Take the 2" lens from above, but add another 1" #60 scratch. Assume the specified maximum scratch width is #80



$$1/4 * 60 + 1/4 * 60 + .2/2 * 80 + .2/2 * 80 = 61$$

This value is more than half of 80m, so the lens does not meet specifications, even though it still meets specification 1.

Note that when element in question is not circular; the diameter used is that of a circle with an equivalent area.

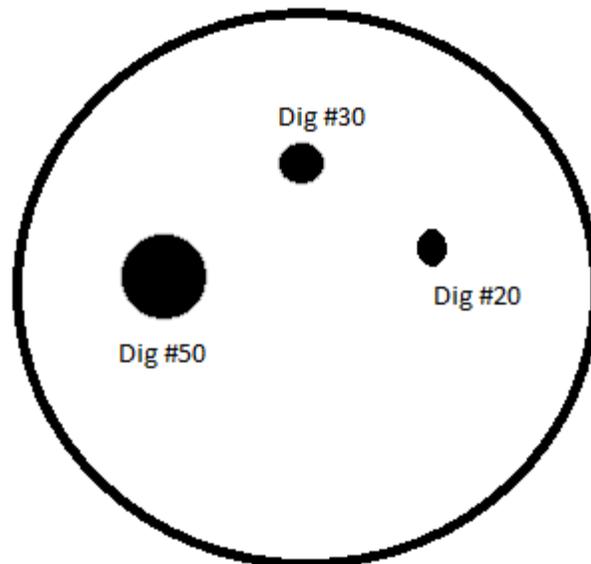
3. Areas of surface whose maximum specified scratch width is #20 or better shall have no 1/4" diameter area with more than 4 scratches (#10 or larger)
4. Surface area outside of the defined clear aperture is expected to meet 80-50 unless otherwise specified.
5. Coating scratches must also comply with surface specifications even if the scratch is not deep enough to affect the actual glass surface.

Digs:

A dig is any pit-like hole in the surface. They are usually round in shape. The dig specification defines the maximum allowable diameter of any dig in the surface. In the case of irregular shaped digs, the average diameter of shape is used.

Implied Specifications of a Dig:

1. The number of maximum size digs must not exceed 1 per 20mm of diameter or fraction thereof. For example a 50mm lens may have 3 maximum size digs across the area of the surface, because you get 1 extra allowable dig for the "fraction thereof." This also allows for any surface smaller than 20mm to have up to 1 maximum size dig.
2. The sum of all the digs larger than 2.5 microns shall not exceed twice the number of the dig specification.



Take the above 1" lens, with 3 digs on its surface. Note the digs are not drawn to scale. Assume dig specification is #50.

25mm diameter allows for 2 #50 digs on the surface. The specification is met. The sum of the dig numbers across the surface is 100. This just barely meets specification. Any other digs on the surface larger than 2.5 microns would make this surface not meet specifications.

3. All surfaces with dig specifications of #10 or smaller must have 1mm separation (edge-edge) between each dig.
4. A bubbles and inclusions should be considered as an equivalent size dig,
5. There should only be 1 maximum size bubble per 20mm of light, or fraction thereof.

Scratch and Dig Specifications in the Real World:

Below is a table that represents common scratch/dig specifications vs application.

Commercial:	80-50
Semi-precision:	60-40
Precision:	20-10
High Precision:	10-5
Super Precision:	0-0

Mirrors typically have a tighter surface specification than lens as a surface defect cause a greater deviation in the light path.

I found two nearly identical broadband metallic mirrors from Newport varying only in optical surface quality. Both mirrors are 1" Zerodur Aluminum mirrors with a wavelength range from 450-700nm.



Model 10Z40ER.1 Scratch Dig: 10-2

Price: \$129.00

Model 10Z20ER.1 Scratch Dig: 15-5

Price: \$110.00

The mirrors don't vary that much in price. A 1" BK7 lens is much cheaper in comparison, but it is hard to compare elements made from different materials.

Model KPX079 Scratch Dig: 40-20

Price: \$ 40.00

References:

<http://www.vpglass.com/technical.php>

www.Newport.com

http://www.savvyoptics.com/files/April_2009_-Release_of_new_Scratch_and_Dig_standard.pdf

<http://fp.optics.arizona.edu/optomech/references/Mil-O-13830A.pdf>