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Max Levy Autograph, Inc.

**HIGH EMISSIVITY TESTING OF MATERIALS
USED IN IR LONG-WAVELENGTH TARGETS**

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1.0 Introduction:

This study was performed in order to update our previous evaluation on what materials and coatings for high emissivity in the IR spectrum on different substrates, specifically between 5 and 12 microns and at varying angles of incidence to the substrate. Prior testing had concluded that a paint-based coating would yield the best results. This investigation focuses on two different paint coatings on electrodeposited nickel, black nickel, and black-oxidized BeCu substrates. Since emissivity is typically a difficult variable to measure accurately, the emissivity of the coatings were determined by drawing a relationship between emissivity and reflectivity. According to Kirchoff's Law, "the emissivity of a surface at temperature T is equal to the absorbance a which the surface exhibits for radiation from a source at the same temperature." Also, for opaque bodies, "reflectivity is the complement of absorbance" (Baumeister 4-108). For this experiment, all test samples were completely opaque. From this, it can be derived that by determining how reflective the test surface is, its corresponding emissivity can be gauged. For example, a very low reflection curve for a given sample would indicate high emissivity, and vice versa.

2.0 Applicable Documentation:

For producing the material substrates, military specification MIL -P-18317 for electrodeposited black nickel and federal specification QQ-N-290 for electrodeposited nickel were used. To apply the "MIL-SPEC" paint coating, the MIL-F-18264 procedure was followed.

3.0 Apparatus, Tools, Materials, Unique Shop Supplies and Equipment Required:

The two paint coatings tested were a Krylon 1602 Ultra Flat Black Spray Paint and Randolph 37038 Flat Black TT-E-527D Enamel. The material substrates are electrodeposited nickel with and without a black nickel finish under the paint. To measure the reflectivity of each of the samples, a Buck Scientific Model 500 IR Spectrophotometer was used. The Model 500 is able to scan in the near-IR to IR range at wavelengths between 2.5 and 16.7 microns. A Model 501 Variable Angle Specular Reflectance Accessory (Fig 1) was used to hold the sample at the desired incident angle to the beam. There are five mirrors that the beam reflects off of before continuing on through the rest of the machine. These mirrors are indexed in the figure as mirrors M1 through M5. The sample and the gold mirror used to collect the baseline are both held in the M4 position. All angles are defined in terms of θ , where θ is the number of degrees away from the normal. For this experiment, $\theta=0^\circ$ will be defined as normal to the substrate.

4.0 Safety:

A ventilation hood and exhaust fan was used when spraying the substrates to prevent paint fumes from contaminating the area.

5.0 Process Details and Procedure:

5.1 Sample Preparation

Two different coatings were tested in this experiment. The first coating was a Krylon 1602 Ultra Flat Black spray paint. The second paint was a "MIL-SPEC" Randolph 37038 Flat Black TT-E-527D Enamel. Both paints were applied to both 10 mil electrodeposited nickel, black nickel finished, and black oxide finished BeCu samples. The TT-E-527D Enamel was applied using an airbrush according to the procedure specified by MIL -F-18264. The Krylon 1602 was applied with a spray distance of 10-14 inches to achieve a grainy texture on the substrate, which was necessary in order to be able to achieve low reflection in the upper IR spectrum, specifically past 10 microns. To ensure that the nickel and black nickel samples remained flat during testing, they were bonded to 0.060" backing glass using a 3M Spray 77 adhesive. The main difference between how the Krylon 1602 samples and the Randolph TT-E-527D samples were prepared is that the MIL -F-18264 procedure calls for a baking process at 300 degrees for one hour whereas the Krylon 1602 samples were air dry only.

5.2 Testing

All four samples were tested using the Model 501 accessory, collecting 5 reflectance curves per sample at 25°, 35°, 45°, 55°, and 65° off axis from the normal. This was determined to be the range at which the most useful data was obtained. For each angle the sample was tested at, a separate baseline was collected to ratio against the sample run to account for fluctuations in the detector as it scanned the sample. This also reduced, but did not completely eliminate, any atmospheric noise that may have corrupted the resulting reflectance trace. Due to the fact that the signal-to-noise ratio was so low, all reflection curves were curve-fitted with a trend line later using Adobe Illustrator for easier readability.

5.3 Conclusion

The complete set of 25 reflectance curves for all five samples can be found in Figs. 2 through 6. A tabular listing of the minimum and maximum % reflectance for each sample at each angle can be found in Fig. 7.

The Randolph TT-E-527D clearly had the better response of the two coatings, on both on the nickel and black nickel finished substrates (Figs. 4 and 5). The black oxide finished BeCu substrates were tested with Randolph TT-E-527D paint only. The resulting curves were essentially identical to the black nickel finished electroformed nickel substrates. With the exception of $\theta=65^\circ$ (Figs 4.5 and 5.5), reflectance was under 1.5%. Both the Krylon 1602 and Randolph TT-E-527D coatings had similar reflection curves in the range of 2.5-5.0 microns, with all of the responses having <1% reflectance, regardless of the angle away from the normal or whether it was nickel or black nickel. In almost all cases, the difference in substrate material did not produce any significant advantage over another one, with only one exception. At $\theta=65^\circ$, the Randolph TT-E-527D had a noticeably better response on black nickel (Fig 4.5) than with plain nickel (Fig 5.5). At 16.7 microns, the nickel sample showed >11% reflectance whereas the black nickel was <2%. In nearly all of the reflectance traces, there was an anomaly at around 8.0 microns where the reflectance rises above 1% to about 1.5% and then drops back down again around 10.0 microns. It was found that the reflectance curve could be coarsely manipulated to achieve low reflection in the higher IR spectrum (>10 microns) by varying how the coating was applied to the nickel, specifically by varying the spray distance to the substrate. By maintaining a spray distance of at least 14 inches, the paint would spray onto the substrates in a diffuse, grainy texture. It was found that the more grainy the surface was, the better response it had past 10 microns. In the case of the Randolph TT-E-527D, using an airbrush provided more flexibility when trying to achieve different textures, whereas the Krylon 1602 was supplied in its own spray can with a very fine nozzle, making it difficult to get any sort of grainy texture on the substrate. This difference is most likely what accounts for the Krylon's poor reflection response past 10 microns in most cases, in particular its off-axis response.

6.0 Reference Material:

Baumeister, Theodore. "Marks' Mechanical Engineers' Handbook". 6th Ed. McGraw-Hill, 1958.

7.0 Revision History:

Revision Level	Revision Date	Revised By	Brief Description of Revision
Original	12/18/01	Chris Hess	Original Issue

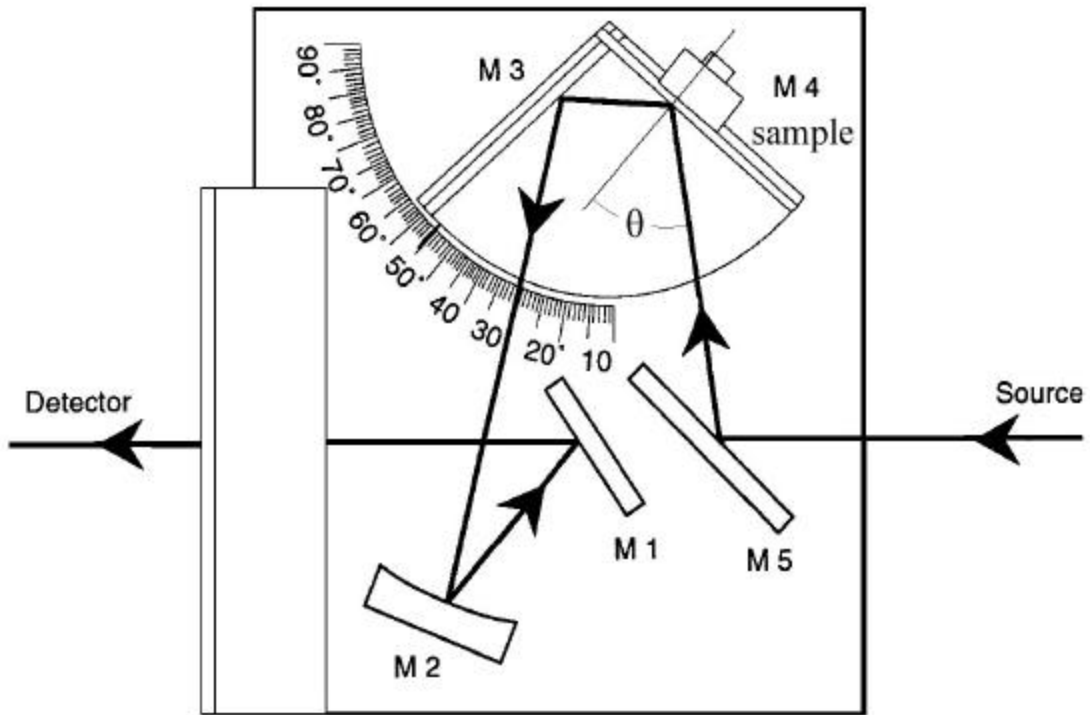


Fig. 1
Model 501

Fig 2.1

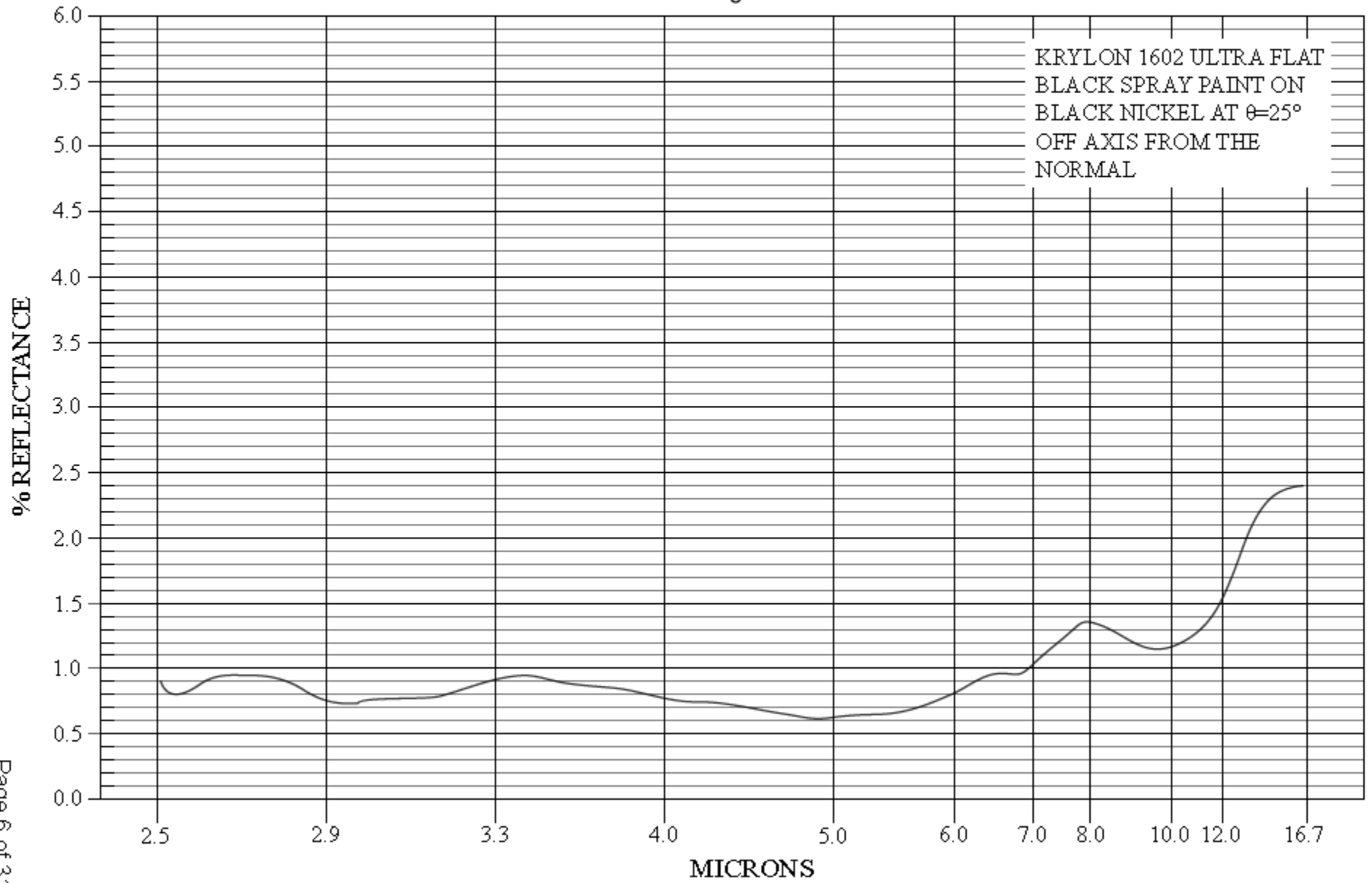


Fig 2.2

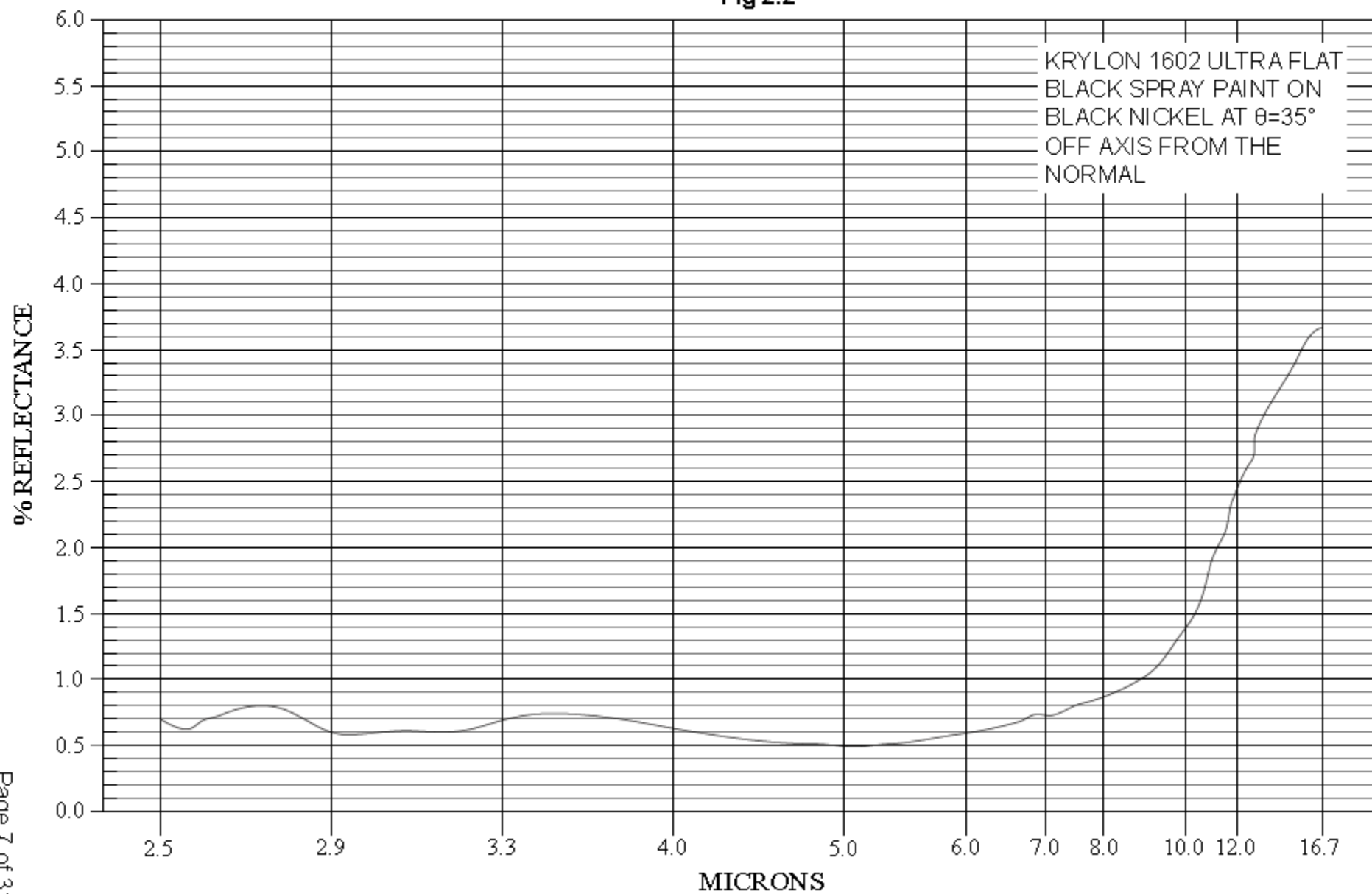


Fig 2.3

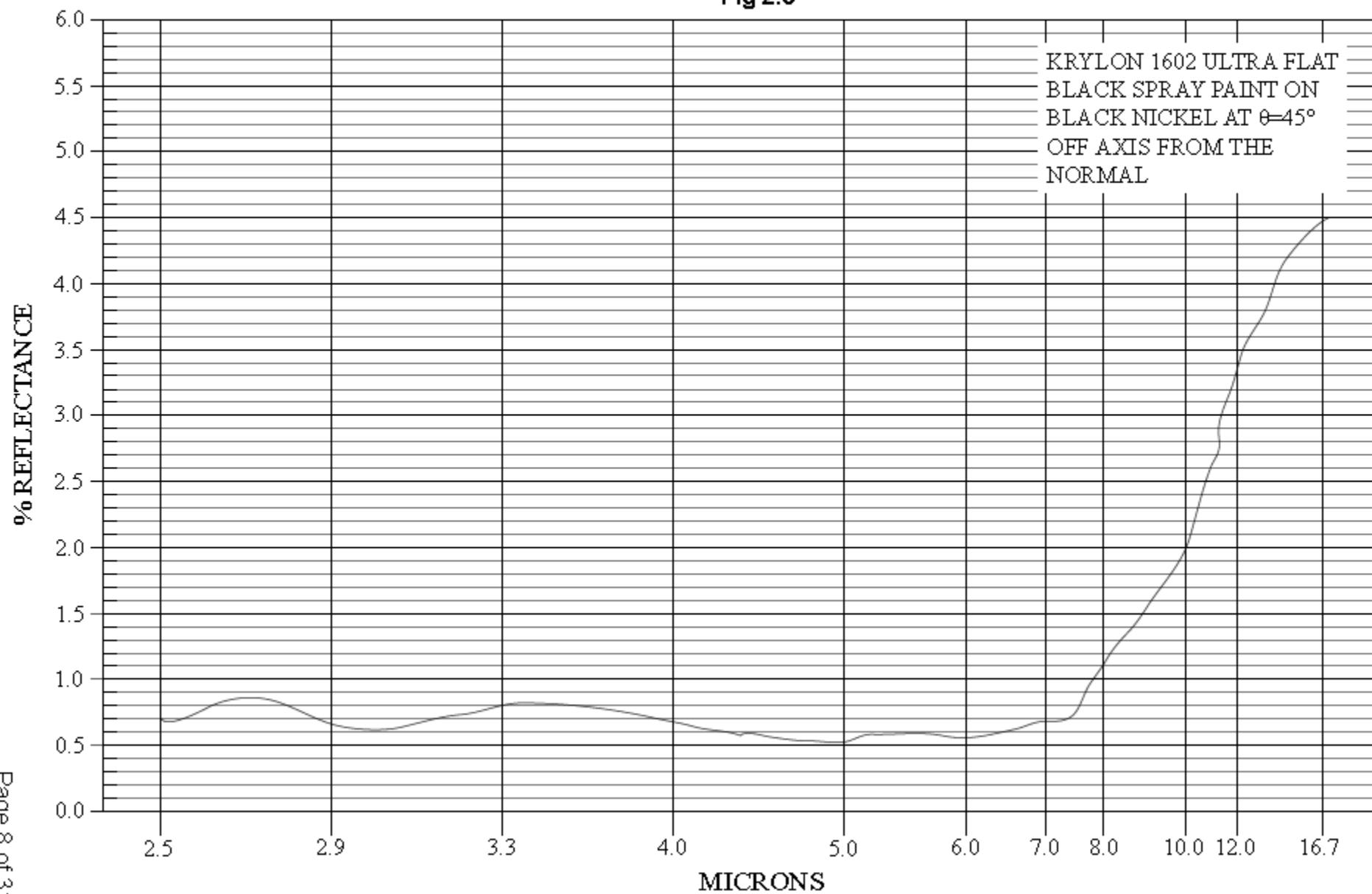


Fig 2.4

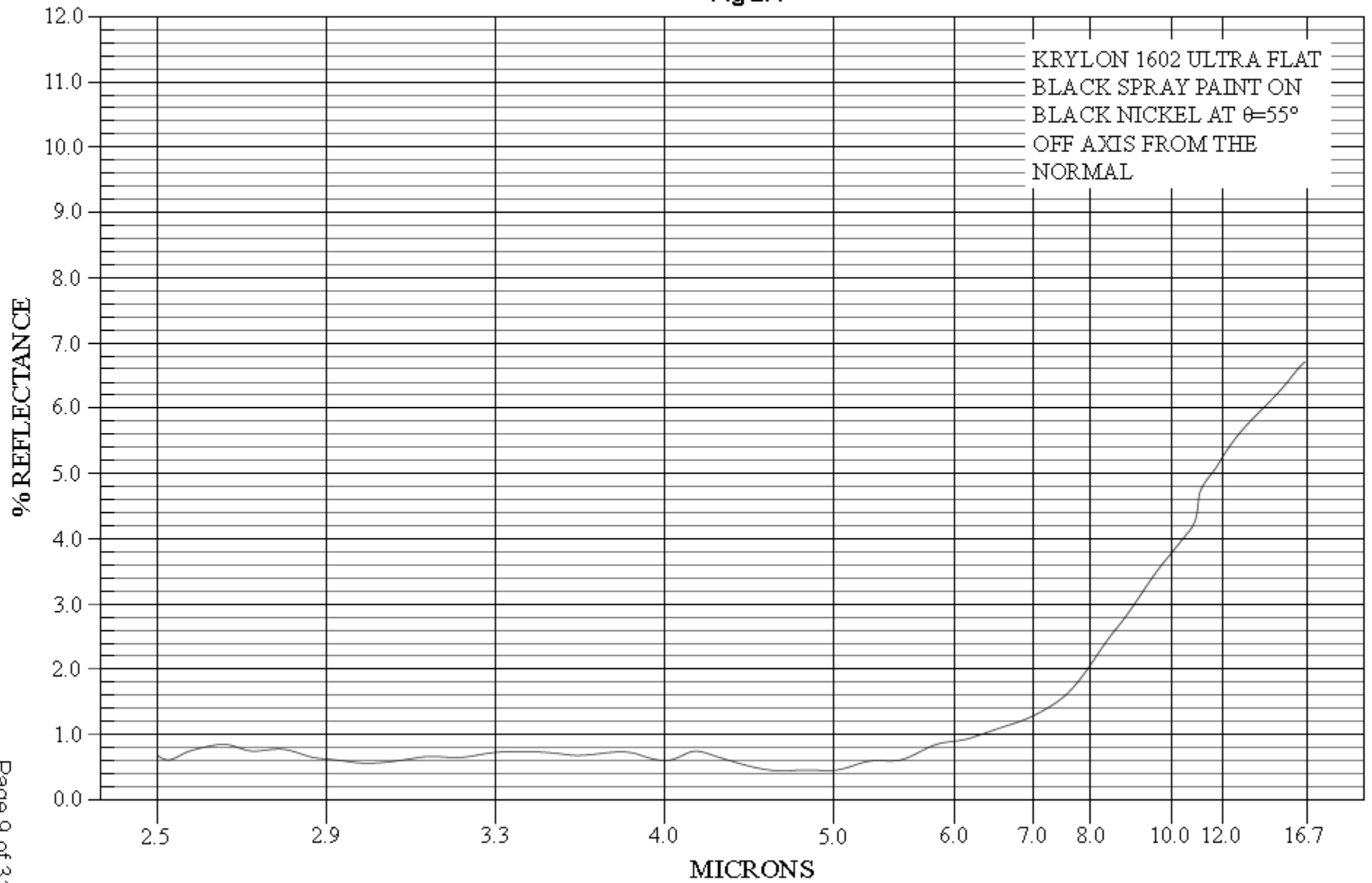


Fig 2.5

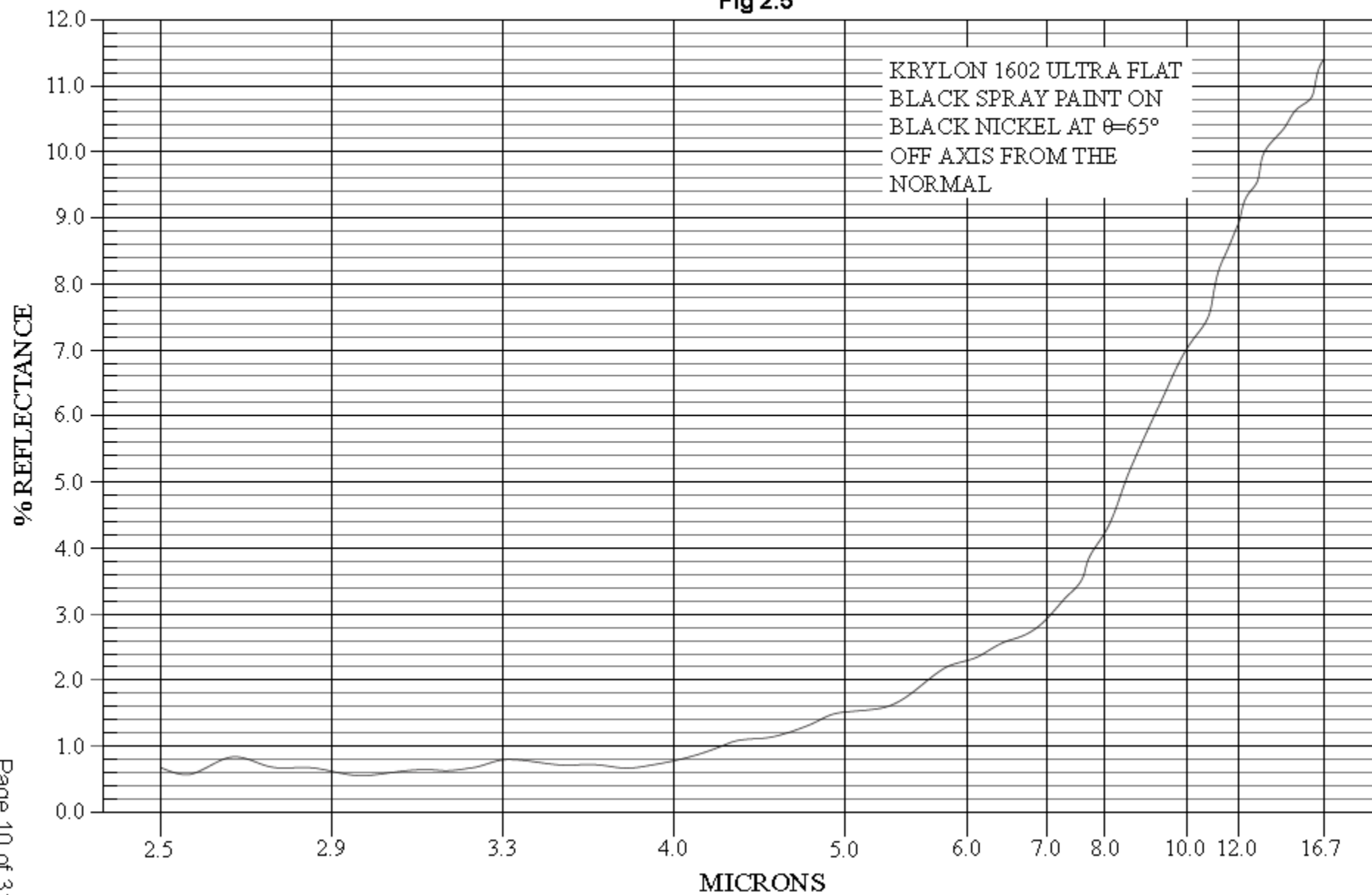


Fig 3.1

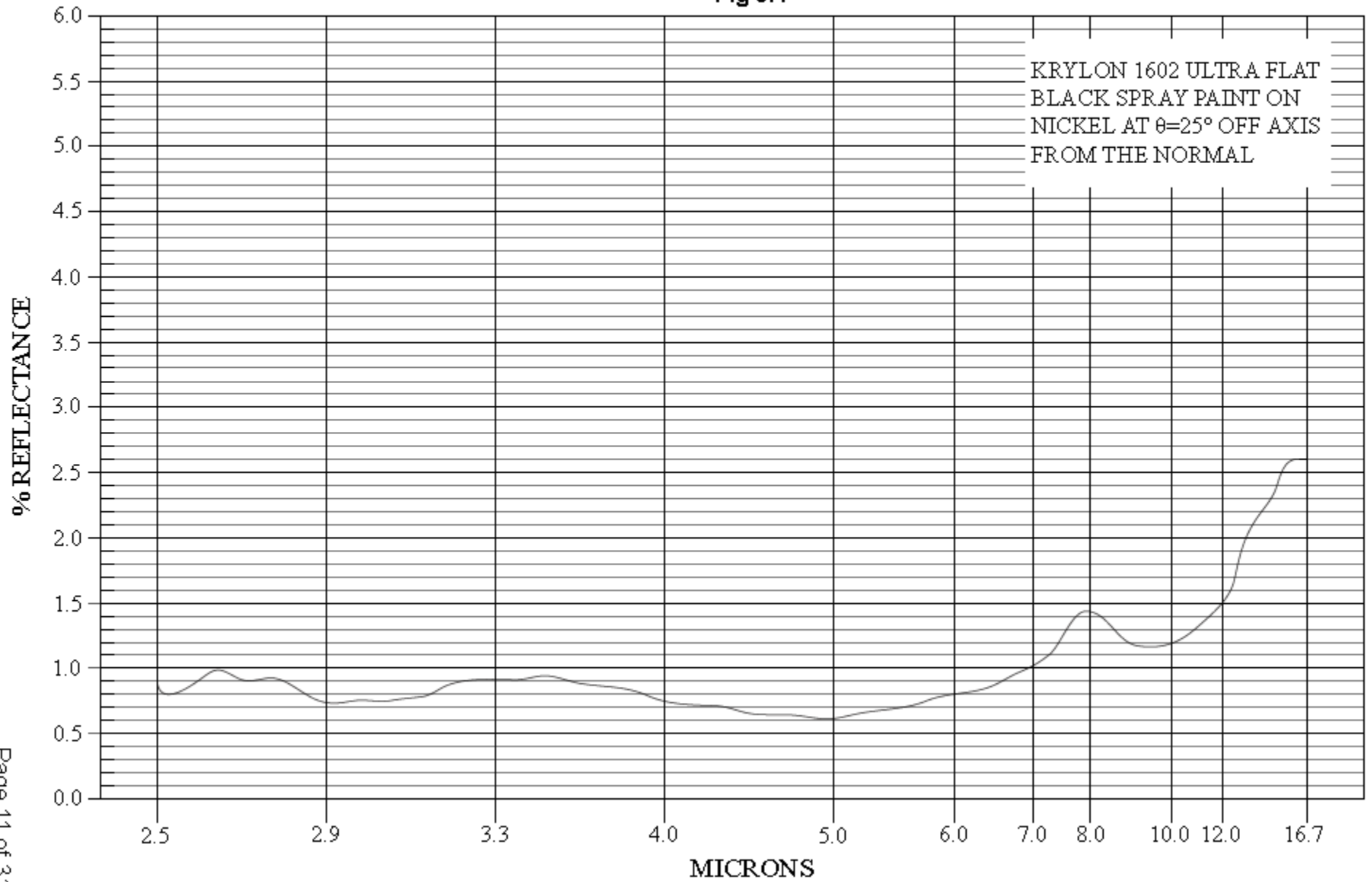


Fig 3.2

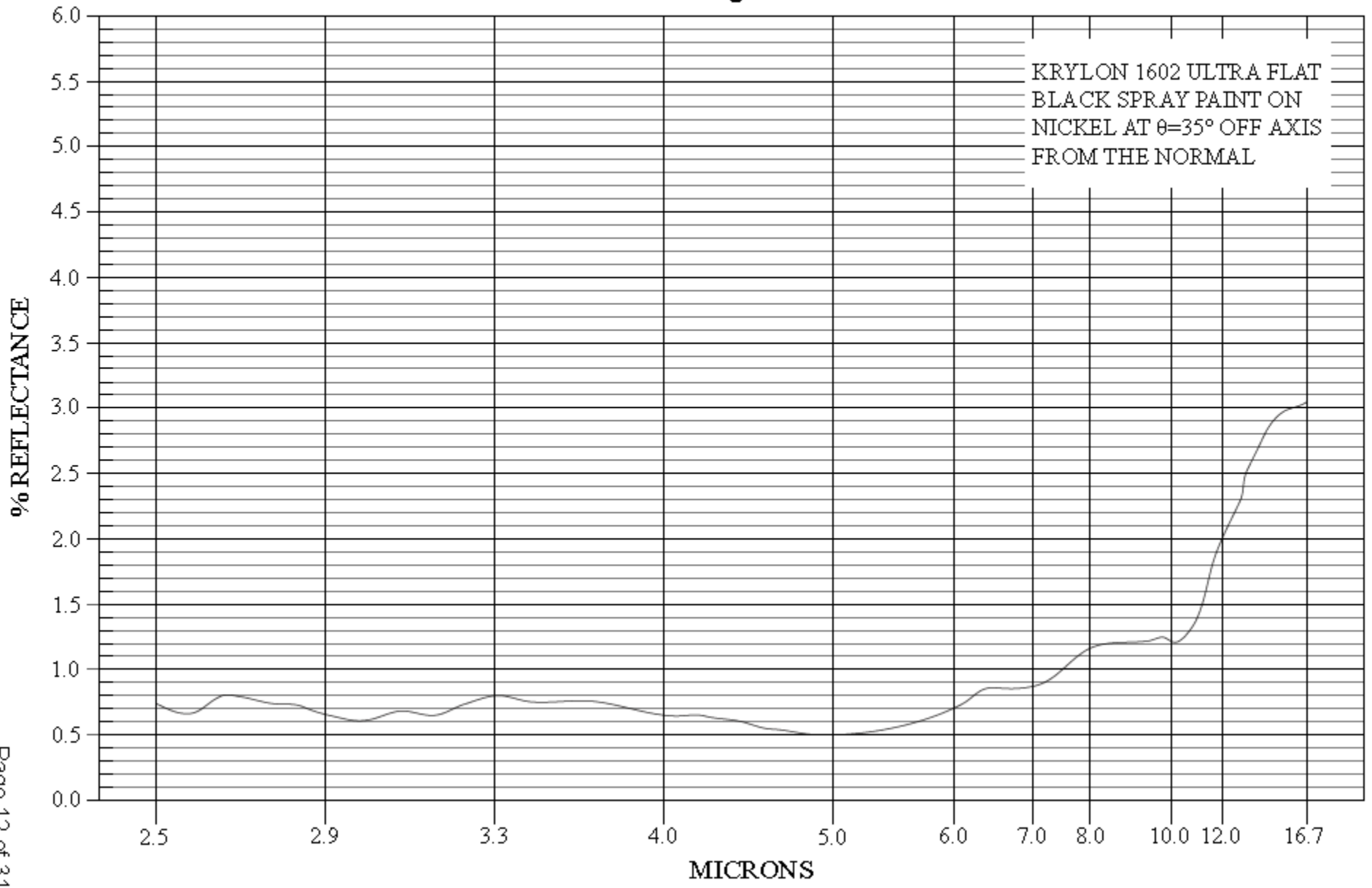


Fig 3.3

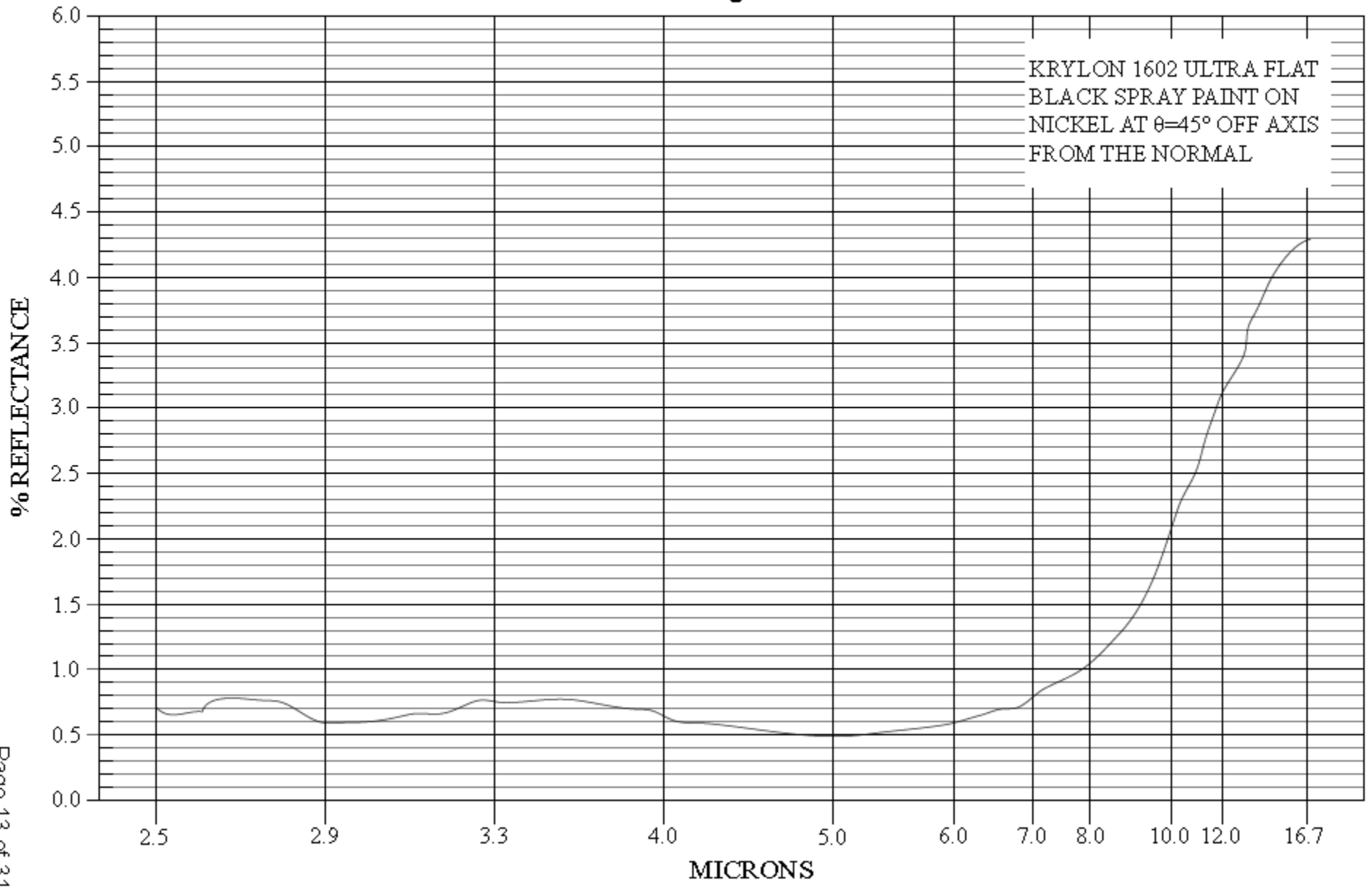


Fig 3.4

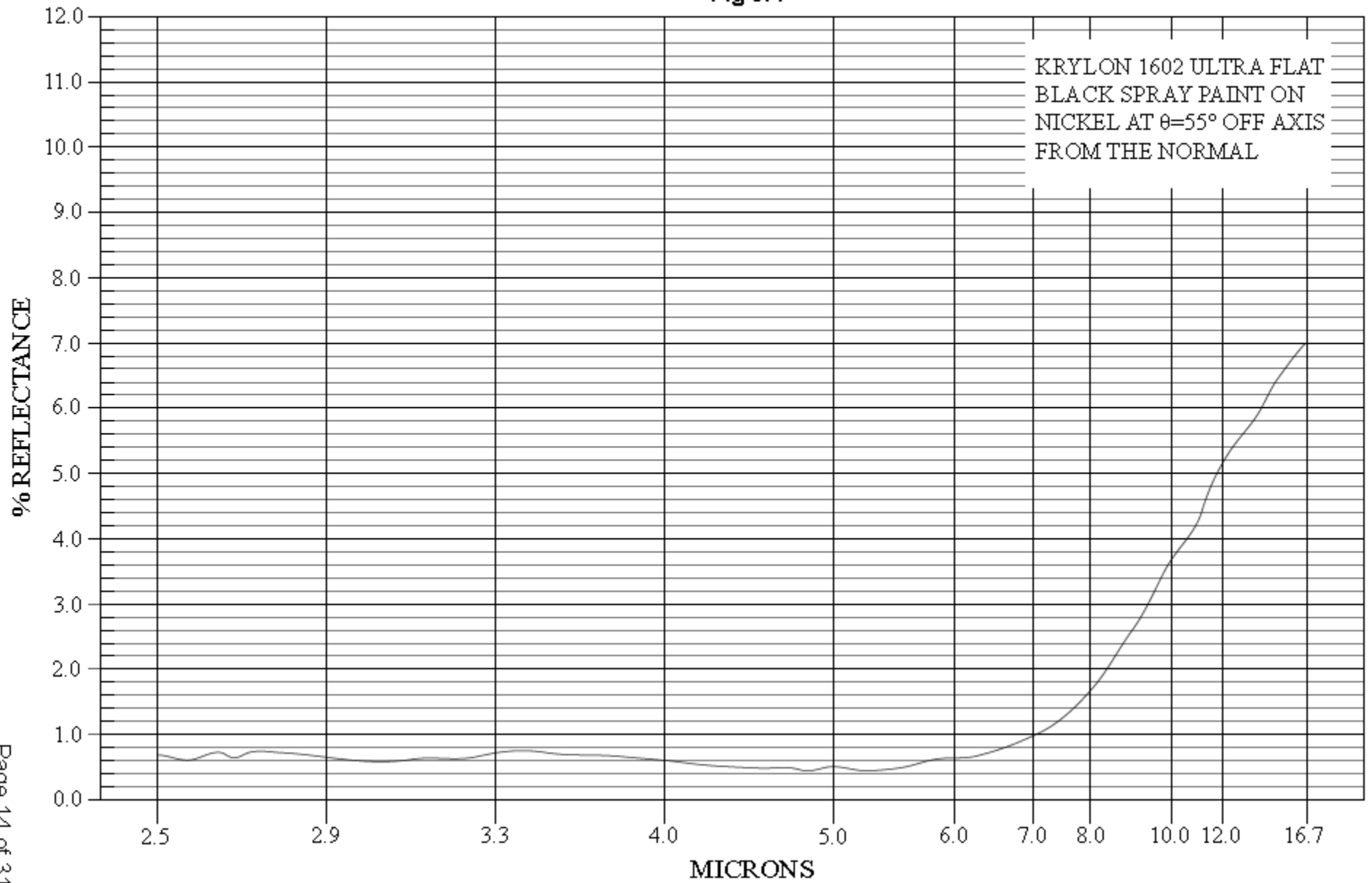


Fig 3.5

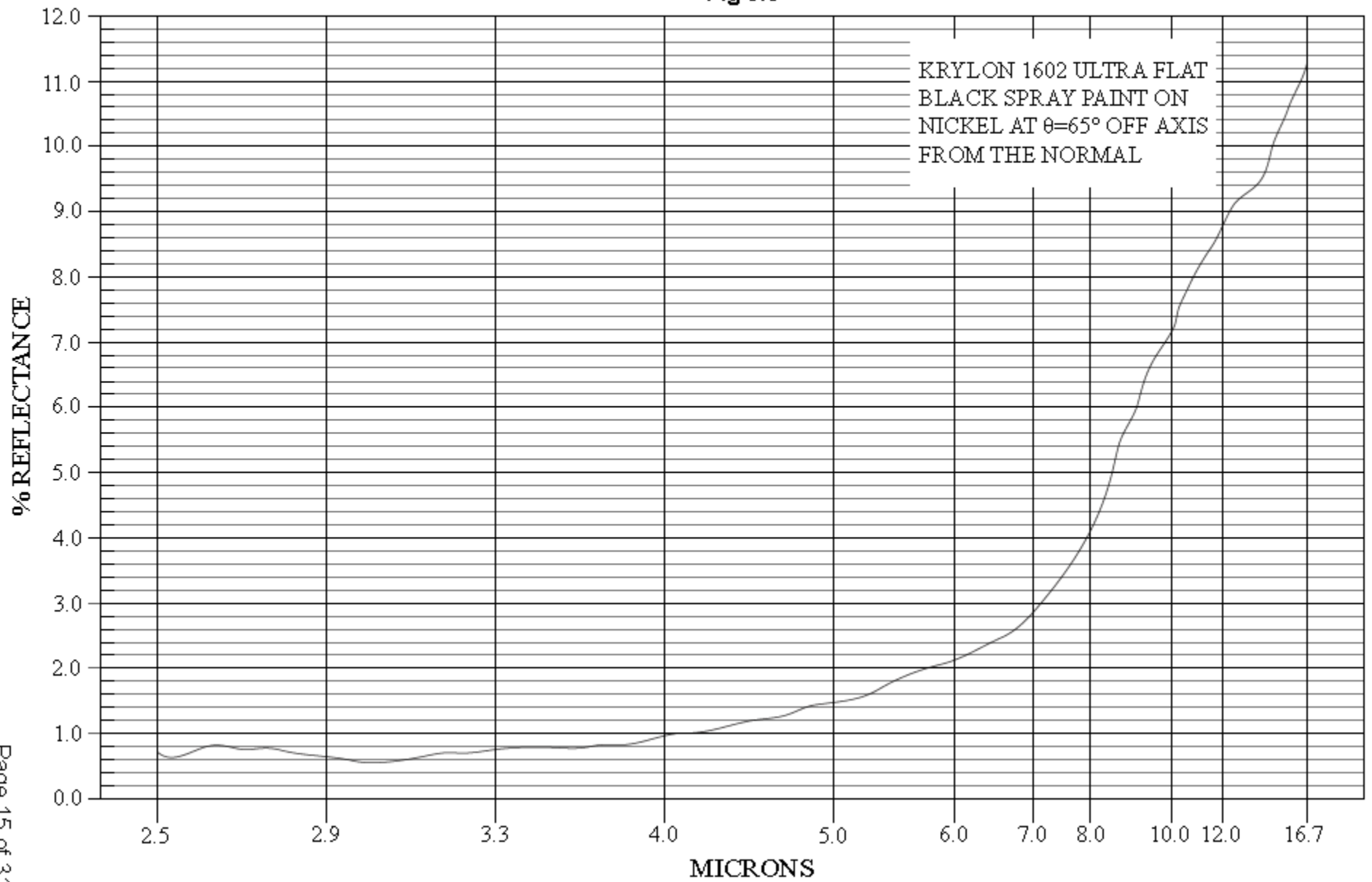


Fig 4.1

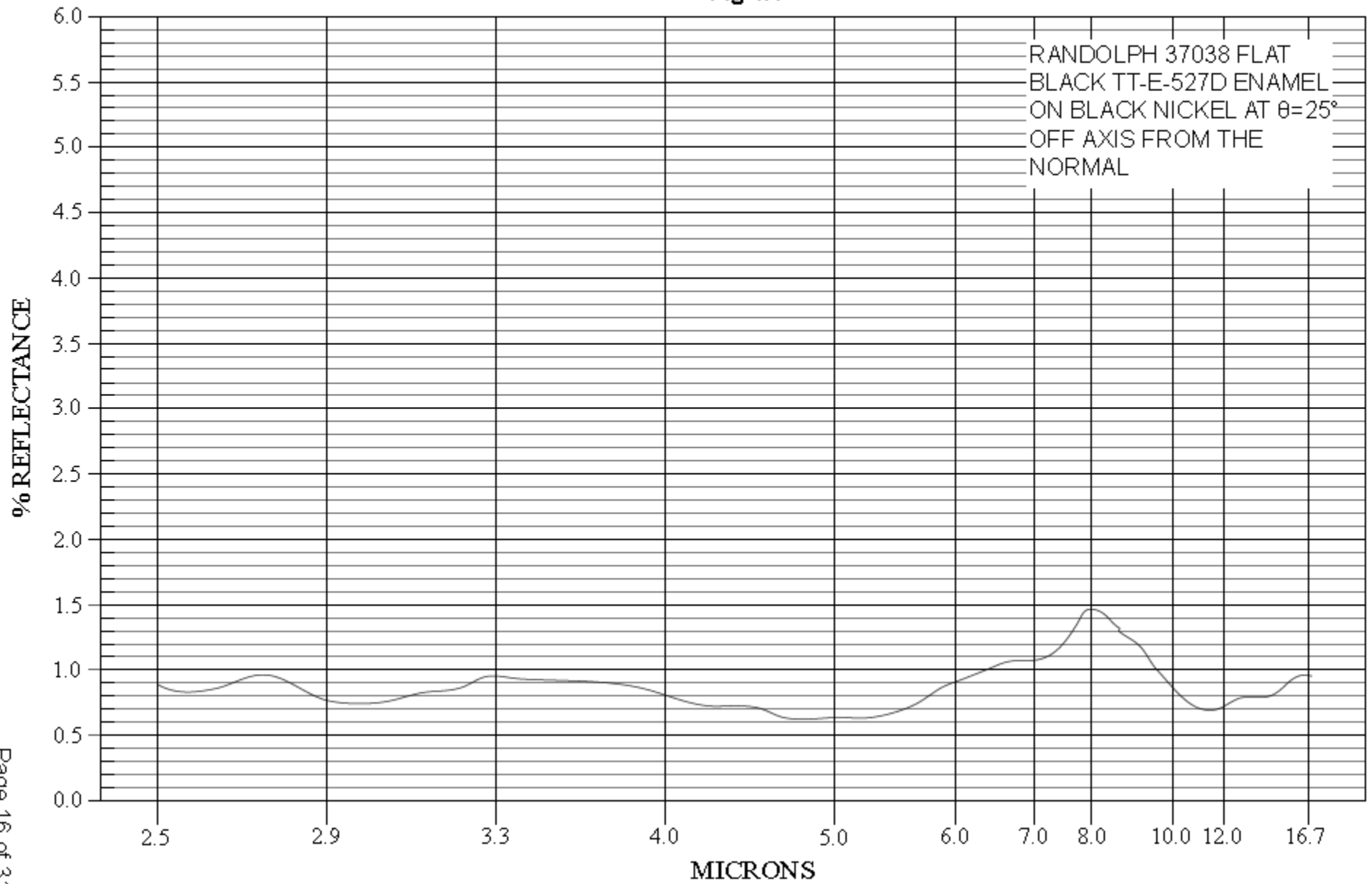


Fig 4.2

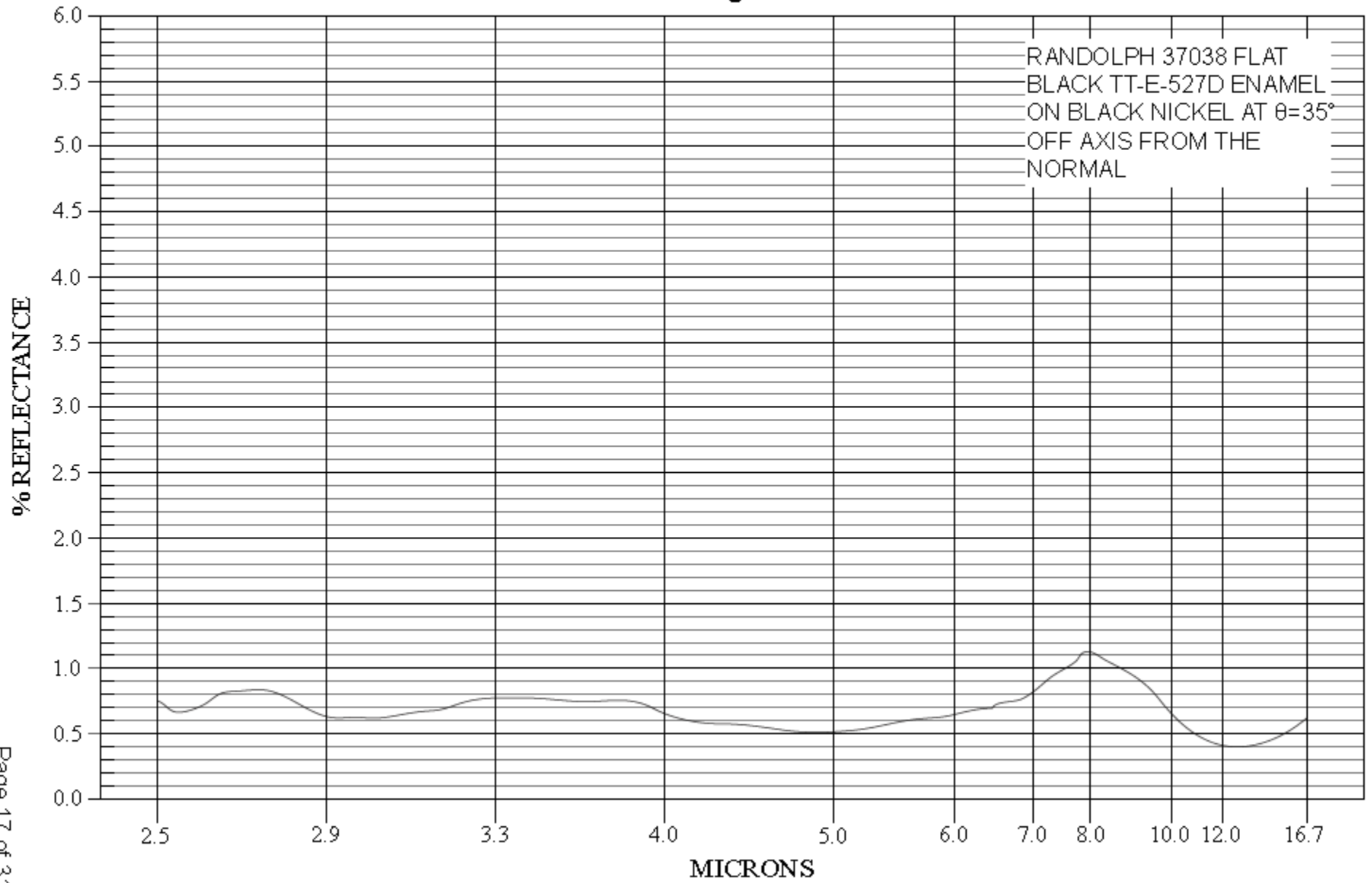


Fig 4.3

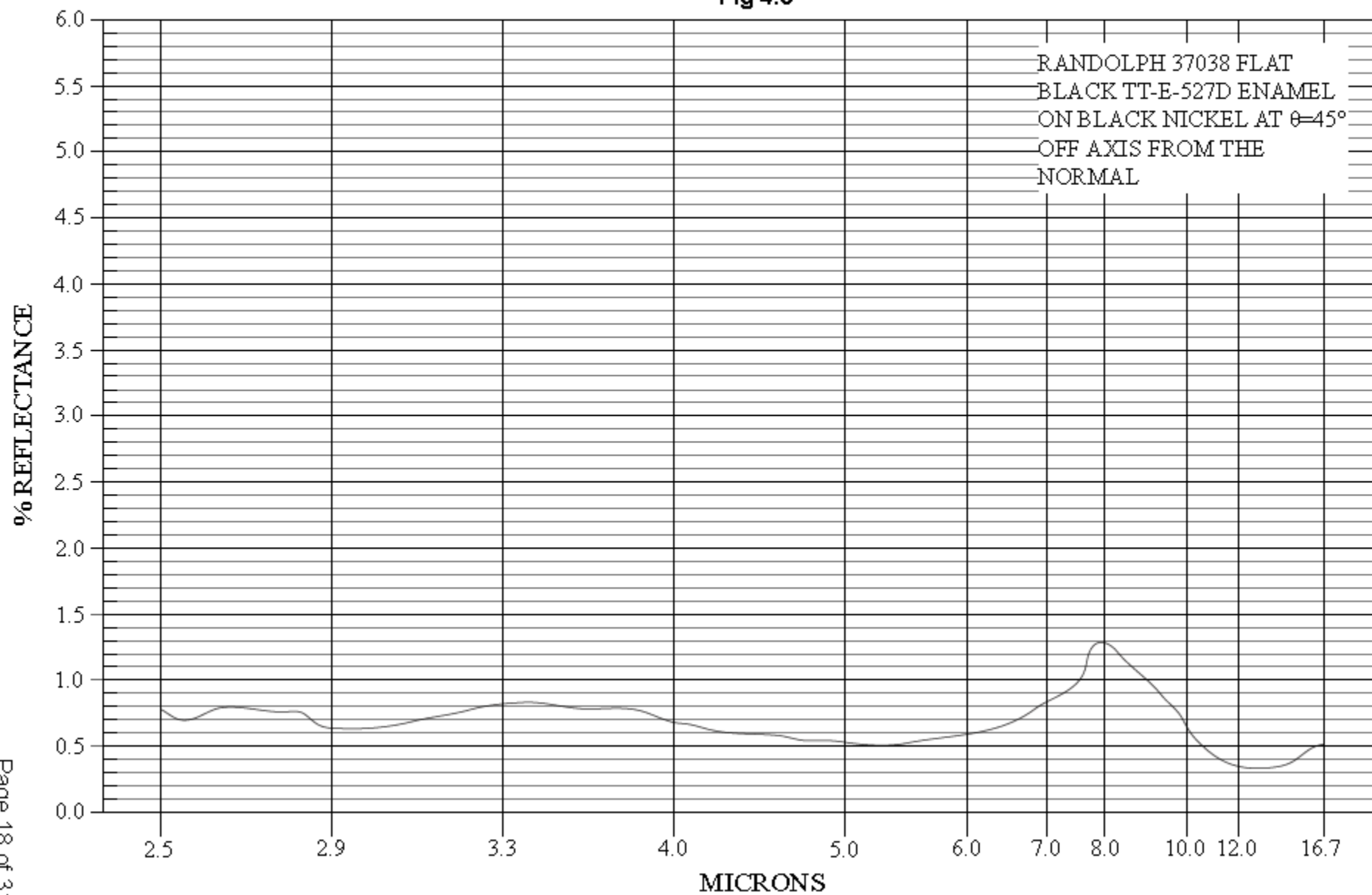


Fig 4.4

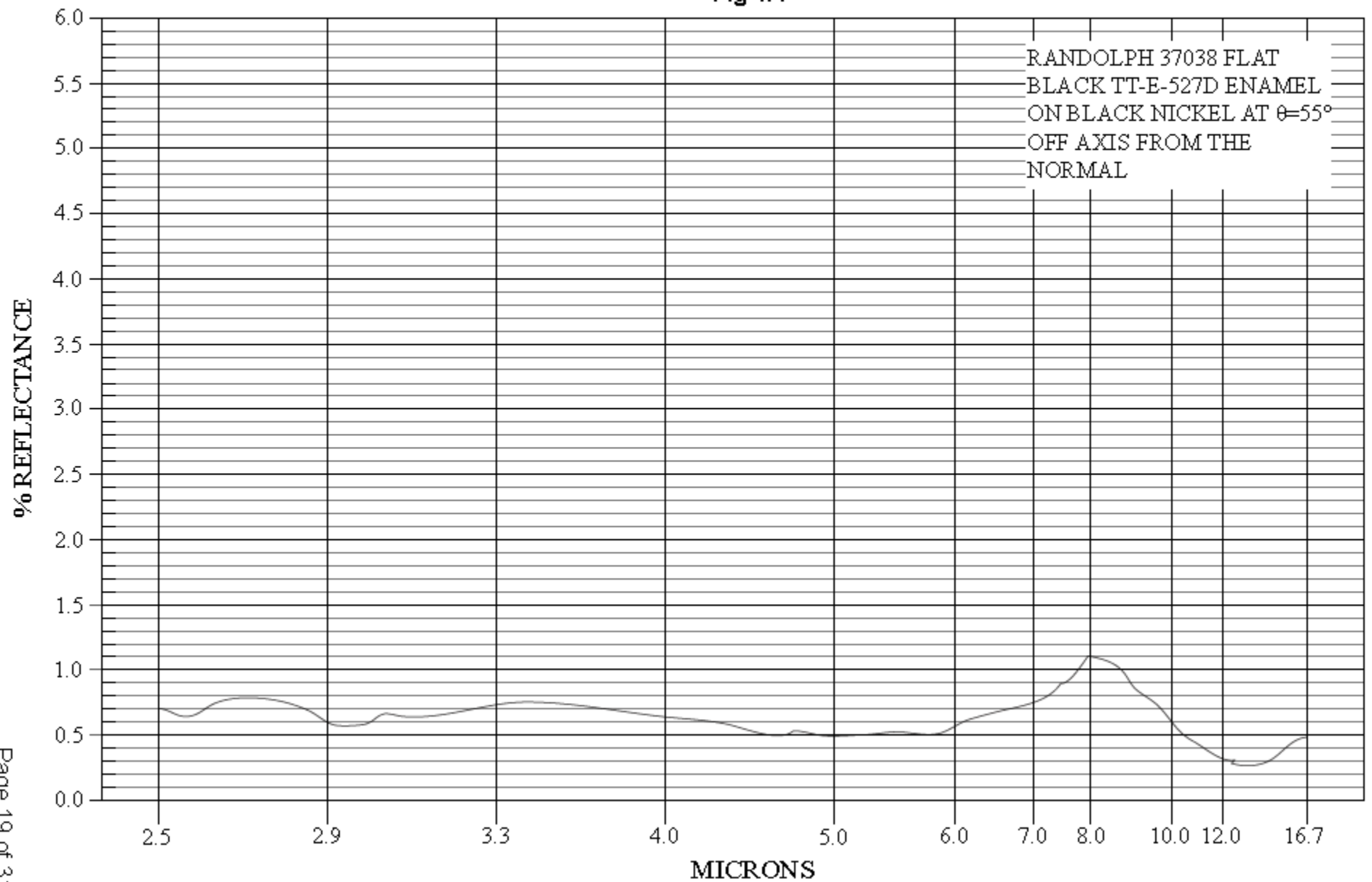


Fig 4.5

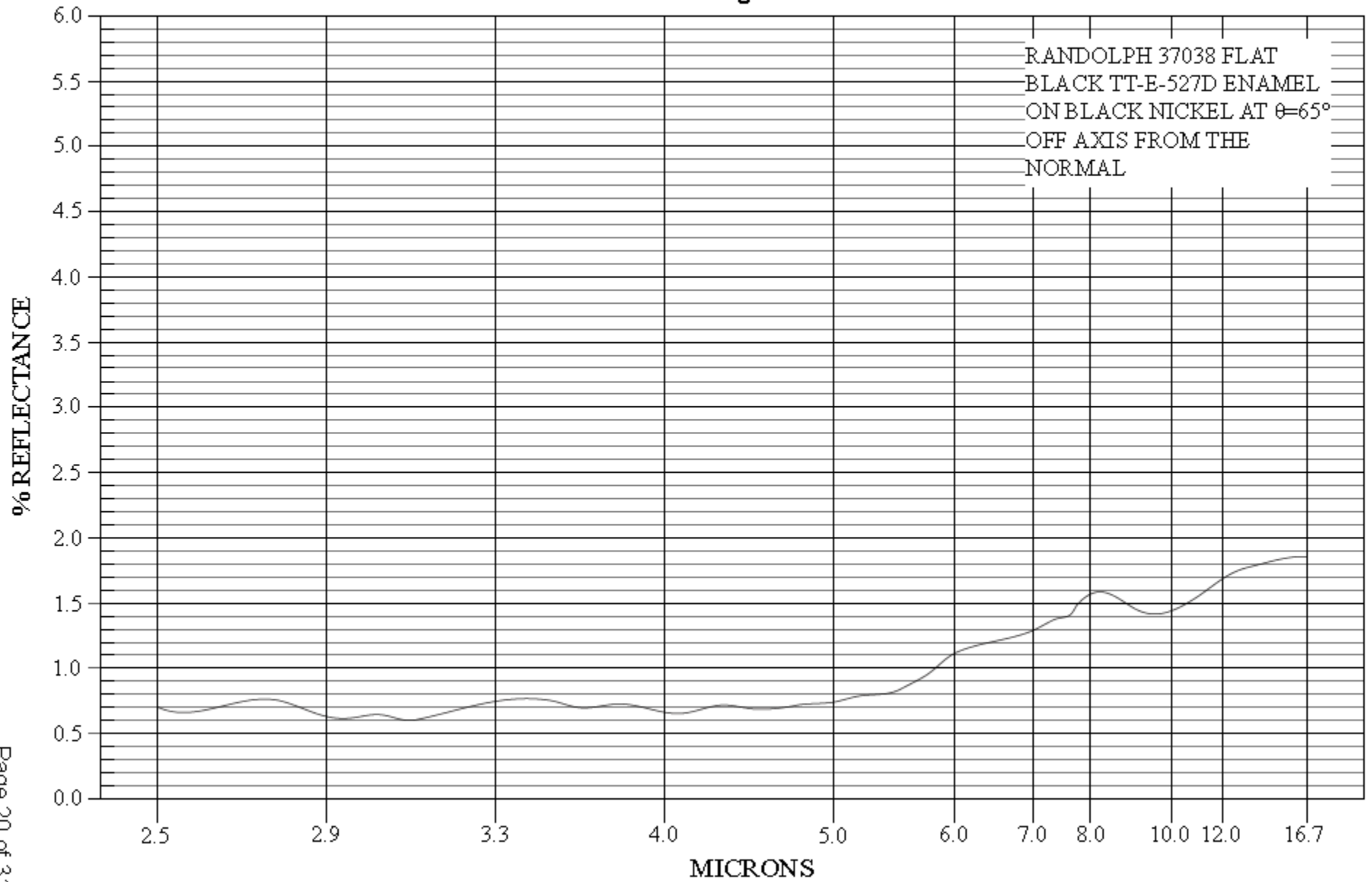


Fig 5.1

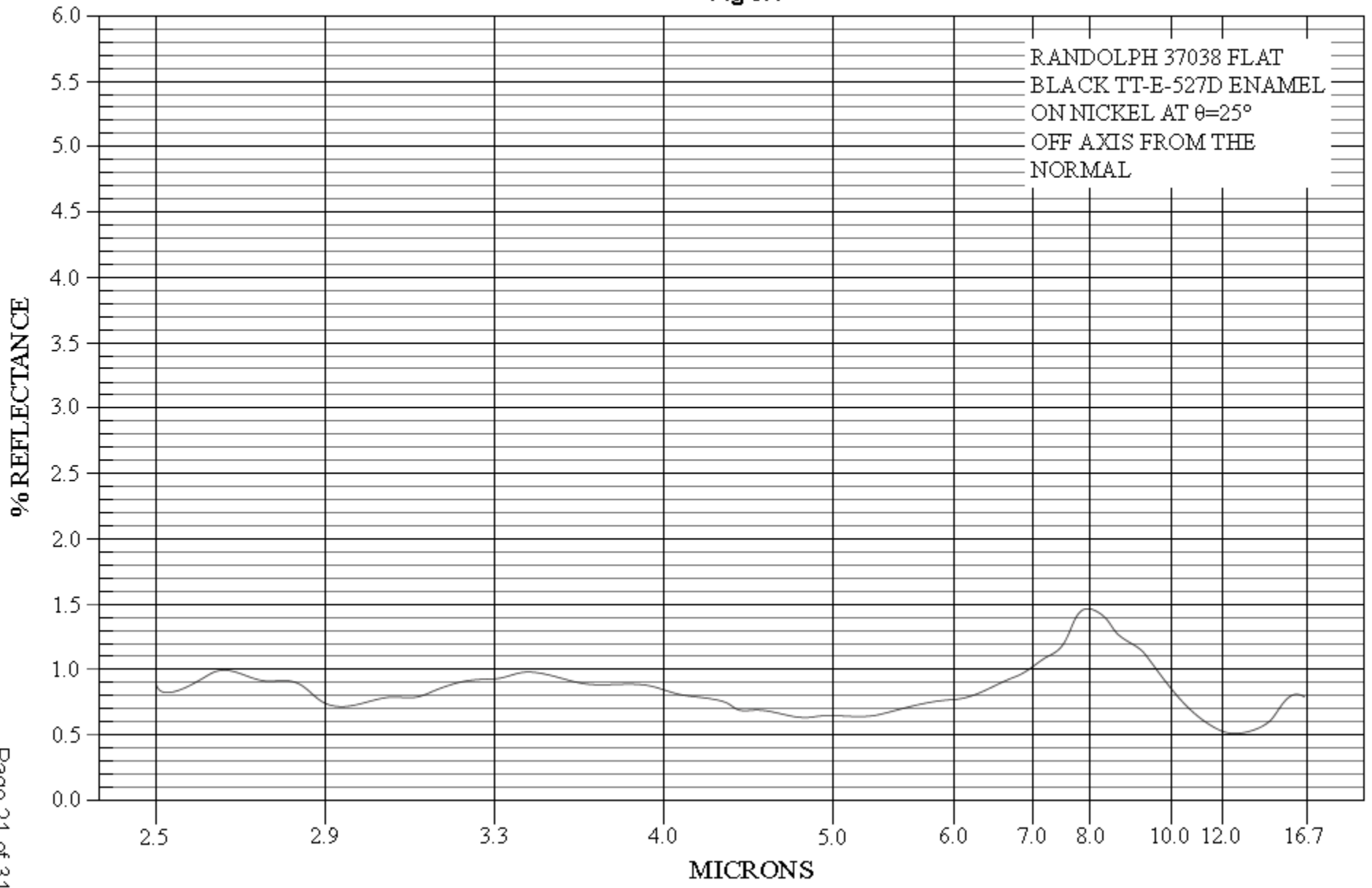


Fig 5.2

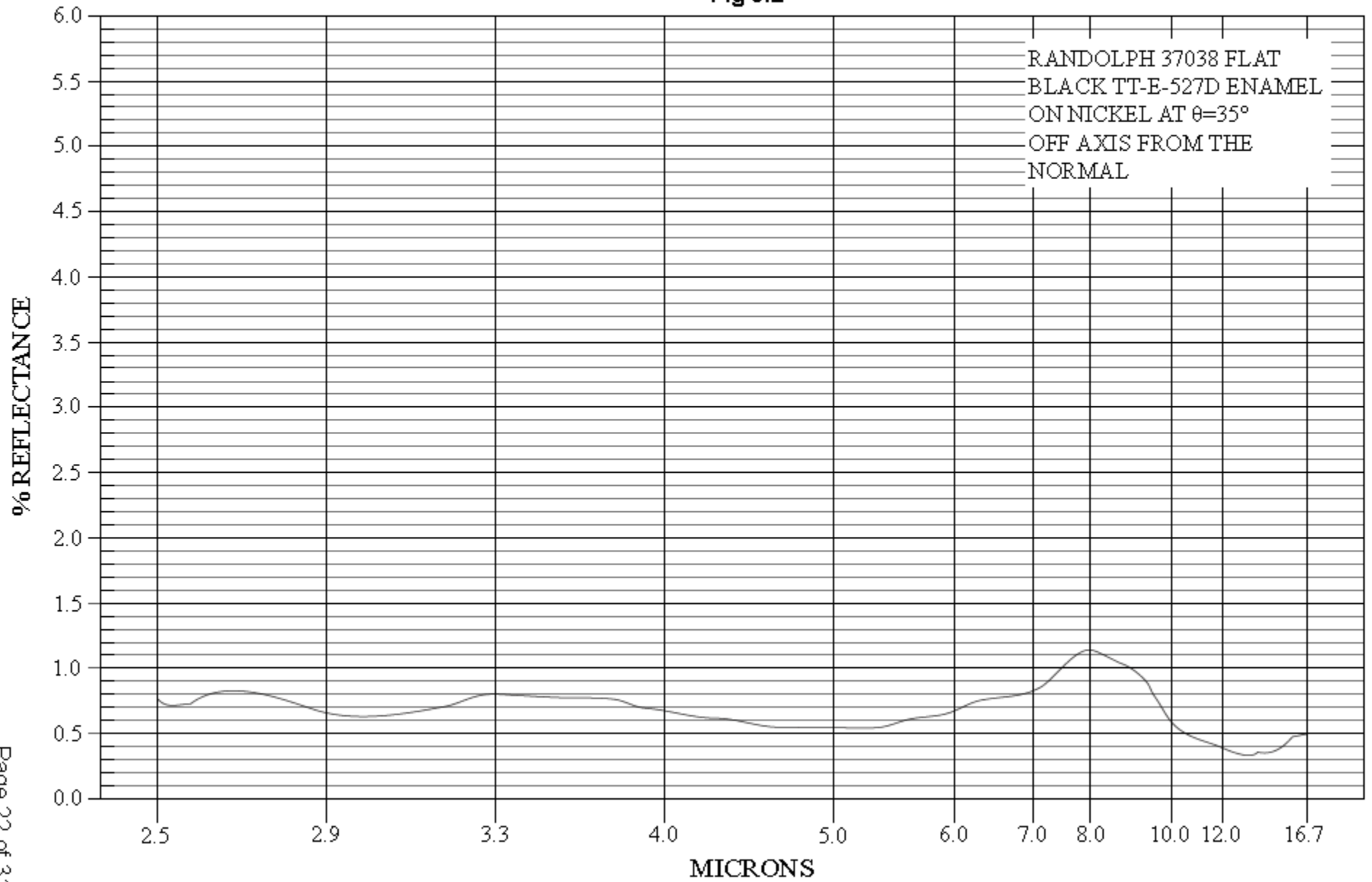


Fig 5.3

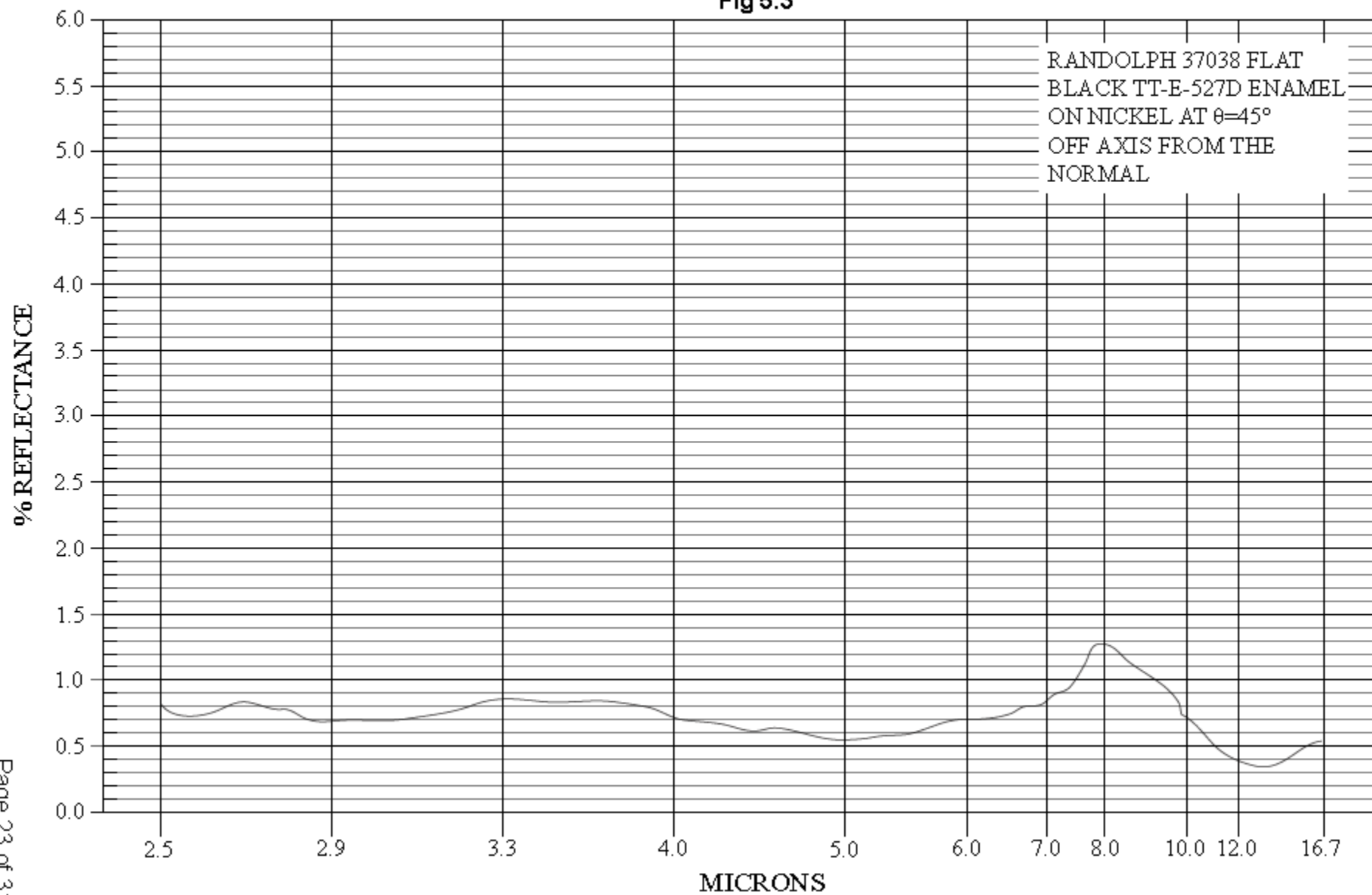


Fig 5.4

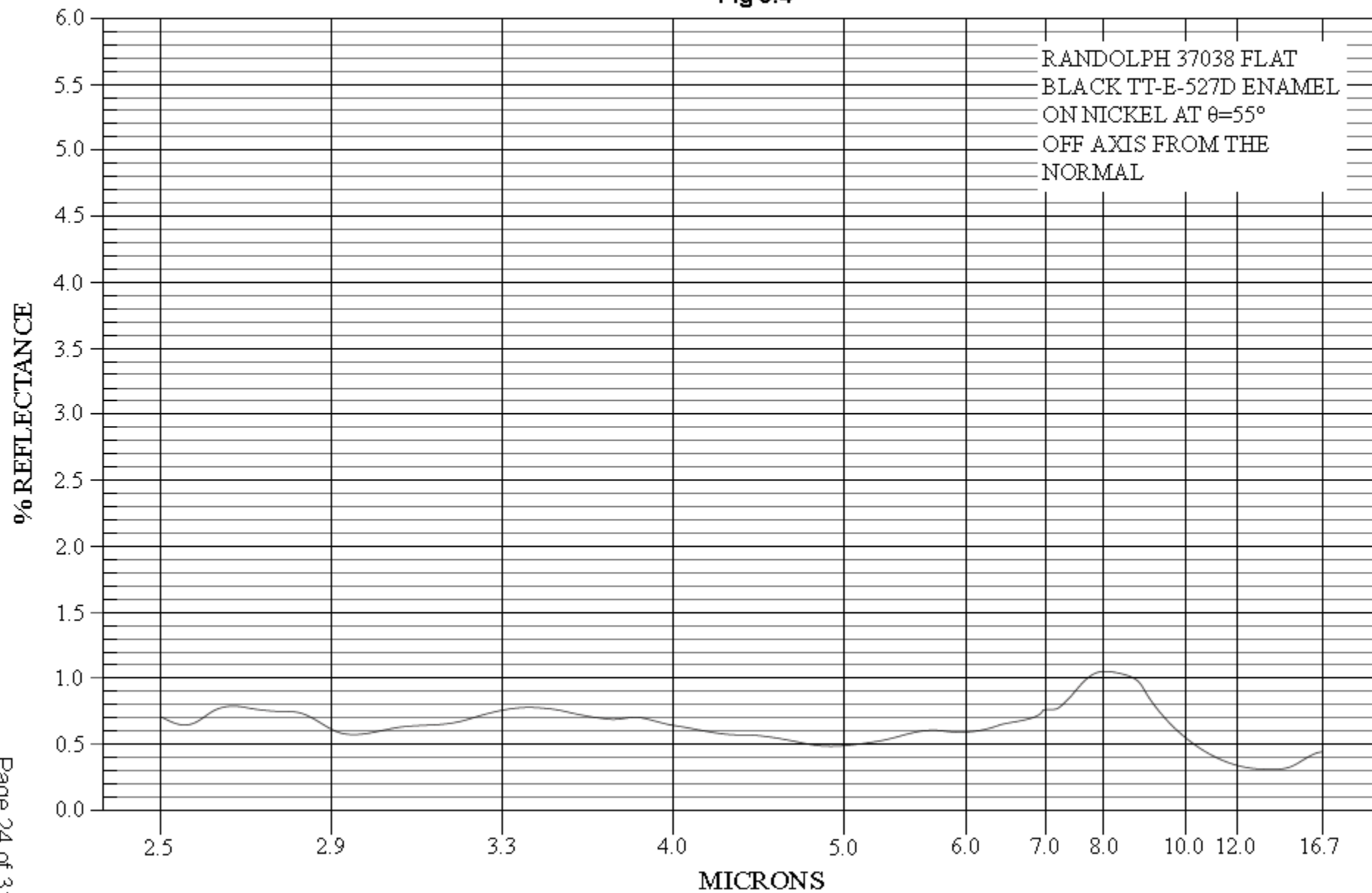


Fig 5.5

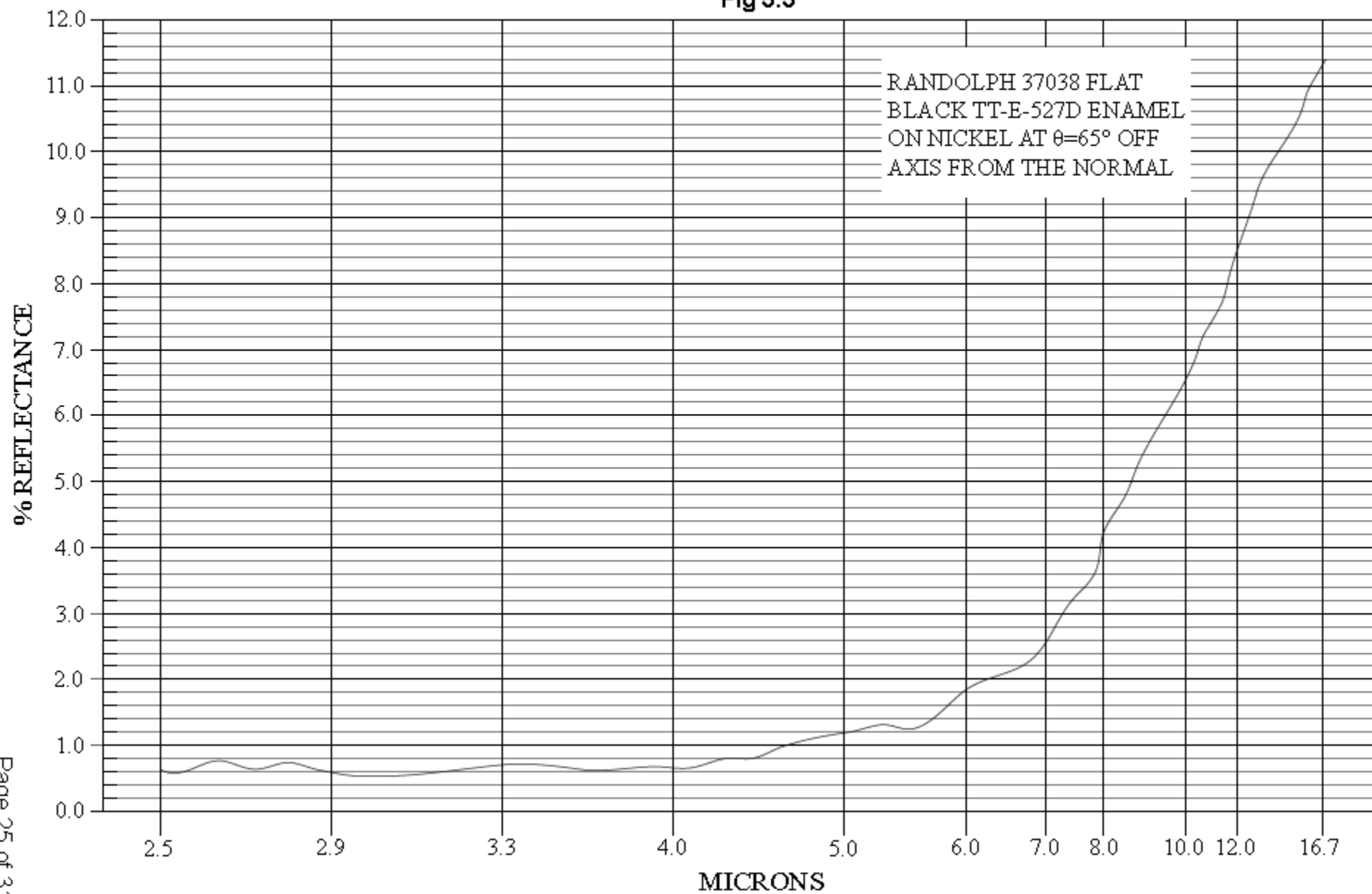


Fig 6.1

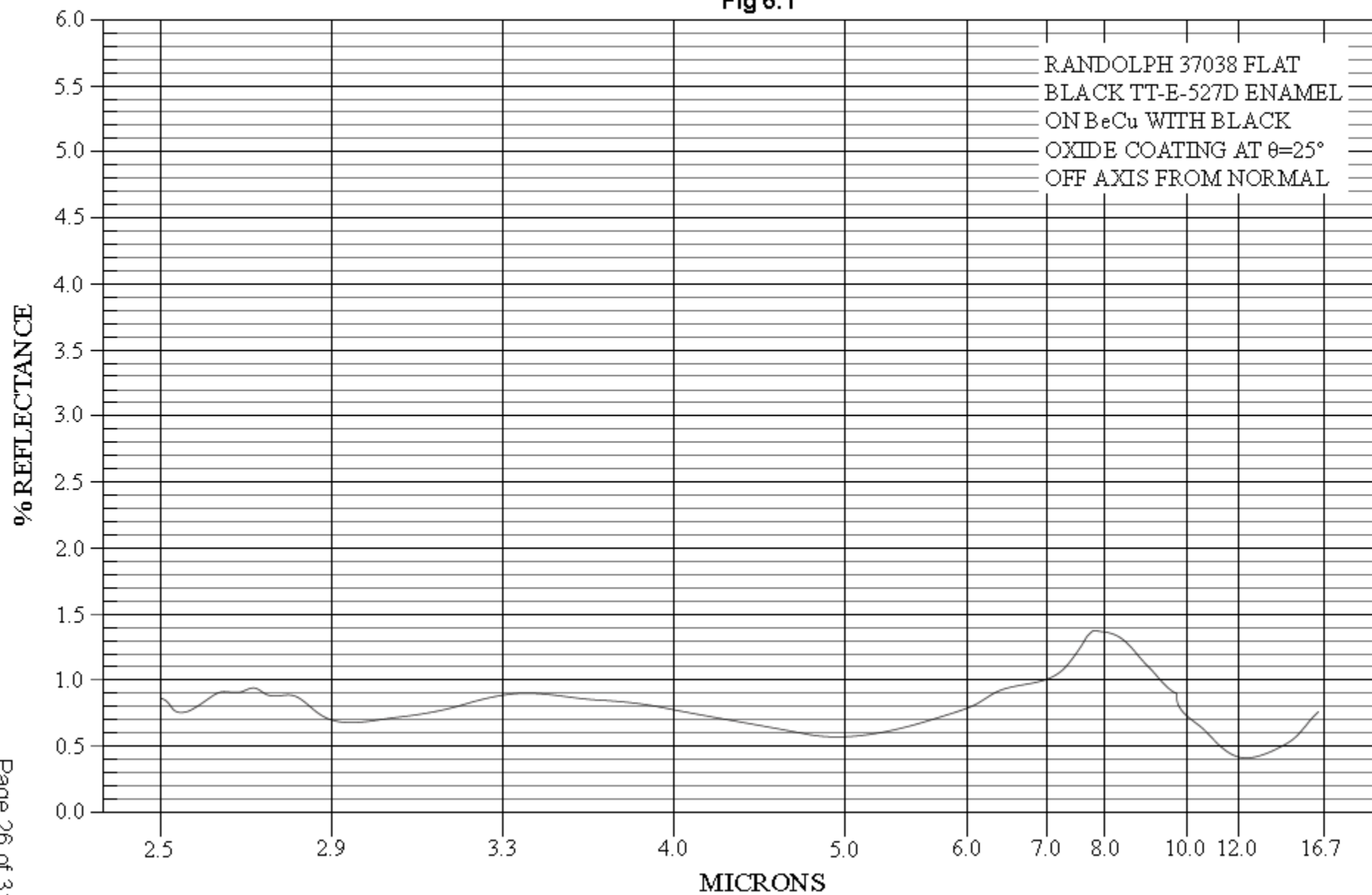


Fig 6.2

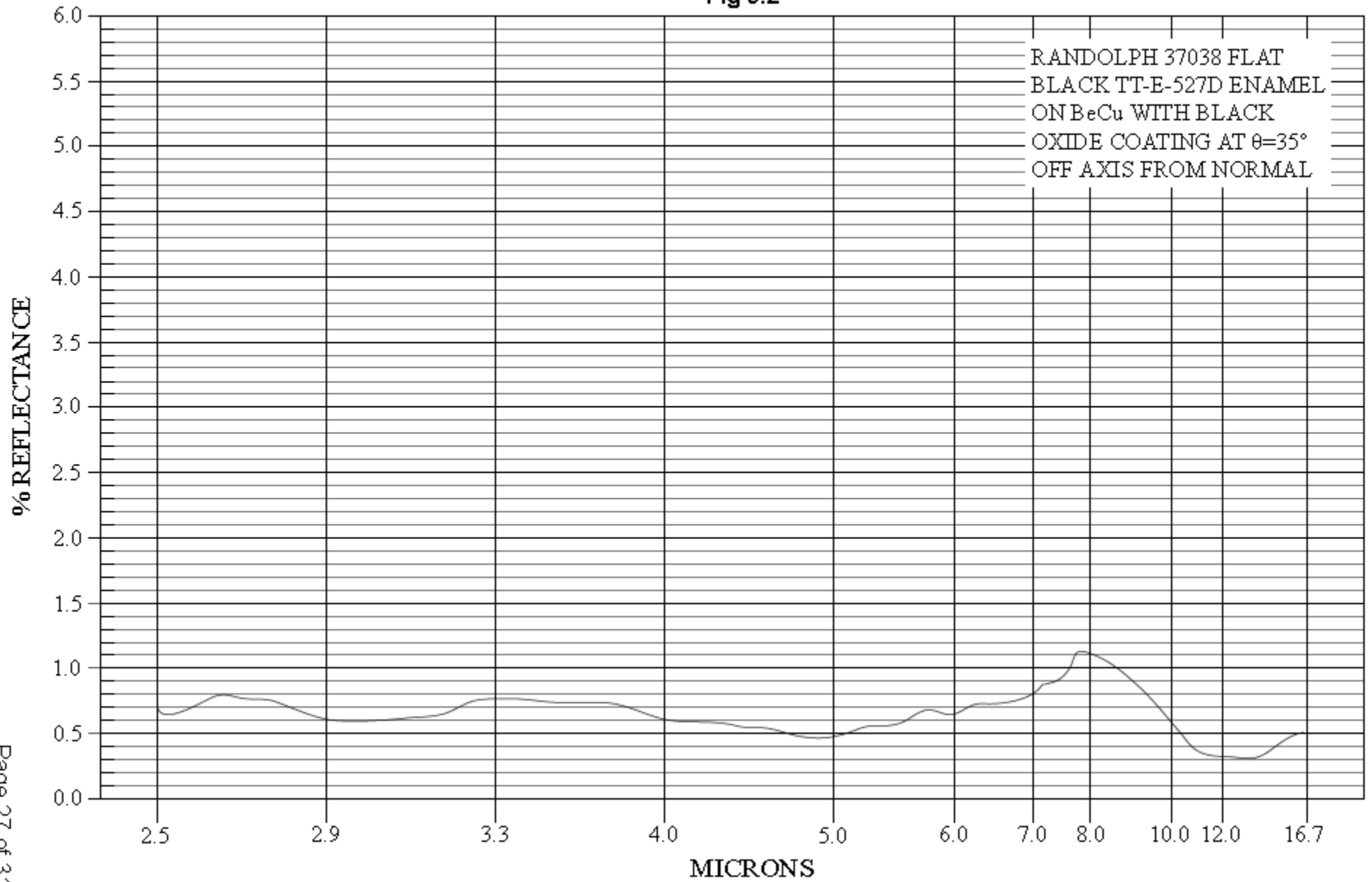
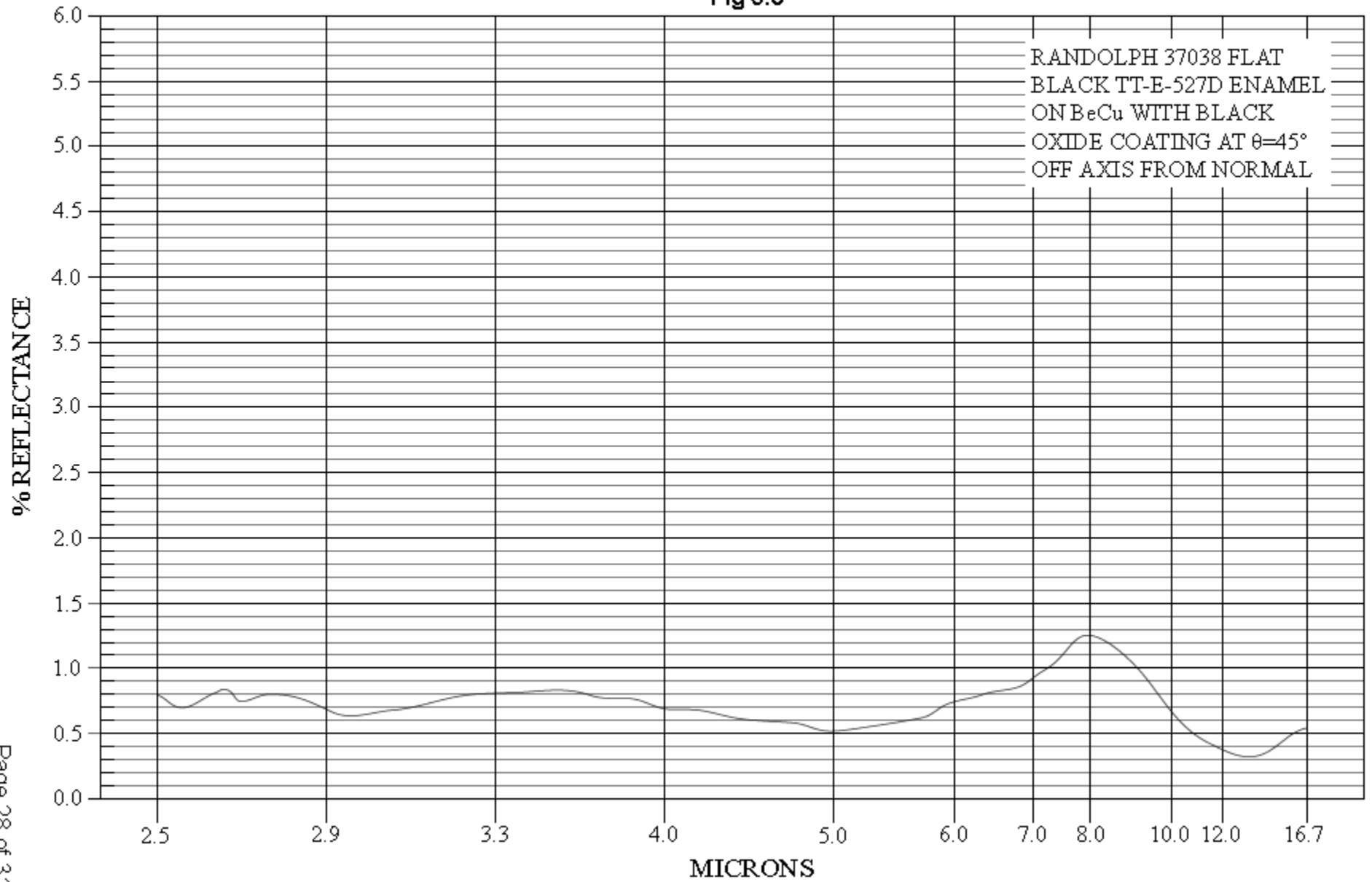
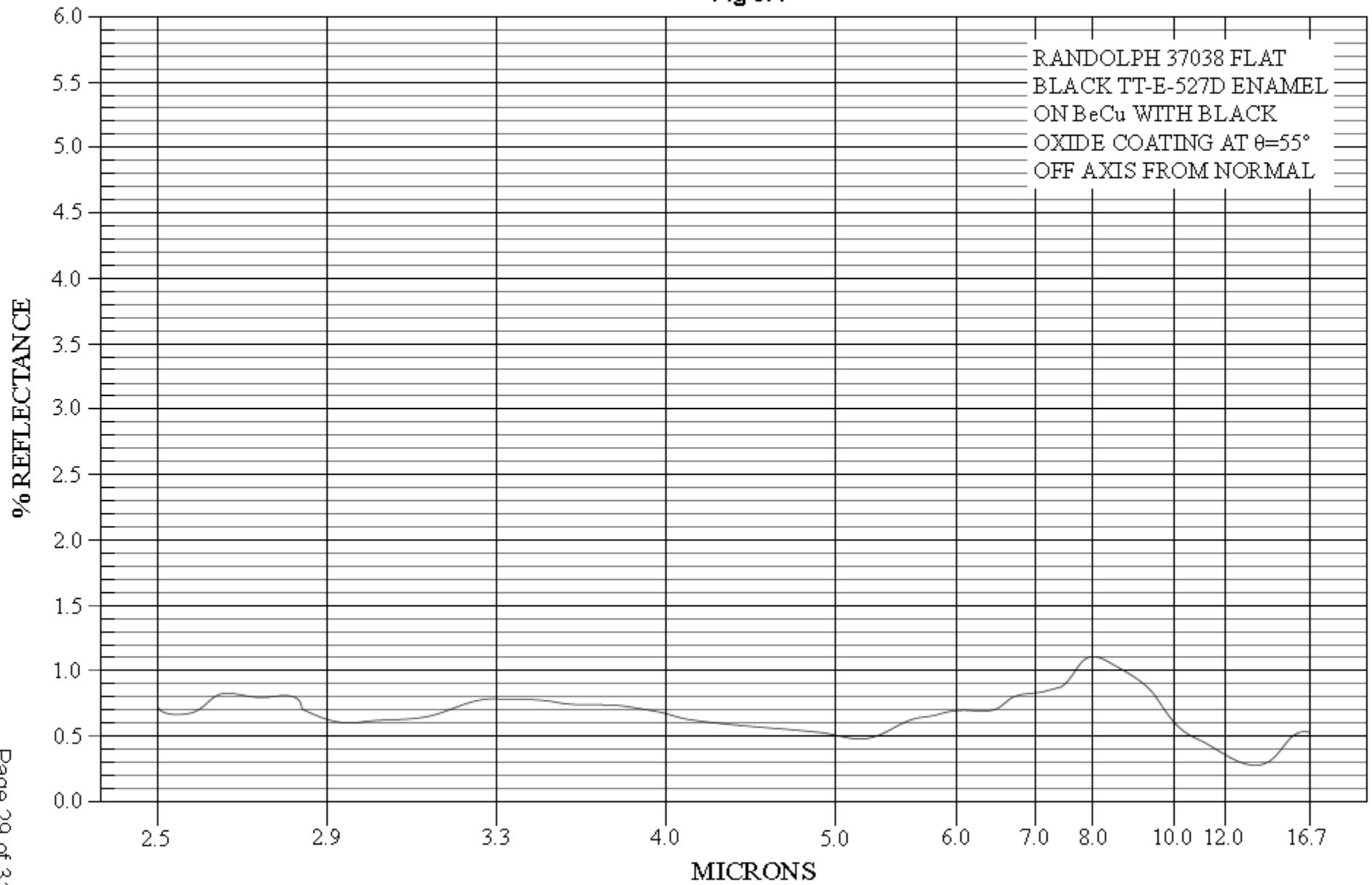


Fig 6.3



RANDOLPH 37038 FLAT
BLACK TT-E-527D ENAMEL
ON BeCu WITH BLACK
OXIDE COATING AT $\theta=45^\circ$
OFF AXIS FROM NORMAL

Fig 6.4



RANDOLPH 37038 FLAT
BLACK TT-E-527D ENAMEL
ON BeCu WITH BLACK
OXIDE COATING AT $\theta=55^\circ$
OFF AXIS FROM NORMAL

Fig 6.5

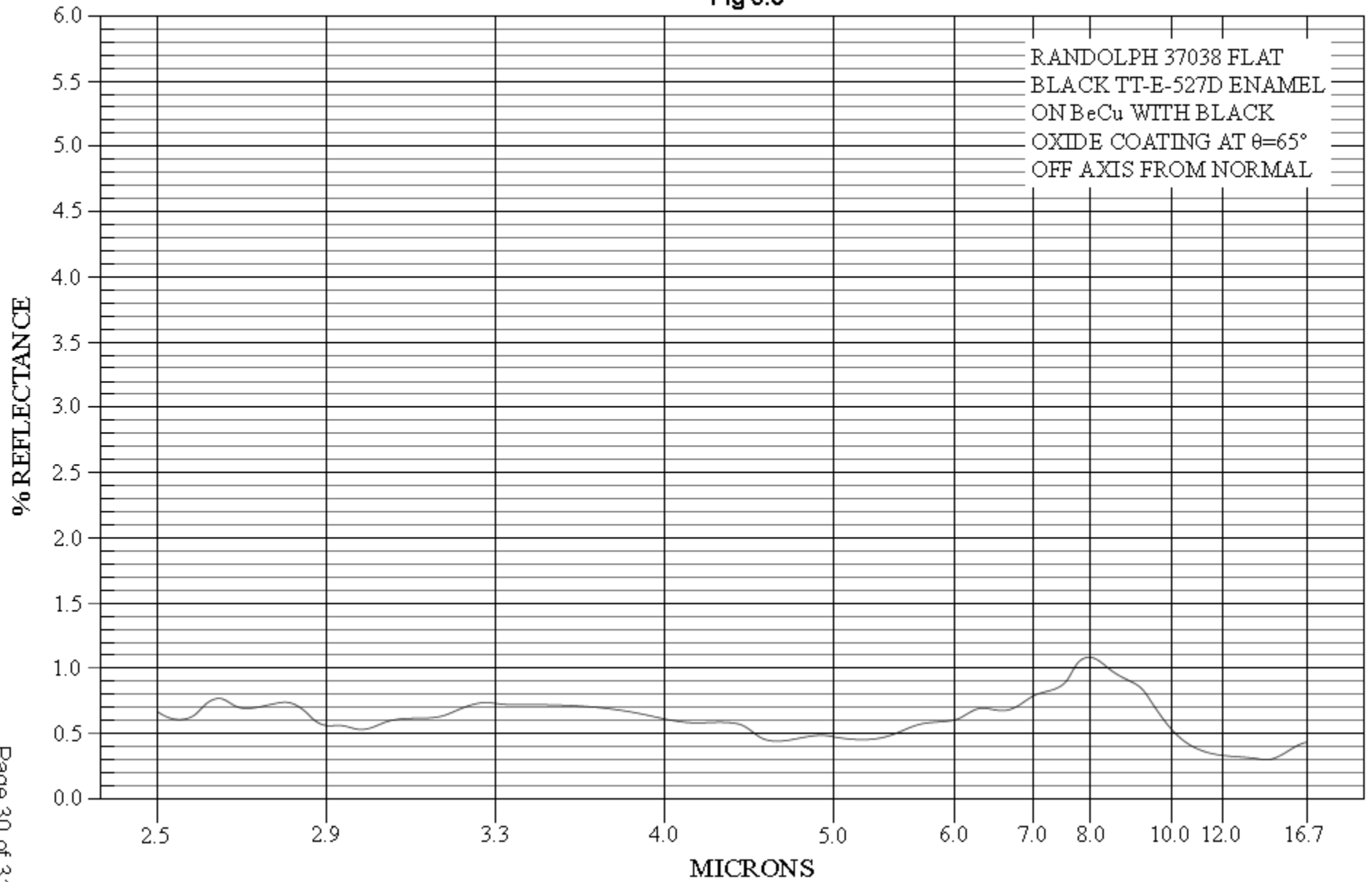


Fig #	paint coating	substrate	θ	% Reflectance	
				min	max
2.1	Krylon 1602	black nickel	25	0.6	2.4
2.2			35	0.6	3.7
2.3			45	0.5	4.5
2.4			55	0.4	6.8
2.5			65	0.6	11.4
3.1		nickel	25	0.6	2.6
3.2			35	0.5	3.0
3.3			45	0.5	4.3
3.4			55	0.4	7.0
3.5			65	0.6	11.2
4.1	Randolph TT-E-527D	black nickel	25	0.6	1.5
4.2			35	0.4	1.1
4.3			45	0.3	1.3
4.4			55	0.3	1.1
4.5			65	0.6	1.9
5.1		nickel	25	0.5	1.5
5.2			35	0.3	1.1
5.3			45	0.3	1.3
5.4			55	0.3	1.0
5.5			65	0.3	11.4
6.1		black oxide BeCu	25	0.4	1.4
6.2			35	0.3	1.1
6.3			45	0.3	1.3
6.4			55	0.3	1.1
6.5			65	0.3	1.1

Fig. 6
min-max comparison