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To: G. D. Mc Ghee

26 July 1968

Subject: Optical Surface Quality Specification

From: L. E. Watson

A meeting was held with Dr. A. Meinel, University of Arizona (Aerospace and Air Force Consultant) to review more a meaningful way to specify the quality of optical surfaces to be manufactured. From these discussions it was agreed that, ideally, three of at least five observable variables should be specified and controlled. These would be:

(1) the rms surface elevation error

(2) the autocorrelation function

(3) the rms slope error.

A minimum specification should include at least (1) and (2). At present, we only specify the rms surface elevation error. It is recommended that we change the EK Statement of Work to specify (1), (2) and (3). If overriding contractual problems are incurred, then at least (1) and (2) should be the minimum requirement. Otherwise, the optical performance range encountered by specifying only the rms surface error allows a wide variation in the optical performance to be expected. The following was summarized by Dr. Meinel.

There are five observable quantities that can be obtained from the current test procedures.

(1) RMS surface error

(2) Autocorrelation function

(3) RMS slope error

(4) Peak-to-peak wavefront error

(5) Maximum slope error

Various levels of specification have been used. These are listed in chronological order.

(1) Maximum slope (used originally by astronomers)

(2) Peak-to-peak wavefront error (with an assumed

relationship to rms wavefront error)

(3) RMS wavefront error (with an assumed OQF dependent solely on the rms value).

In terms of the MTF (OTF) the above single quantities do not fully describe the operational performance of a system. Several new levels of specification can be devised to give a better description of system performance in terms of the test observables. They are, in order of increasing complication:

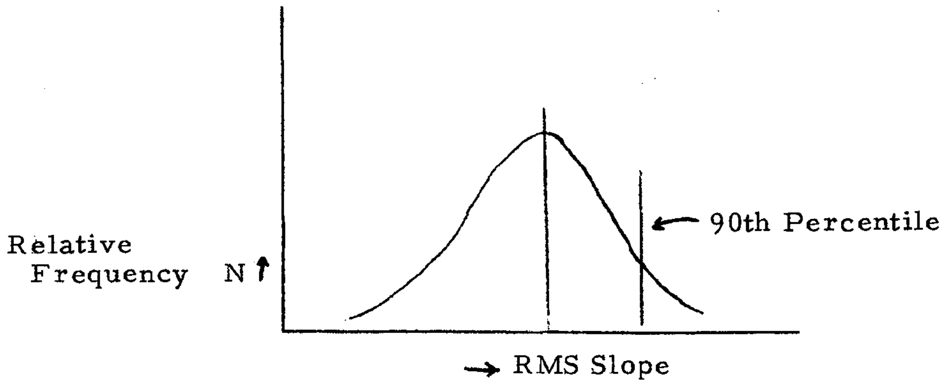
(1) RMS Wavefront Error and Autocorrelation Function

For example, under the specification of rms only, the possibility of actual negative portions of the autocorrelation function means that at certain spatial frequencies the OQF can drop below the specification level as it is now defined. This new specification (1) only partially solves the current problem in that it does not place any limit on how rapidly the autocorrelation function ($\nu$) reaches zero. For best system performance one would like to have ($\nu$) both positive and drop to zero as slowly as possible within the current state of the art. If we admit this aim at specifications that maximize the information handling capability of the system then we need to add one more quantity to the specifications, as follows.

(2) RMS Wavefront Error, Autocorrelation Function and RMS Slope Error

The addition of rms slope error gives a measure of the relative steepness of the slopes associated with the figure errors that yield the rms wavefront error. At the present time the specification of rms wavefront error does not place any limit on the slope errors. The rms slope error, however, determines the rate at which the OQF trends from ~~the~~ unity down to the asymptotic value specified by the rms wavefront error. In the interest in maximizing the information handling capability of the system there is a real interest in also keeping the OQF high at the lower spatial frequencies. Hence, it would seem desirable to define a specification on the allowable rms slope error of an optical element or system of optical elements.

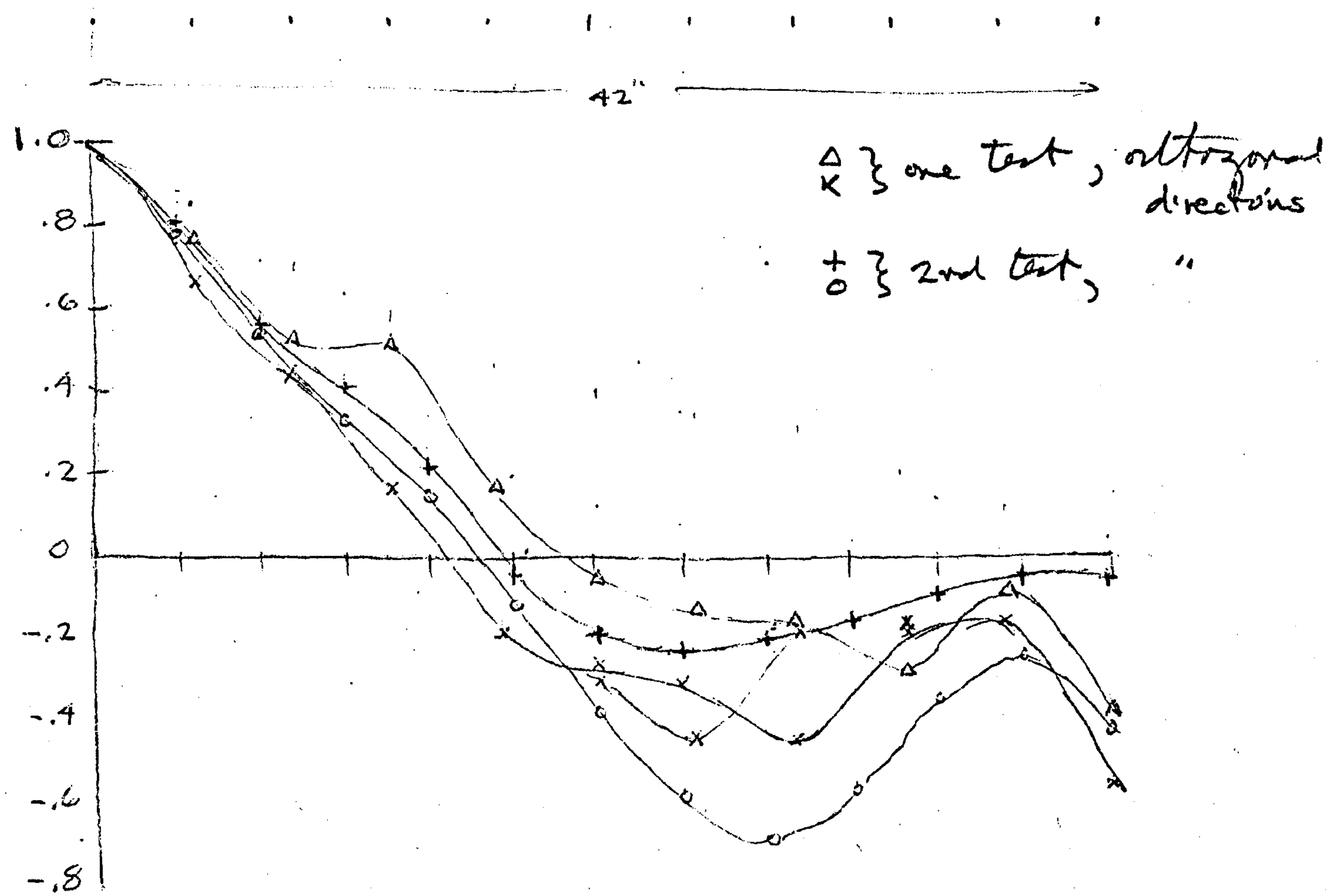
One way of arriving at a significant specification on rms slope is to study the distribution of values of currently accepted products.



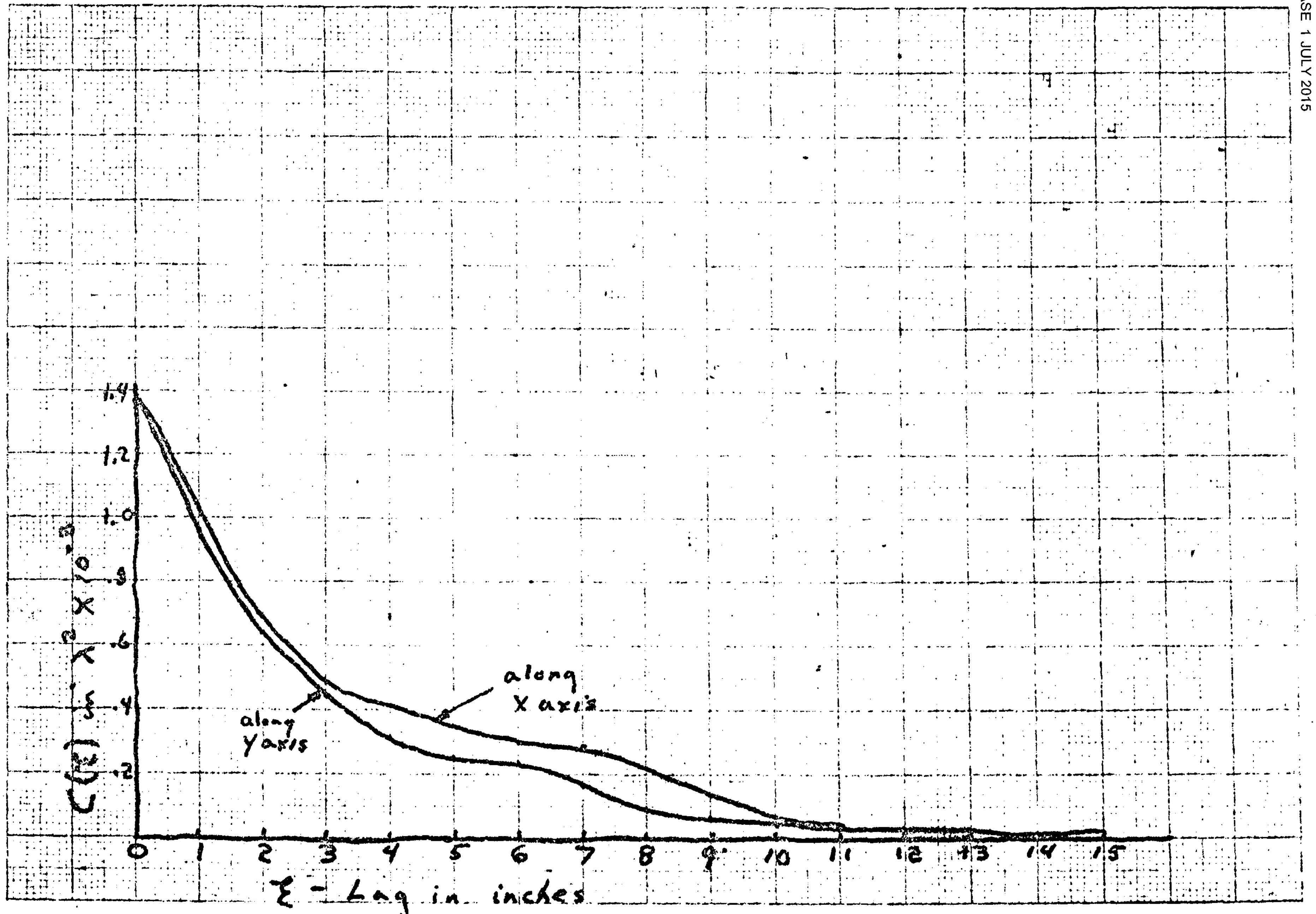

A typical limit might be the 90th percentile of the above distribution.

AUTOCORRELATION FUNCTION

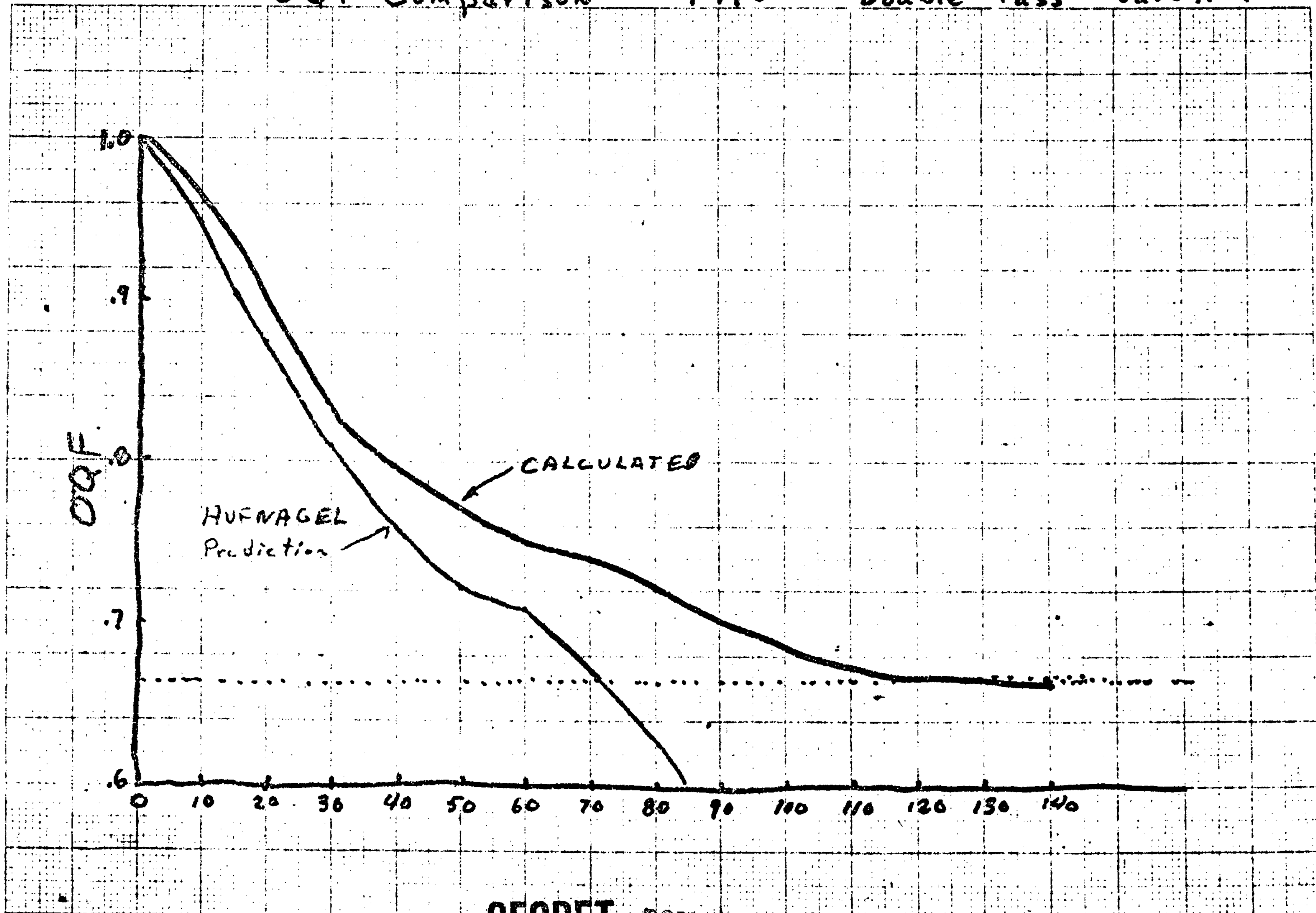
KITT PEAK 84 INCH TELESCOPE



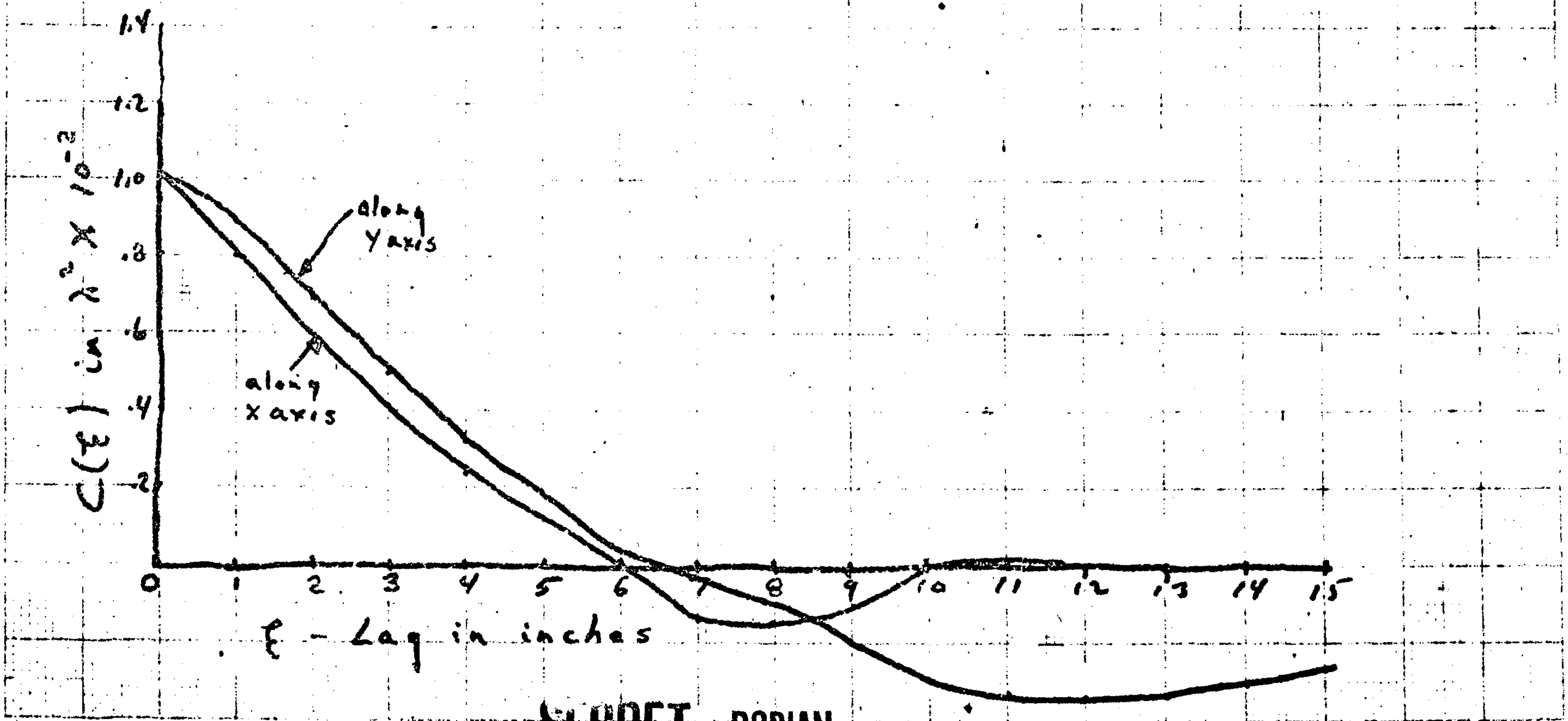
Auto correlation - 4431 - Double Pass Wave front



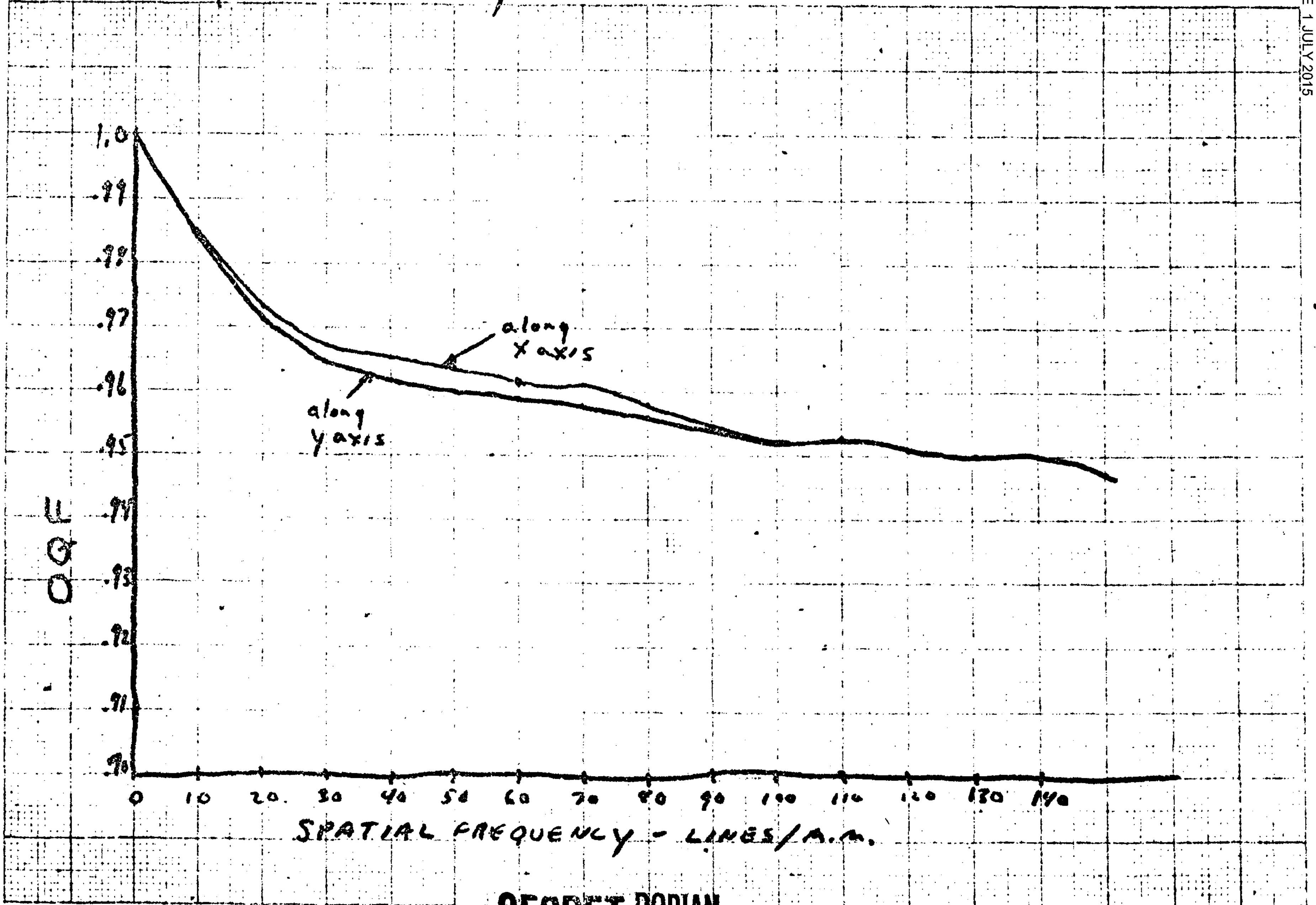
# OQF Comparison - 4416 Double Pass Wavefront



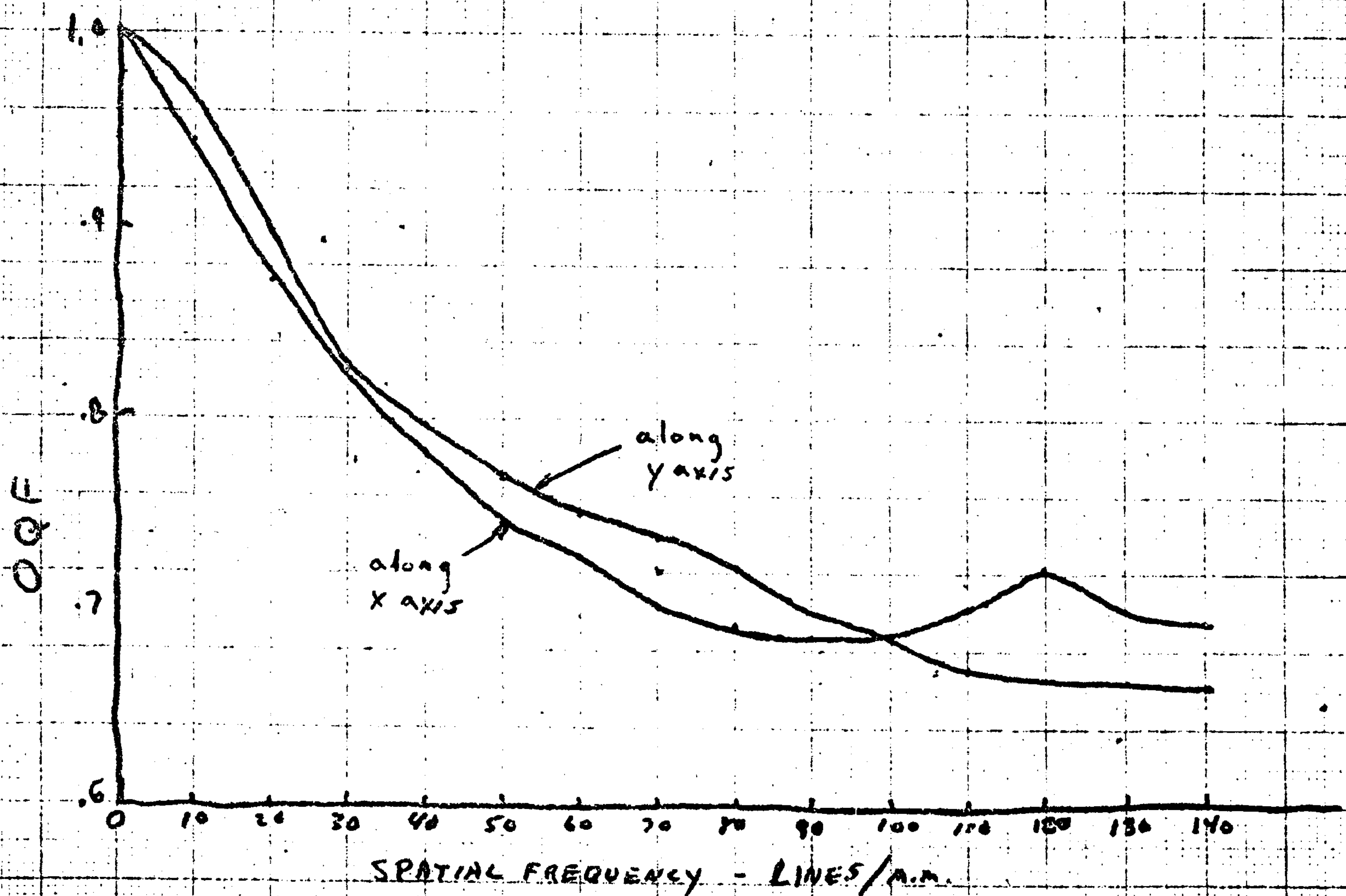
# Autocorrelation - 44/6 - Double Pass Wavefront



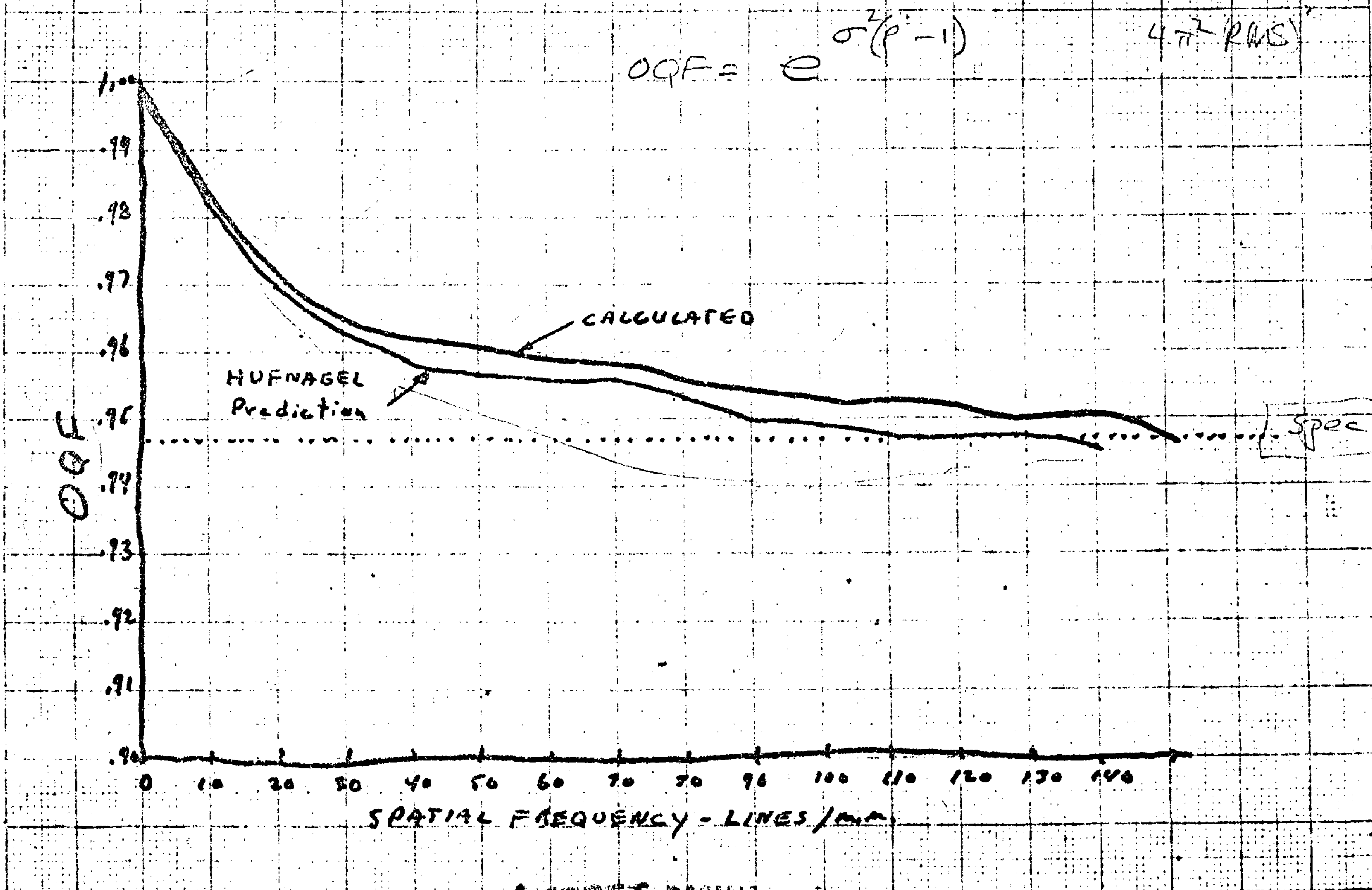
# Optical Quality Factor - 4431 - Double Pass Wavefront



Optical Quality Factor - 4416 - Double Pass Wave Front



# OQF COMPARISON - 4431 Double Pass Wave Front



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9 August 1968

Lloyd Watson
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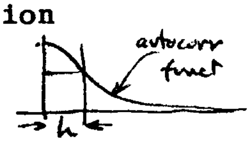
Dear Lloyd:

I am sorry that I was not able to reach you today to return your telephone calls.

In thinking about the problem of specification of optical quality I am becoming more inclined to the idea of the use of two RMS values rather than adding "functions" to the specifications. The thought is that we are already used to using RMS wavefront error as a specification. In an exact sense, the full [redacted]F of an element is specified then by adding the RMS SLOPE ERROR. Both quantities can readily be obtained by present testing methods.

The exact function necessary to specify the [redacted]F in the usual equations is the autocorrelation function. It seems, however, that one has some complication in writing this function into a specification. The single number that encorporates the autocorrelation function, and thereby gives a description of how rapidly the [redacted]F approaches the limit described by the RMS wavefront error, is the RMS slope error. The RMS slope error is given by the equation

$$\sigma_a = \frac{\sigma_w}{h}$$




$\sigma_w$ = RMS wavefront
$\sigma_a$ = RMS angular error

where h is the half-height distance of the autocorrelation function.

One of the potential problems to acceptance of the slope error parameter may be the opposition to the general question of relevance of slope errors, but I admit that in cases where the AIM curve crossing does occur at spatial frequencies where the [redacted]F curve has not reached the asymptotic value, that the slope parameter is desirable.

Roland Shack has drafted a report that includes the above question and this will be ready next week when I get back from vacation.

Sincerely yours,

A. B. Meinel