 Attachment 4

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Supplement to [redacted] Interim Report

8 April 1966

Declass Review by NGA.

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15 April 1966

Supplement to Interim Report

Several questions have arisen with regard to the proposed Integration Viewer Printer as it was outlined in the Interim Report. While many of the questions concern design details, they all revolve around one major concern; namely whether or not the output produced by the proposed printer will indeed be substantially better than the input material. The material below was prepared in an attempt to clarify all those questions which arose from this principal concern.

1. Purpose of Image Combination

Multiple image combination is the technique of utilizing several independent images of the same object as an aid to photographic interpretation. The improvement obtained in certainty and accuracy of interpretation may be due to any one, or a combination, of the following effects:

a. Improvement in the contrast of low contrast images due to the coherent addition of image detail and the non-coherent addition of other random disturbances (which may be outside the collection system).

b. Revelation of image detail hidden in shadows or missing due to other causes, by the superimposition of two or more inputs taken at different times of day or from different viewpoints.

c. Detection of changes.

It is not the intention of the proposed Image Combination and Integration Printer to increase the resolution in terms of the highest spatial frequency that can be resolved at the output. While some improvement in resolution can be obtained by image integration when relatively coarse-grained films are used, it is found that little improvement in resolution can be obtained when the high resolution emulsions presently in use for aerial photography are employed. This is true of any image integration system, including purely optical systems. One very real advantage of image integration lies in the increase in signal to noise ratio or the threshold of perception of the integrated image over any one input. This is important at any spatial frequency. It is, of course, necessary to determine that the image integration process does not degrade resolution significantly so that the advantages of integration are lost.

Analysis of the modulation transfer functions in Section 3 of this supplement shows that the resolution of the image integration system is comparable with that of a high quality optical enlarger.

2. Performance of Electronic Imaging Systems

In evaluating the proposed Image Combination and Integration Printer, a distinction must be made between electronic viewing systems and electronic printing systems. Viewing systems are limited in the number of resolution elements per second that can be presented to an observer. The necessity to avoid flicker makes high frame rates and interlacing necessary, causing additional problems.

The proposed image combination system produces its output on film by means of slow scanning. In this mode, the number of resolution elements that can be recorded is not limited by bandwidth considerations and no interlace is necessary.

This approach yields considerably higher resolution than can be obtained in a direct viewing system.

3. Expected Performance of Image Combination and Integration Printer

While an analysis of the expected modulation transfer functions and resolution of the printer is useful, it does not determine the improvement in the quality of the output image versus that of the input images. This improvement depends on many factors outside the collection system that cannot be included in a paper analysis.

Such factors as visibility, illumination, haze, turbulence, target motion and many others affect the result. The only way in which the answers can be obtained is to build and evaluate the equipment.

However, there is a trade-off in that the resolution of the integration device must be sufficiently good to enable its advantages in other areas to be employed. For this reason, the following analysis is presented.

For the purpose of this discussions,we can divide the input materials into two broad categroies: 1) photographic records of film limited systems (grain limited) and 2) photographic records which represent the outputs of non-film limited acquisition systems. Input materials in the first category would typically comprise original negatives on materials such as 3401 and Tri-X while the second category is characterized by original negatives on 3404 film. Let us consider inputs on 3404 first. In order to be able to make a meaningful comparison between the output of the Image Combination Integration Printer with a typical, single aerial scene, the steps shown in Figure 1 were followed. Figures 2, 3 and 4 show the MTF curves which are associated with the various steps outlined on the Data Flow in Figure 1.

Figure 4 shows that three images on 3404 can be combined into a single output print. This single output print will be twelve times enlarged with all the inherent advantages of transferring detail shown in one of the three input negatives to the final geometrically corrected output print, essentially without loss in resolution as compared to the throughput of a single negative. On the other hand, for input material on film such as 3401 or Tri-X, i.e. grain limited inputs, the Image Combination and Integration Printer combines the three inputs, and, indeed, produces an output which has better resolution than a compatible output produced from a single negative. Figures 5 through 10 show in a manner analogous to that used previously in Figures 2 through 4 what the relation among MTF's is when input material such as 3401 and Tri-X is handled according to the data flow in Figure 1. Of particular interest is Figure 10 which shows the improvement in resolution obtained with the Image Combination and Integration Printer.

Figure 11 shows how the densities can be manipulated during the image combination and integration process in such a manner that the "Visual Threshold" is significantly lowered in the output print in comparison with each individual input negative. This advantage inherent in the electronic image manipulation of the image combination/image integration printer appears to make it possible to obtain information from under exposed negatives which otherwise would be buried below the "Visual Threshold."

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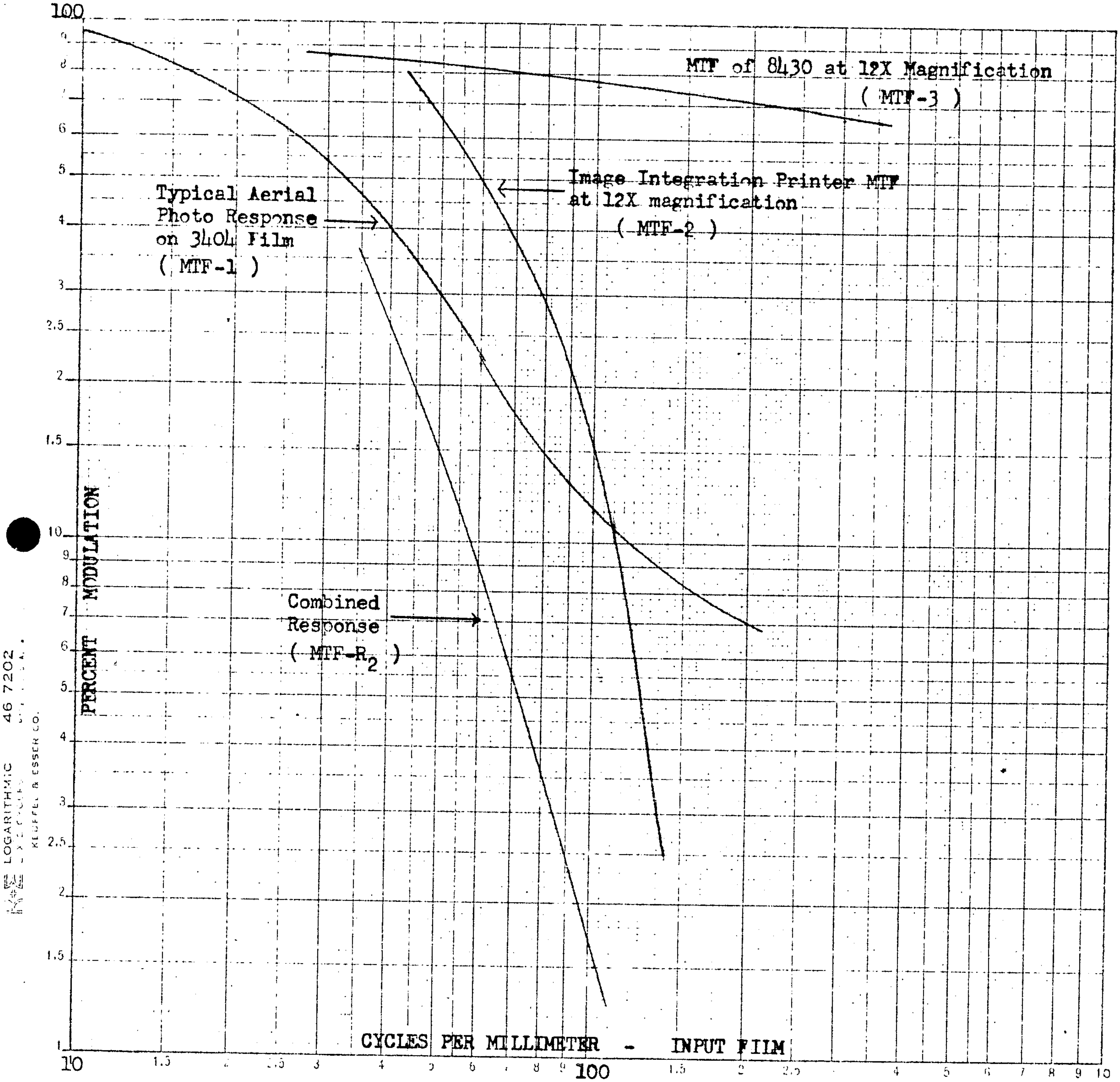

Figure 2. Modulation Transfer Function for Electronic Multiple Image Integration Printer and typical aerial scene on 3404 film.

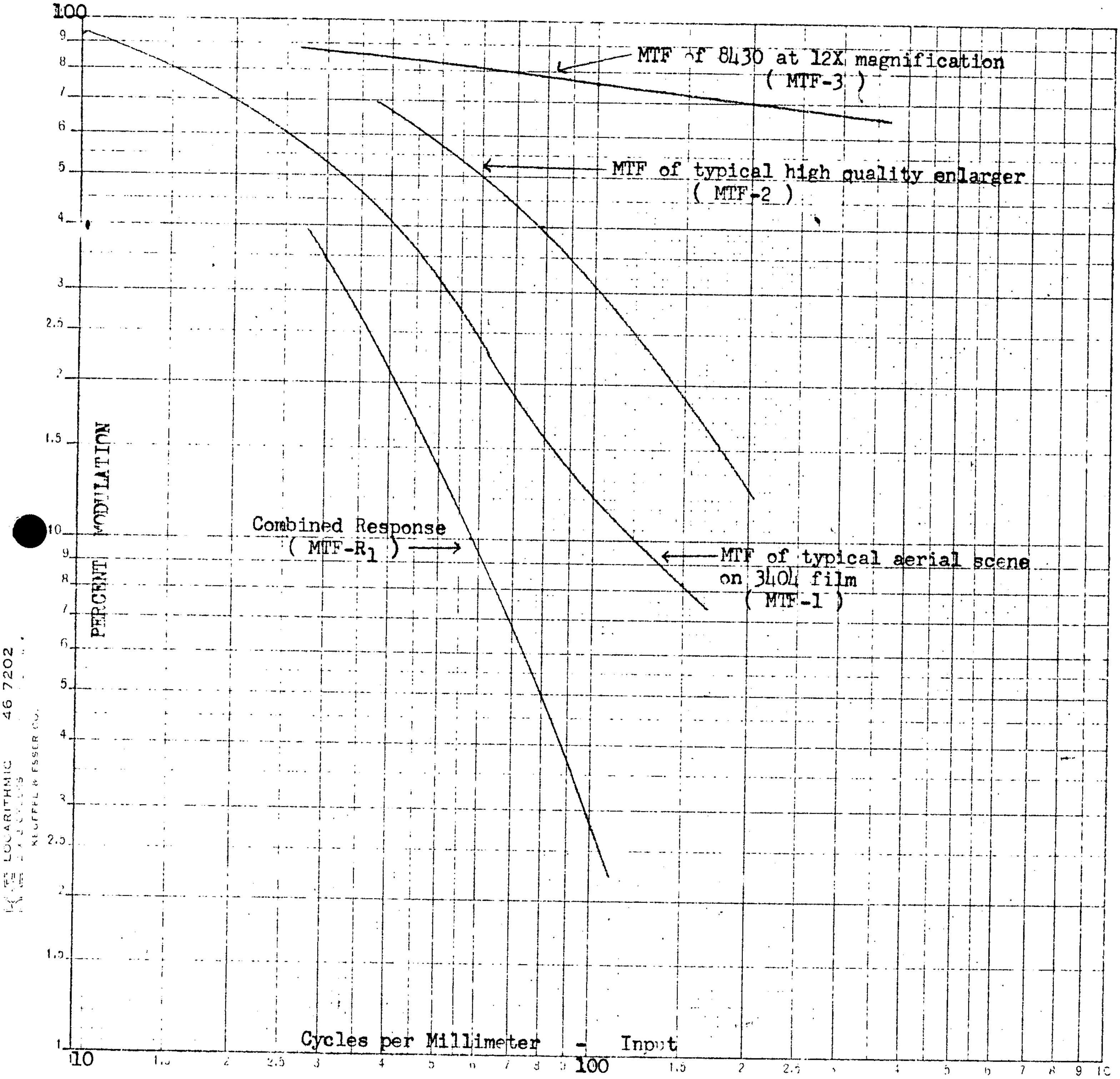

Figure 3. Modulation Transfer Function for typical high quality optical enlarger and typical aerial scene on 3404 film.

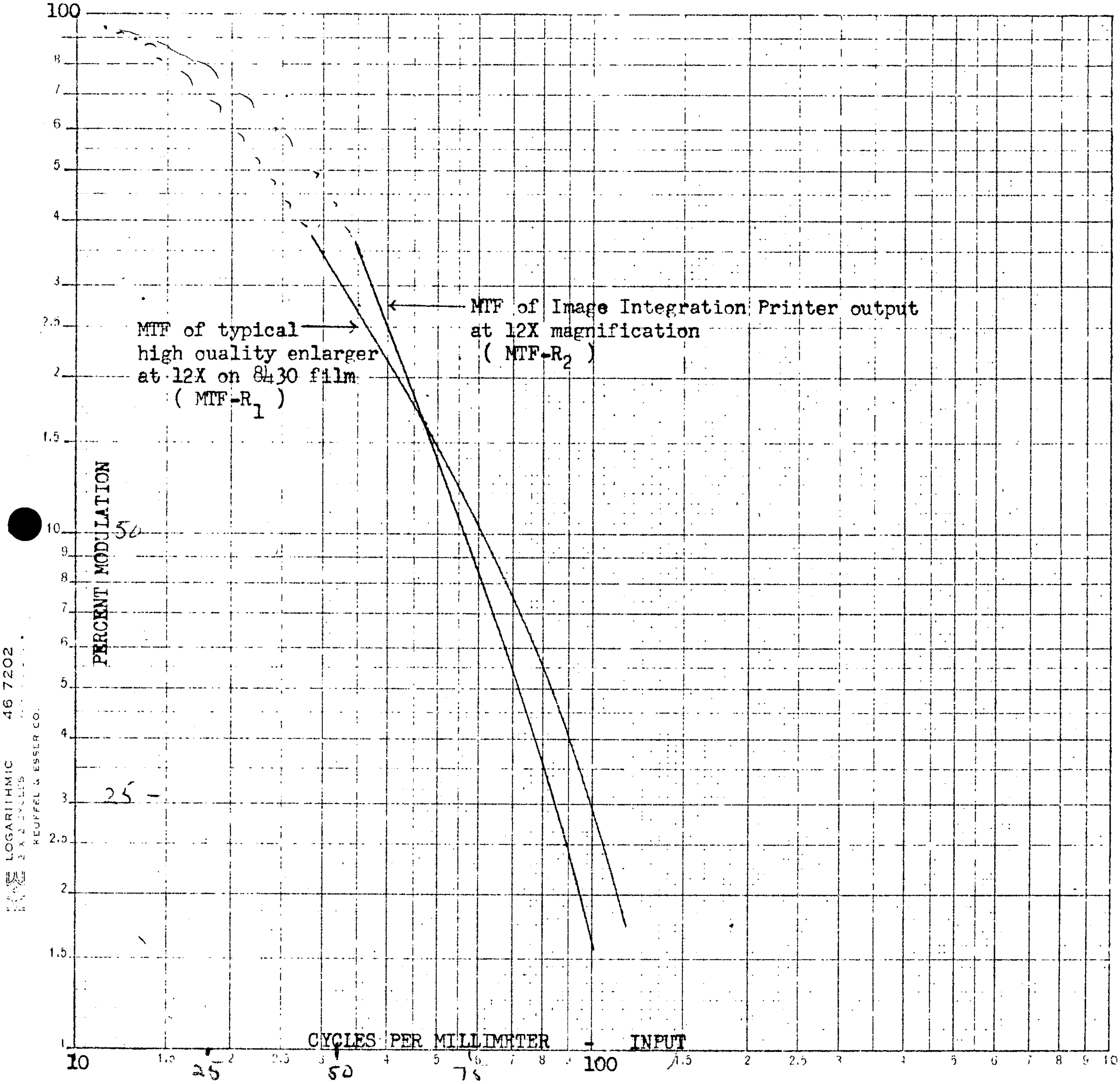

Figure 4. Comparison of Modulation Transfer Functions for outputs of Multiple Image Integration Printer and typical high quality optical enlarger. Input is typical aerial scene on 3404 High Definition Aerial film.

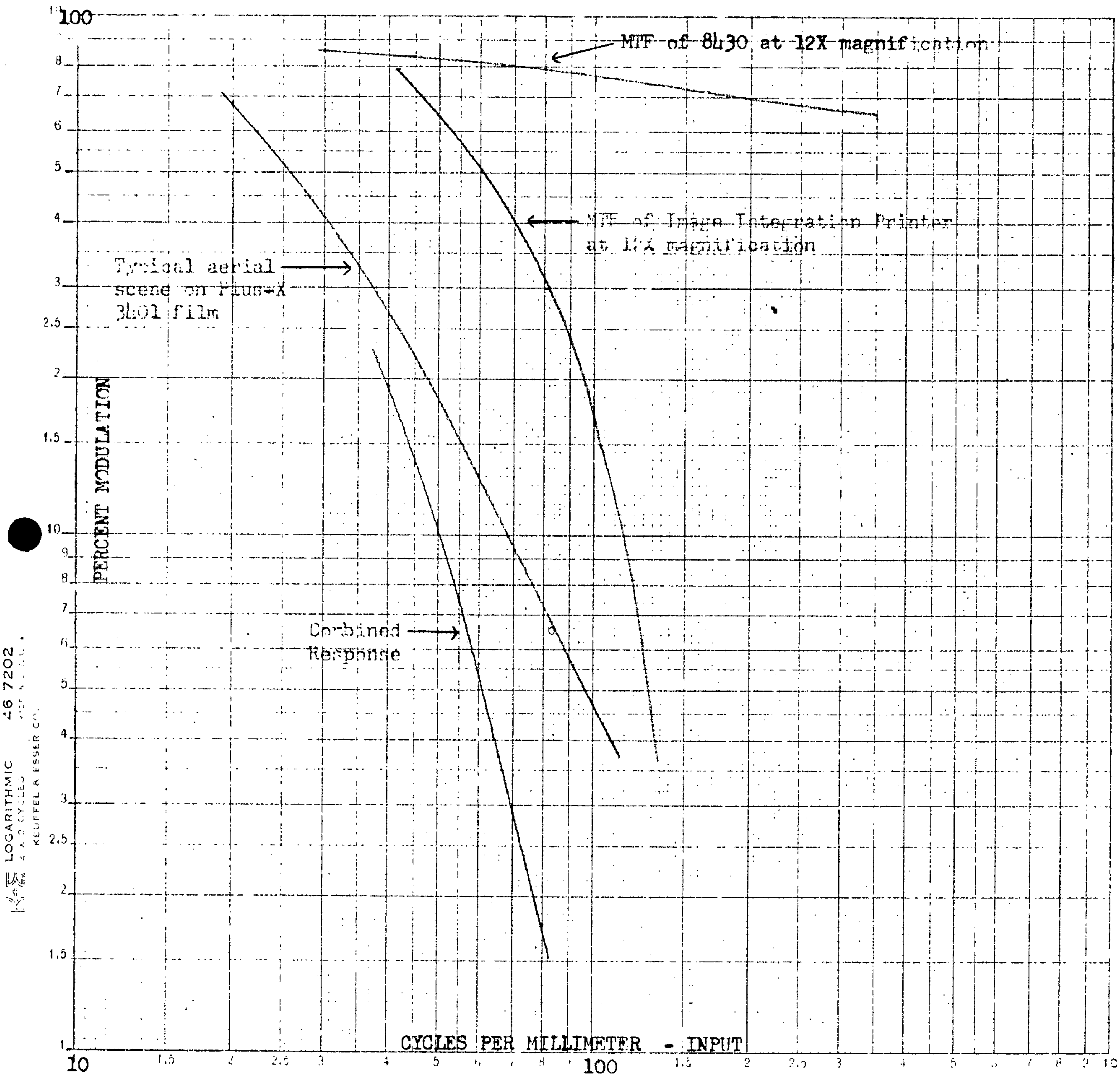

Figure 5. Modulation Transfer Function for electronic Multiple Image Integration Printer and typical aerial scene on Plus-X 3401 film.

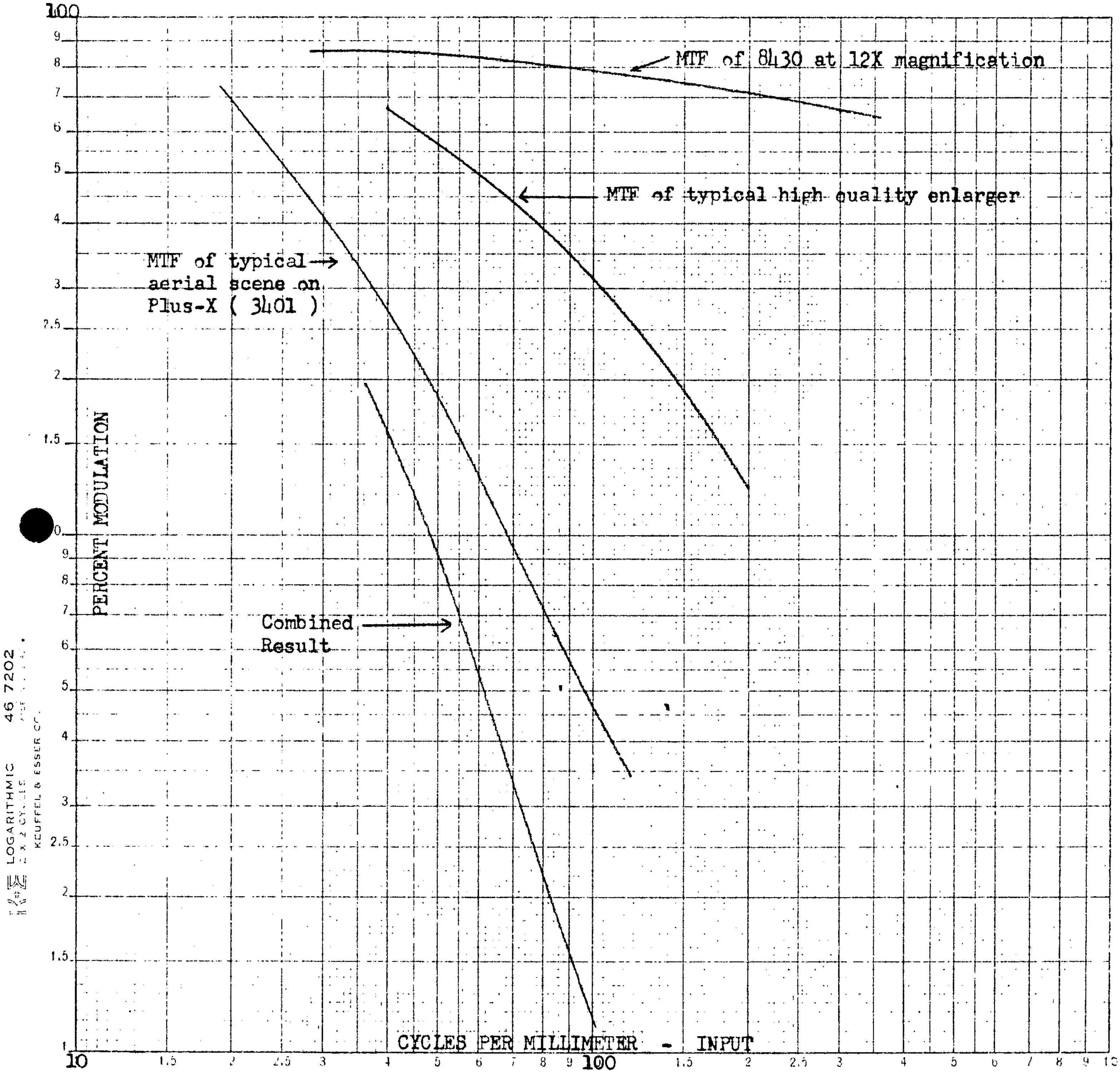

Figure 6. Modulation Transfer Function for typical high quality optical enlarger and typical aerial scene on Plus-X 3401 film.

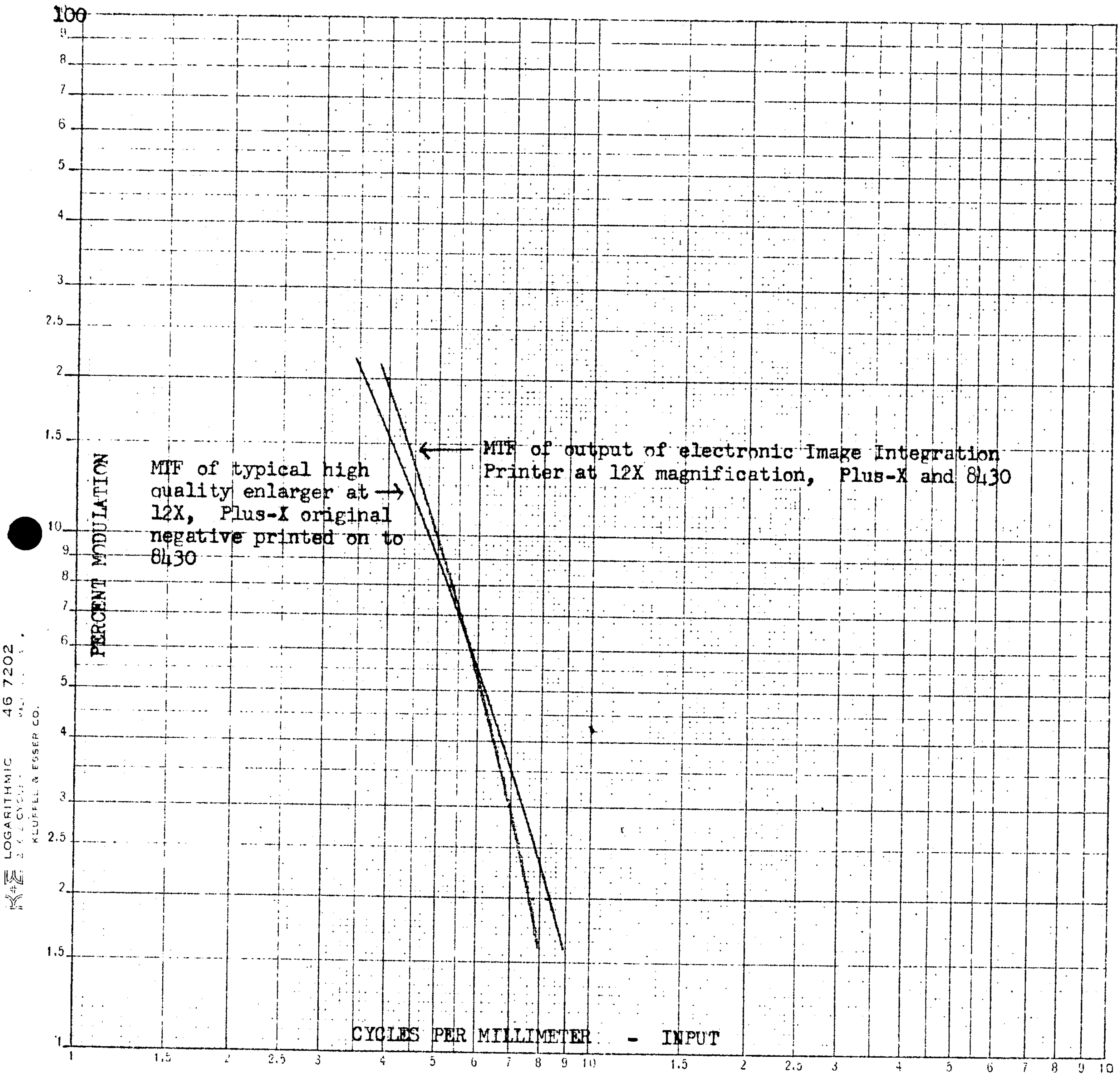

Figure 7. Comparison of Modulation Transfer Functions for outputs of the Multiple Image Integration Printer and a high quality optical enlarger. Original negative on Plus-X 3401 film.

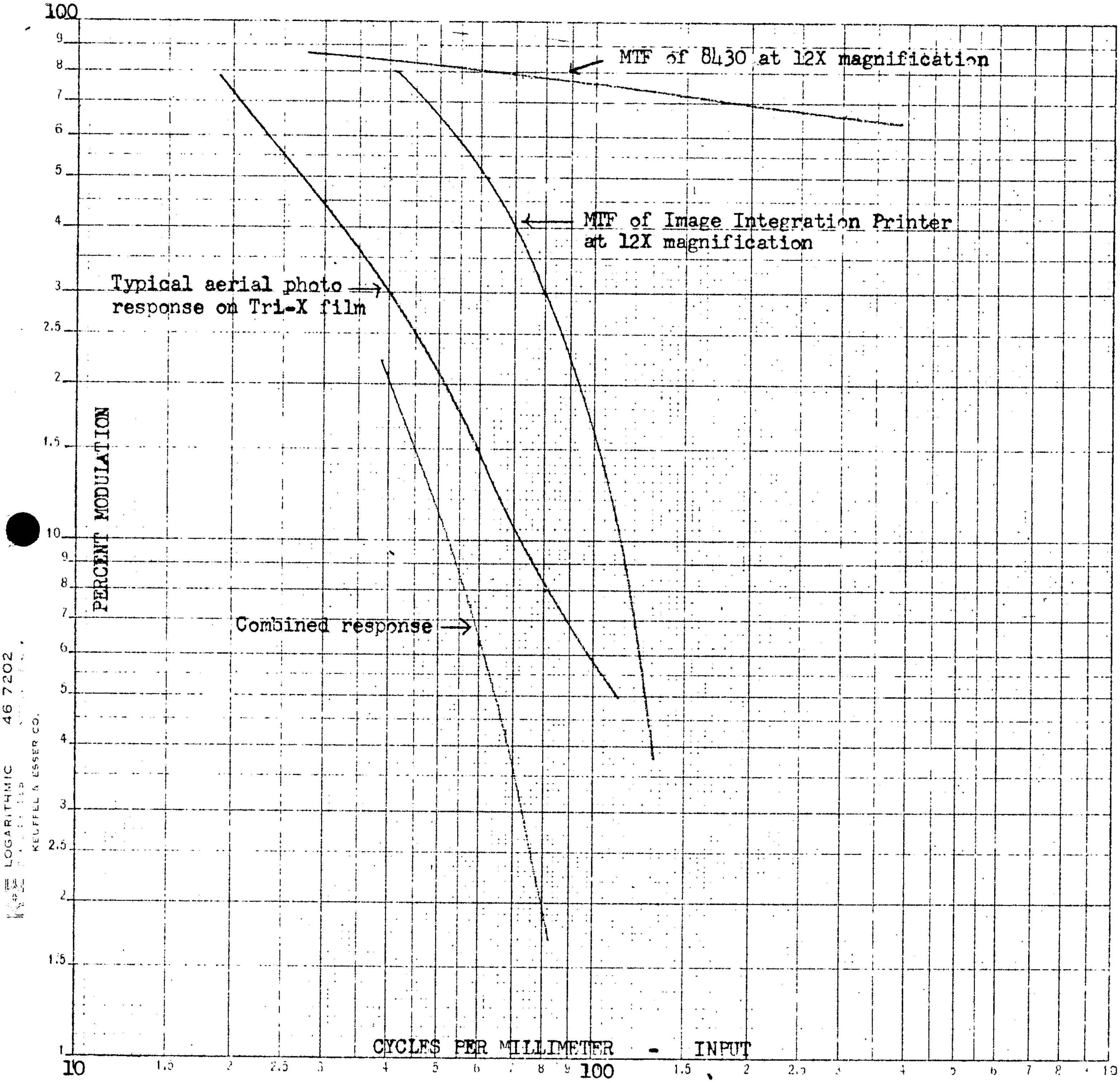

Figure 8. Modulation Transfer Function for Electronic Multiple Image Integration Printer and typical aerial scene on Tri-X film.

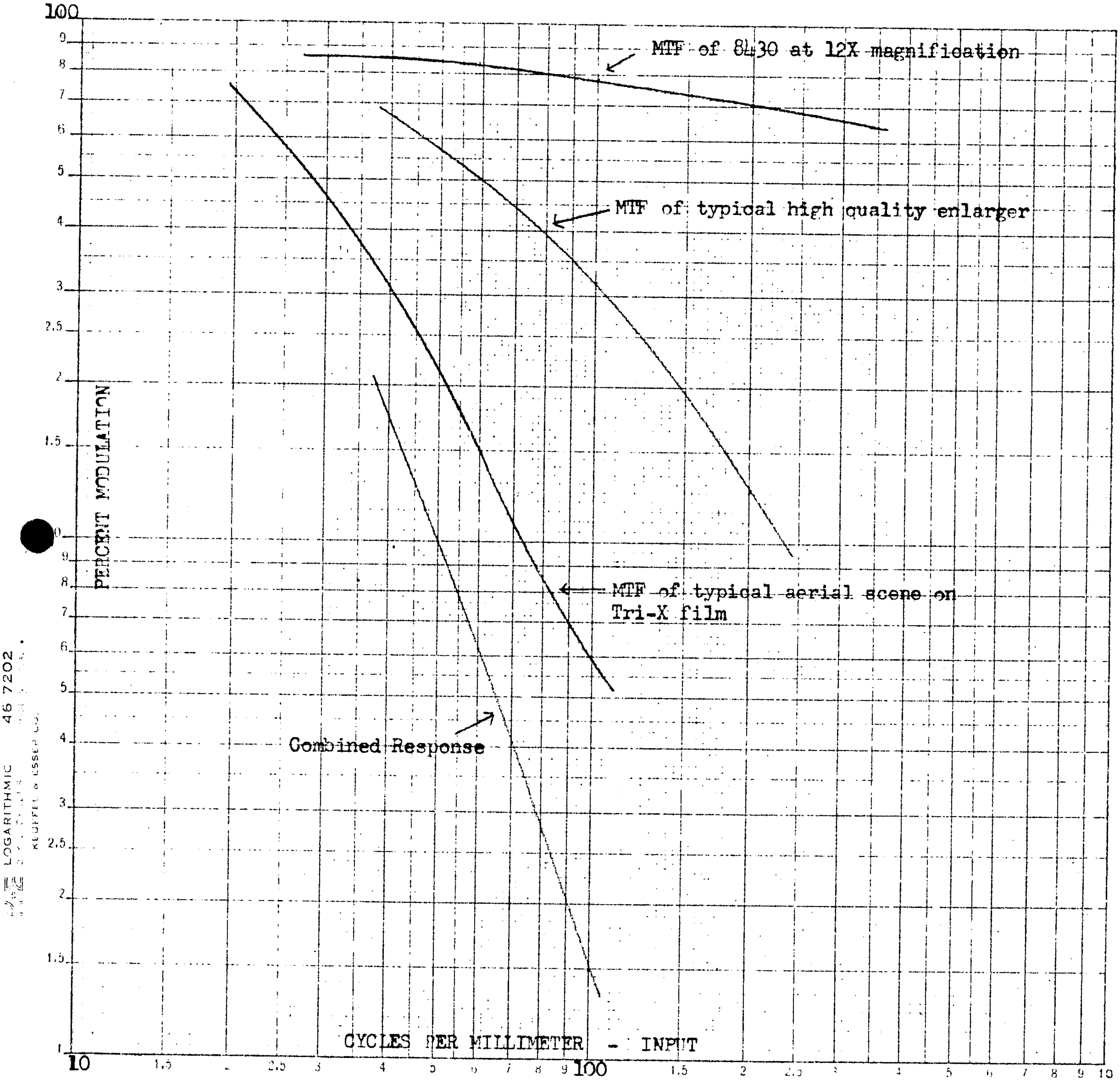

Figure 9. Modulation Transfer Function for typical high quality optical enlarger and typical aerial scene on Tri-X film.

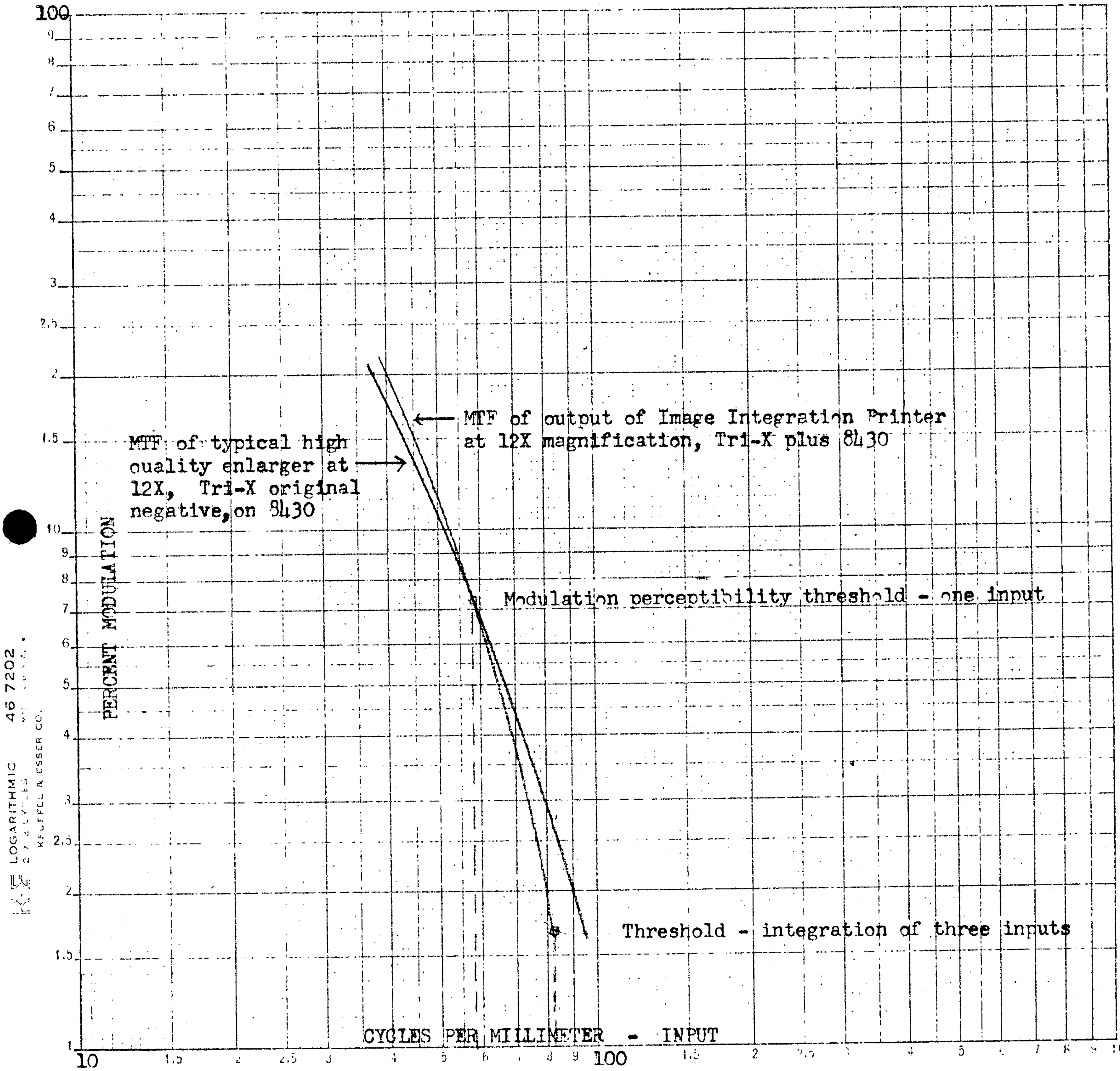

Figure 10. Comparison of Modulation Transfer Functions for outputs of Multiple Image Integration Printer and typical high quality optical enlarger. Original negative on Tri-X film.

Figure 11

Visual threshold of modulation perceptibility due to granularity of film. On this illustration, step densities greater than 1.2 disappear into the "noise" for a single input. Integration of three inputs theoretically will improve the visual threshold by $\sqrt{3}$ or 1.7, moving the visual threshold to a density of 1.4.

11 April 1966

QUESTIONS & ANSWERS

1. Graphic material, MTF and S/N at various bandwidths - better output picture than input

   Answer - See pages 1-13.

2. Input better than 100/150-200 lines per millimeter

   Answer - By increasing the magnification of the system relative to the image dissector photo-cathode, higher film resolving power can, in principle, be provided. This, of course, shrinks the total film area being scanned in proportion. Depth of field problems will be very difficult to solve for the higher magnifications.

3. Documentation on Image Dissector and "Follow Spot" Technique

   Answer - Copy of paper by G. Papp, on a Novel Application of the Image Dissector, Journal of the SMPTE, Vol. 74, page 782-3, September 1965 has been supplied. [redacted] STAT STAT

4. How many gray steps effect on MTF

   Answer - Using as our definition a step value equal to a .15 density increment, ten shades of gray will be perceptible. This is equal to a system providing a 30 to 1 contrast ratio, i.e., the black is 3% of the highlight value. The MTF shows the contrast available theoretically for each spatial frequency. Image integration will add one grey step.

5. Spot size on pickup tube

   Answer - The spot size is 16 microns on the image dissector tube (.6 mil).

6. Interlace

   Answer - Interlace is not used in the hard copy mode. Sequential scanning is used which will avoid the noise problems inherent in interlaced systems and will produce a more homogenous image on the hard copy output.

7. Dynamic range of illumination

   Answer - The dynamic range of illumination on the hard copy printout CRT will be adjusted to produce the maximum to minimum exposure values required for correct exposure of the hard copy material. This is approximately 20 to 1, although higher values can be used for lower gamma materials.

8. S/N to include all noise in input

   Answer - See the answer to Question 1.

9. Slow scan - effect of decay.

   Answer - In the hard copy printout mode, the decay of the phosphor has no effect.

10. Varying density input effect on resolution of 3.0-0.1 (vs) 2.0-0.3.

    Answer - The higher contrast range (3.0-0.1) will be degraded relative to the lower contrast material. Most aerial photography, fortunately, is closer to the latter.