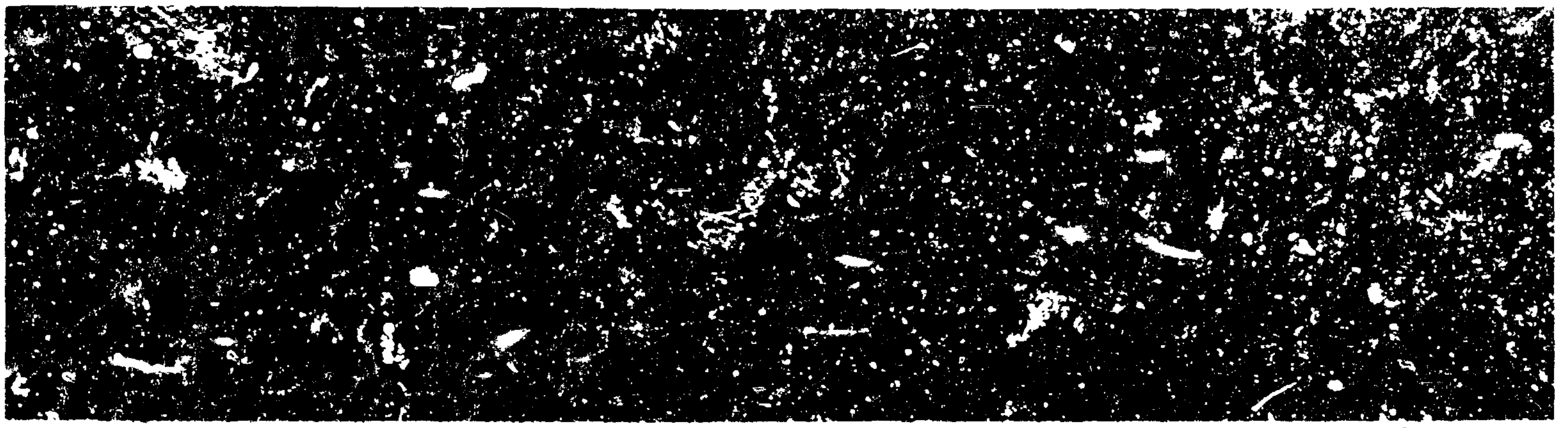
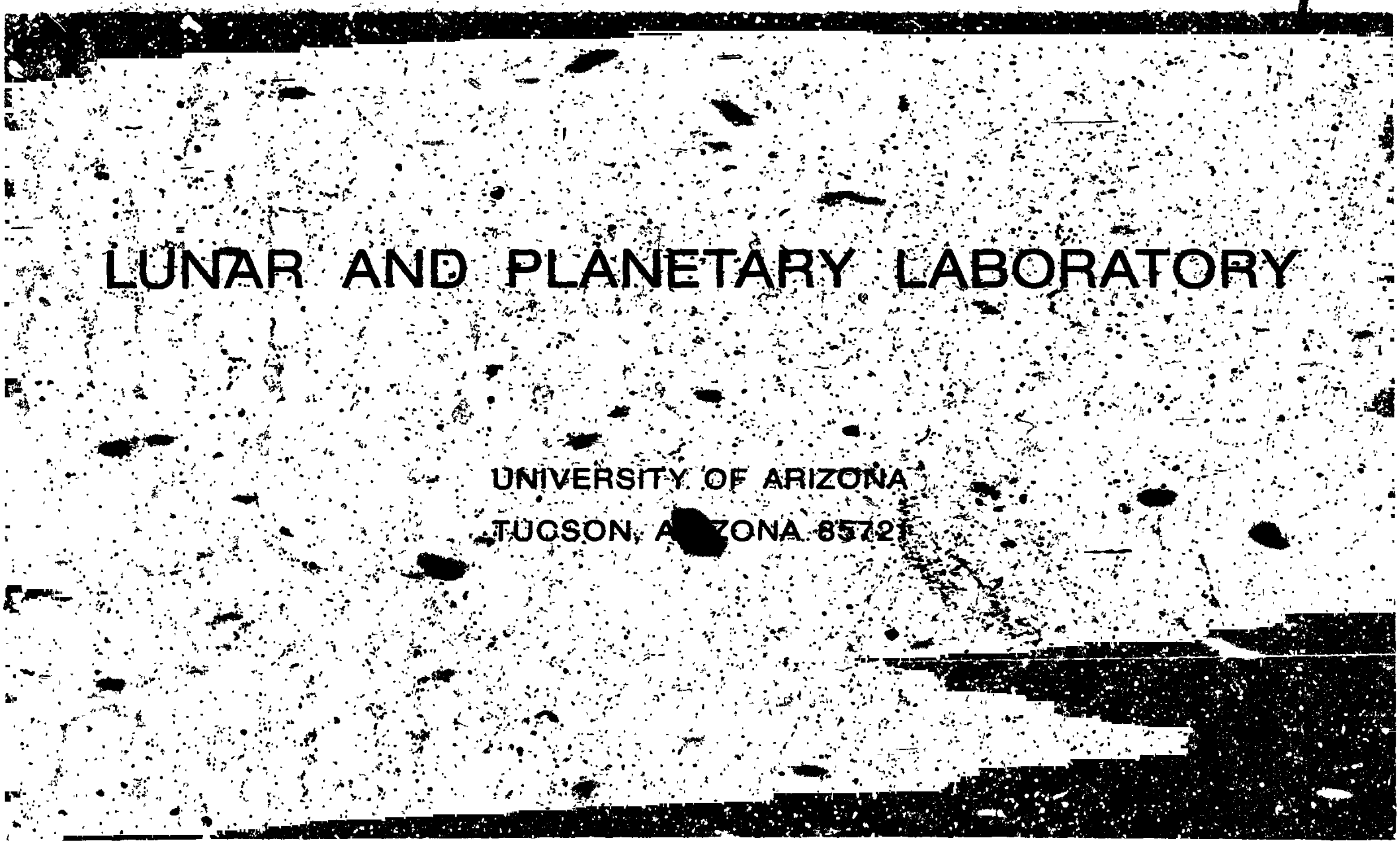


NGR-03-002-343

FINAL REPORT

OBSERVATIONS OF COMET KOHOUTEK (1973f)

by Stephen Larson



OBSERVATIONS OF COMET KOHOUTEK (1973f)

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ABSTRACT

The coma region of Comet Kohoutek (1973f) was observed with a 40-mm proximity focused image intensifier tube and filters to isolate principal emissions. The low brightness of the comet limited the results, but it was possible to compare the intensity profiles of C_2 and continuum in the coma. It appears that Comet Kohoutek was a typical comet in that it did not exhibit unusual coma structure similar to that of Comet Bennet (1970 II). Photographs taken with the 42 cm Schmidt showed typical type I, type II, and antitail morphology, with increased type II activity after perihelion passage. A technique for eliminating the type II (dust) component of the tail is given by means of photographic subtraction of blue and red sensitive layers of a color photograph.

An important factor in the determination of the physical characteristics of comets is observation spatially and temporally of the variation of constituents in the coma and tail. Comets rarely reach the brightness where observation by direct photography is possible with filters whose bandpasses are narrow enough to isolate the principal emissions. However, with the addition of an image intensifier, it is in principle easier. In practice, others have experienced problems with such devices due to geometric and photometric distortion as well as inconvenience, limiting their use.

Comet Kohoutek appeared to be well suited to test proximity focused, electrostatic image intensifier tubes. L. Dunkelman of NASA Goddard made available a 40 mm image tube which has exhibited minimal distortions (See appendix). A camera that presses film in contact with the output fiber optic plate, contains power supply and energizers, a reflex mirror and filter pocket was designed and constructed (Fig. 1, 2). The camera is constructed of nonconducting plastic to prevent electrical discharges that might harm the tube or expose the film. Filters to isolate the emissions of CN, CO^+, C_2, C_3, OH and NA as well as pure continuum were used (Table 1).

At the time of purchase of the filters, it was not anticipated that the near infrared sensitivity of the tube would be very high, but it was found that even at 0.89μ the tube was an order of magnitude more sensitive than the film. Consequently, red leaks in some filters caused too much contamination for use. A near infrared blocking filter has been added for future work .

The camera was completed in mid-December just prior to perihelion passage, but observation with the 154-cm telescope at the Catalina Observatory was prevented by the poor southeast horizon at that site. Cloudy weather further prevented observation until January 11, 1974, at which time the total visual magnitude of the comet was about 4. That night exposure tests were made using all filters. While the comet's motion was compensated for by the telescope drives, trailing resulted from atmospheric refraction at the large zenith angles encountered (Fig. 4). With proper exposures determined, more images were obtained on January 12. The next opportunity was on January 17, when the total visual magnitude was 5.5. An attempt to compensate for refraction by frequently changing the drive rates was somewhat successful. Densitometer tracings show the intensity distribution differences between C_2 and the continuum in the comet (Fig. 5). The C_2 isophotes are generally more symmetrical than the dusty continuum. Since C_2 is neutral, it is unaffected by local magnetic fields. The C_2 density distribution in other comets has been determined to vary approximately with the inverse square of the distance, at least in the outer coma (Wurm 1961). If this is the case in comet Kohoutek, it would appear that the dust density falls off at a greater rate due to radiation pressures. Larger particles in the mm size range were produced to form the antitail (Sekanina, 1974).

The experience with observation of Kohoutek has led to several refinements improving the system. Although tracking motions in the telescope drive compensated for the comet's motion and for atmospheric refraction to the first approximation, some residual trailing remained because of the longer than expected exposure necessary due to the comet's brightness. It was obvious that some sort of offset guiding apparatus would be necessary to do work on fainter comets. A double-slide holder was modified, and the guide eyepiece was fitted with a high-gain micro-channel plate intensifier tube 18 mm in diameter (Fig. 3). This was made available by L. Dunkelman in a joint effort with LPL staff to fully exploit the usefullness of electrostatic image tubes for cometary and planetary photography. Preliminary results indicate that the limiting magnitude threshold is no better than the dark-adapted eye, but stars near that limit are amplified sufficiently to allow guiding on stars between one and two magnitudes fainter than usual.

Use of the 40-mm image intensifier on faint comets is now being attempted. If tube noise prevents work on extremely faint comets, it is still possible to photograph medium and bright comets in shorter time, thus allowing the use of a larger number of filters and perhaps detection of short-period changes.

On January 11, 1974, a color photograph of Comet Kohoutek was taken on Kodak Ektachrome EF with a standard 135 mm telephoto lens on a 35 mm camera. Color separations of the blue and red images showed the isolation of the emissions of CO^+ in the type I tail by photographic subtraction. This was accomplished by eliminating the continuum reflection of the type II tail material, which is possible since the energy from the reflected solar continuum is nearly equal in the spectral bandpasses of both the red and blue sensitive layers of the color photograph.* Any excess (in this case, the blue emissions, which are predominantly CO^+ and CN) will be left after a gamma one positive if one layer is superimposed upon the negative of the other. In Figure 7, the first two images are the individual blue and red images. The third image is the positive-negative combination, where anything dark is reddish and anything light is bluish. It should be noted that stars of different spectral classes become quite apparent. The comet appeared as it would if there were no dust particles to reflect the sunlight. The large coma is due to CN emission, and the tail due to CO^+ emission (Fig. 6). The third image compares well with the preperihelion image of December 6 (Fig. 11) which had relatively little dust. It is thus apparent that dust production was greater after perihelion; in fact, the resulting asymetry in the total magnitude curve before and after perihelion due to this fact is already well known. If done carefully, the only drawbacks of this technique arise from differences in the sensitometric response of the different emulsion layers of the color film, which are greatest in the toe and shoulder of the characteristic curve. The advantage is that one color photograph can provide the information that normally would require two.

When possible, additional photographs were taken with the new 42 cm Schmidt telescope at the Catalina Observatory (Table 2). The plateholders were modified to accept cut film for photographs used to investigate the general tail morphology. The Schmidt has a field of about $7^{\circ}.25 \times 7^{\circ}.25$. Tri-X panchromatic film without any filter was needed to

*Kodak Aerial Films and Photographic Plates, M-61, 1972, P. D-30.31.

minimize exposure time and guiding errors. Figure 8 shows the daily motion of the comet and the relatively short, featureless tail. By November 28 (Fig. 9) structure in the predominantly type I tail was evident. The next night (Fig. 10) a kink in the tail was still visible. The mean velocity of the kink between the two nights was about 100 km/sec. which is fairly typical for such features (S. Larson and Minton, 1972). The tail increased in length as it approached the sun (Fig. 11) but retained the predominantly type I tail morphology consisting of rays directed generally away from the heliocentric radius vector.

By January 11, 14 days past perihelion, the comet's character had changed. The type II tail had developed and a stubby antitail was protruding toward the Sun as seen from the Earth. The position angles of the type I and type II tails were different because of differential orbital velocity components perpendicular to the radius vector. As heliocentric distance increased and these velocity components decreased, the position angles became more coincident. The antitail was photographed on January 11, 1974, and persisted through January 17. The earth was sufficiently close to the plane of the comet's orbit that the accumulation of the larger dust particles not immediately swept back by solar radiation could be seen.

Acknowledgments

I wish to thank L. Dunkelman of NASA Goddard for the loan of the 40 mm and 18 mm image tubes. R.B. Minton, S. Kutoroff, and J. Fountain participated in the observations. This work was supported by Special Operation Kohoutek Grant NGR 03-002-393.

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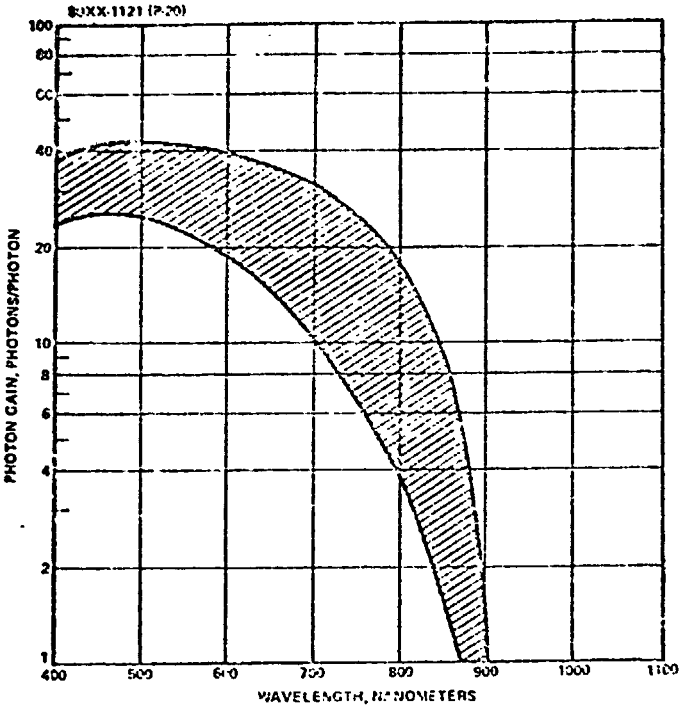
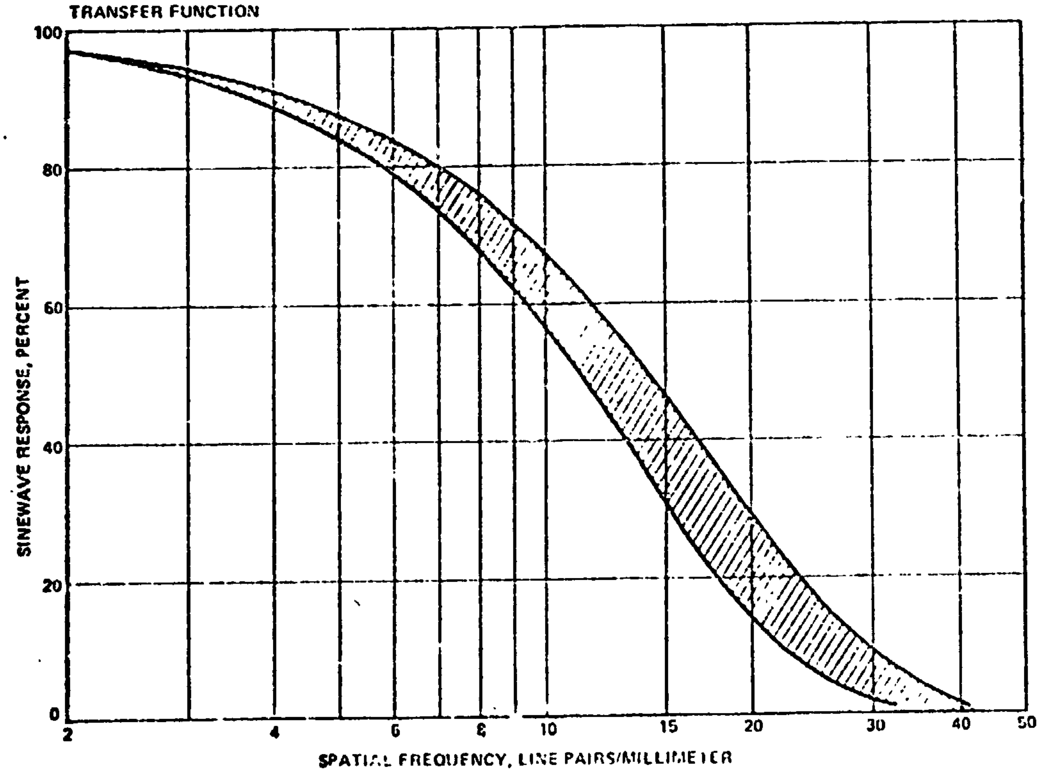
Wurm, K. (1962) in Transactions IAU, v.XIA (Academic Press), pp.131-142.

PHOTON GAIN VERSUS
WAVELENGTH
8UXX-1121 (P-20)



TYPICAL MODULATION
TRANSFER FUNCTION



APPENDIX

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Characteristics of the 40mm proximity focused image intensifier. The particular tube used was essentially free of fiber optic patterns and had only three bright pinhole defects.

	Note	Maximum	Nominal	Minimum	Units
Photocathode luminous sensitivity	(a)	> 500	350	200	μA/ℓm
Photocathode radiant response					
at: 800 nm		> 60	25	12	mA/W
850 nm		> 30	10	5	mA/W
900 nm		> 5	2	1	mA/W
Wavelength of peak phosphor output		-	530	-	nm
Luminious gain	(b)	> 100	50	30	ft-L/ft-c
Luminance uniformity		-	± 10		%
Resolution limiting	(c)	50	36	30	ℓp/mm
Sine-wave modulation transfer function	(d)				
at: 2.5 line paris/millimeter		-	95	-	%
7.5		-	.68	-	%
16.0		-	27	-	%
Resolution uniformity	(e)		± 2		ℓ p/mm
Magnification center and edge	(e)	1.0	1.0	1.0	
Distortion	(f)	-	≤ 0.1	-	%
Equivalent background input	(g)	2×10^{-9}	1×10^{-10}	2×10^{-11}	ℓ m/cm^2
Input illumination	(h)	0.1	-	-	ft-c
Photocathode current density	(h)	1×10^{-7}	-	-	amps/cm^2
Output brightness	(i)	5.0	-	-	ft-L

(a) Specified as the ratio of photocurrent to input luminuous flux measured at a cathode flux level of 1.5 millilumens from a 2854°K color temperature tungsten lamp and uniformly distributed over a diameter of 0.5 inch.

(b) Specified as the ratio of output brightness in foot-lamberts (ft-L) to the input face plate illumination in foot-candles (ft-c). Both input illumination and output brightness are measured with an eye-response-corrected photometer. The input illumination at the input faceplate is derived from a tungsten filament lamp operated at a color temperature of 2854°K. The variation is specified as a percent variation from the average brightness over the quality area included in a circle concentric with the active area visible on the output window whose diameter is 90% of the active diameter.

(c) Limiting resolution is specified at optimum light level. The input image is generated by projecting a 100% contrast USAF 1951 Resolving Power Test Target onto the photocathode. The light source is the same as specified in Note (b). Measurement is made under normal tube operating conditions The variation in resolution is measured at several points within the circle specified in Note (b), and the maximum variation from that measured at the center is given. Maximum resolution is obtained with essentially monochromatic light of wavelength near the threshold of the photocathode.

(d) The modulation transfer function is the percent degradation (or contrast reduction) in a 100% contrast sine-wave image at a specific spatial frequency. The measurement is made by projecting a slit image on the photocathode and Fourier analyzing the resultant output image of the tube into a sine-wave MTF. The illumination for the slit input is the same as specified in Note (b).

(e) As a consequence of proximity focusing used in these tubes the magnification is unity within the quality area and the resolution is constant over the same area. Quality area is defined by a diameter which is 90% of the active diameter.

(f) Percent distortion is equal to the edge magnification minus the center magnification divided by the center magnification times 100. There is no barrel-, pincushion-, or "S"-distortion within the quality area due to the use of proximity focusing.

Table 1

Characteristics of the Interference filters used on Comet Kohoutek (1973f)

Emission	Central λ*	Bandpass(50%)*	Remarks
OH	3080 Å	2875-3425 Å	Comet far too dim, very strong UV absorption by atmosphere
CN	3895	3840-3930	Comet too dim, tube sensitivity not very high
CO^+	3990	3925-4060	Not much emission near nucleus - too dim
C_3	4055	3990-4120	Strong emission-good images obtained
C_2	5140	5060-5220	Weak images-comet dim near-IR leak contamination
Na	5889	5865-5910	Strong images, but near IR leak badly contaminated image
Continuum comparison	4880	4700-5110	Near IR leak, but is continuum there. Contamination minimal

*These are measured values and may deviate slightly from the optimum values

Table 2

Photographs of Comet Kohoutek (1973f) Taken with 42-cm Sc

Date	Universal Time (starting)	Film	Exposures (min)	Remarks
1973 Oct 15	12:20	Royal Pan	5	Bright moon
Oct 29	12:00	Royal Pan	5	Hazy
	12:10	Royal Pan	5	Hazy
	12:20	Tri-X Pan	10	Hazy
Oct 30	12:10	Tri-X Pan	10	Clear
Oct 31	12:00	Tri-X Pan	15	Clear
Nov 1	11:55	Tri-X Pan	15	Clear
Nov 6	12:20	Tri-X Pan	15	Clear
Nov 28	12:32	Tri-X Pan	15	Very Clear
Nov 29	12:00	Tri-X Pan	15	Very Clear
	12:25	Tri-X Ortho	15	Very Clear
Dec 6	12:51	Tri-X Pan	10	Very Clear
1974 Jan 11	01:37	Tri-X Pan	10	Very Clear
	01:59	Tri-X Pan	10	Very Clear
	02:15	Tri-X Pan	16	Very Clear
Jan 12	C2:00	Tri-X Pan	16	Hazy
	02:26	Ektachrome	24	Hazy
Jan 14	02:25	Ektachrome	15	Clear
	02:42	Tri-X Pan	10	Clear
Jan 15	02:26	Ektachrome	15	Clear
	02:48	Tri-X Pan	15	Clear
	03:00	Tri-X Pan	10	Clear
Feb 1	02:21	Tri-X Pan	10	Thin cirrus

Figures

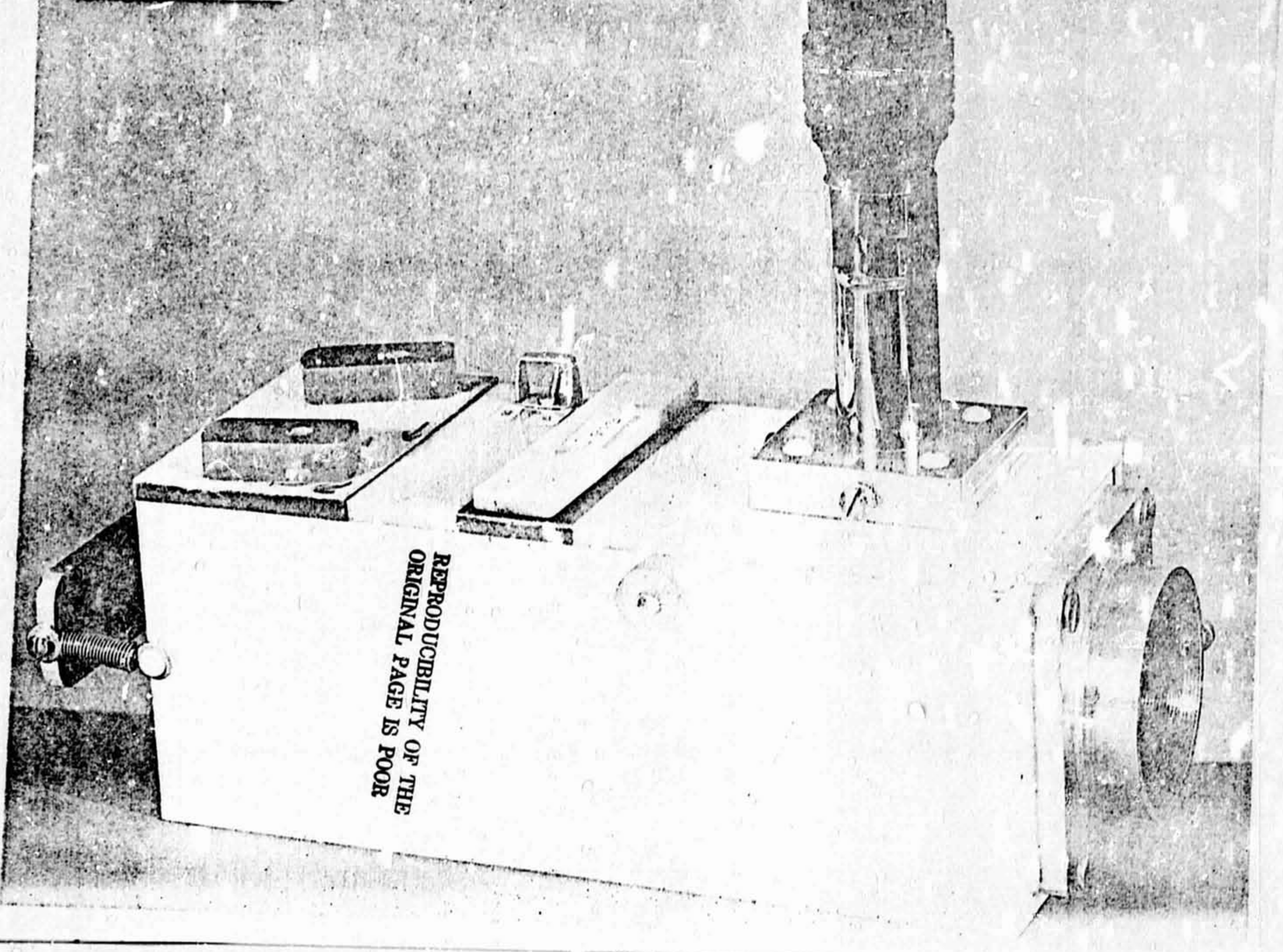
1. Image tube camera as used for Comet Kohoutek.
2. Interior layout of image tube camera showing reflex mirror, centering eyepiece, batteries, filter space, image tube, and pressure plate to hold the film in contact with the tube output.
3. Camera on modified offset guider. The guiding eyepiece has a small, high gain micro-channel plate image tube to guide on fainter stars. Its power supply and control is seen to the left of the offset motion screw.
4. Image tube photos of the coma of Comet Kohoutek in several spectral bands. Note structure difference between continuum and C_2. CN and CO^+ are very weak and are elongated by trailing. C_3 and NA are affected by contamination in the near-infrared.
5. Intensity profiles of C_2 and continuum.
6. Objective prism spectrum of Comet Kohoutek (by R.B. Minton) showing the prominent coma and tail emissions from 3800 Å to about 8000 Å.
7. Color separation from a color photograph and isolation of CO^+ and CH emissions by photographic subtraction.

8-15. 42 cm. Schmidt photographs of Comet Kohoutek. All on Tri-X panchromatic film.

8-11. Pre-perihelion. N to left.

12-15. Post-perihelion. N to left.

Figure 1.



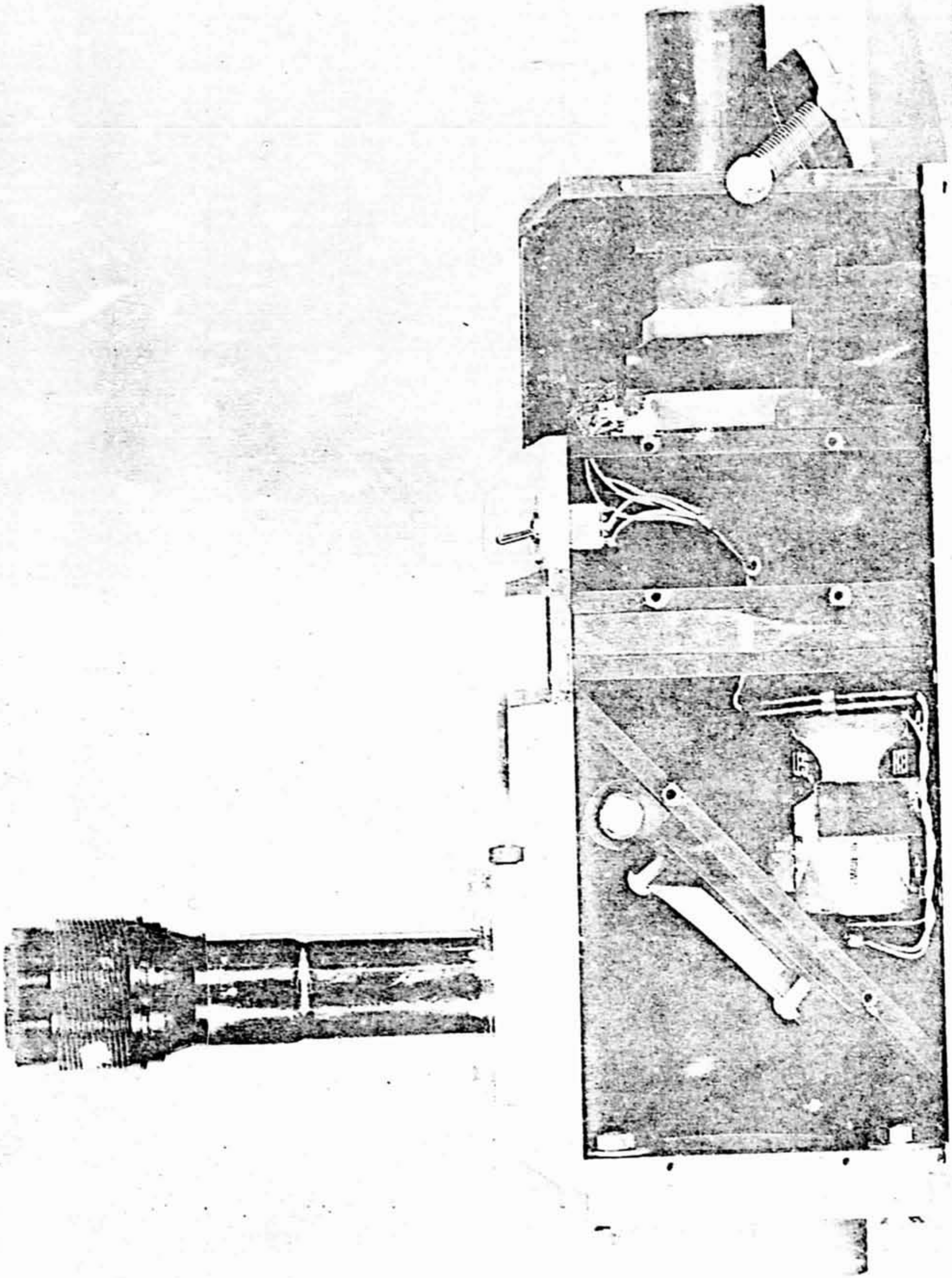


Figure 2.

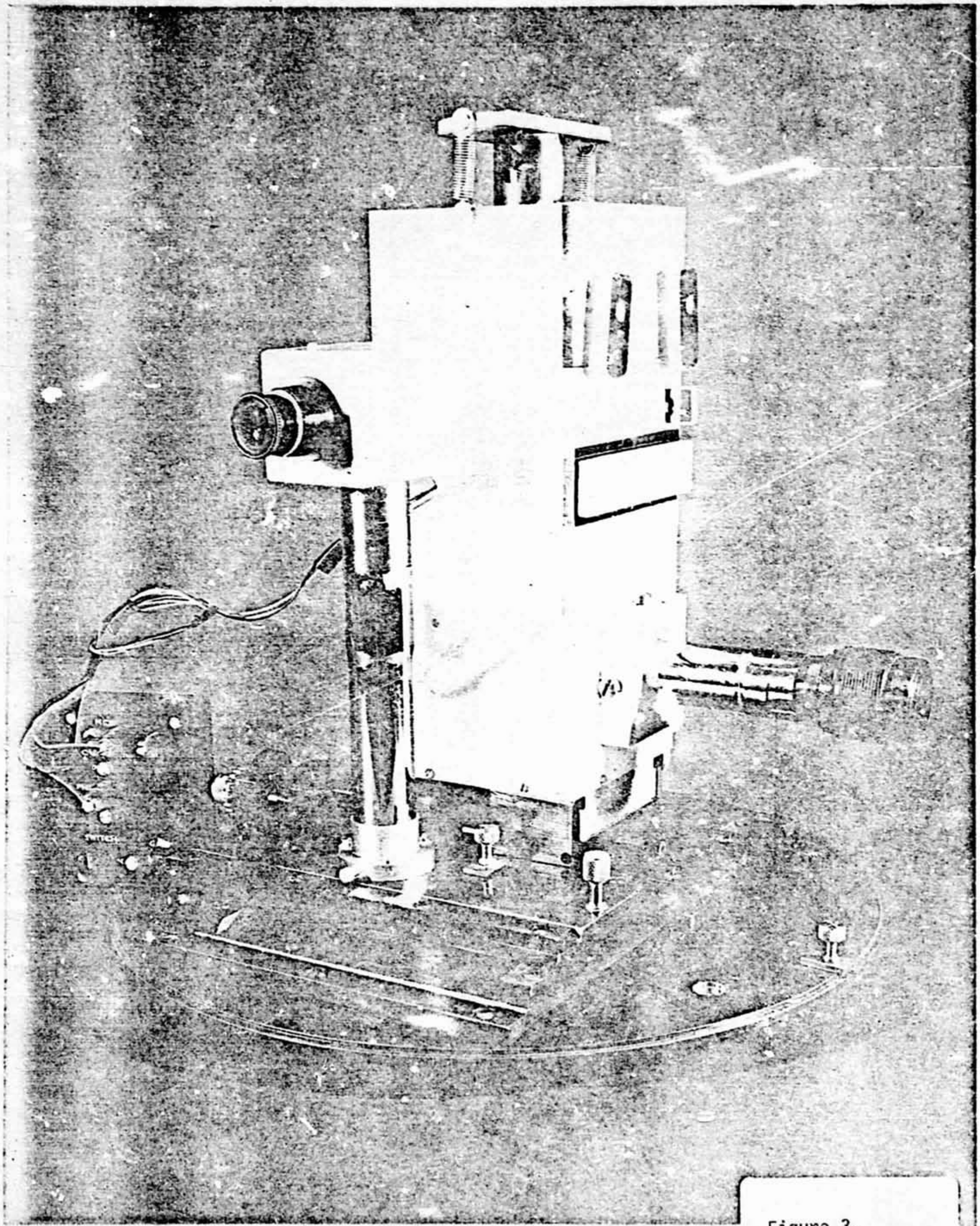
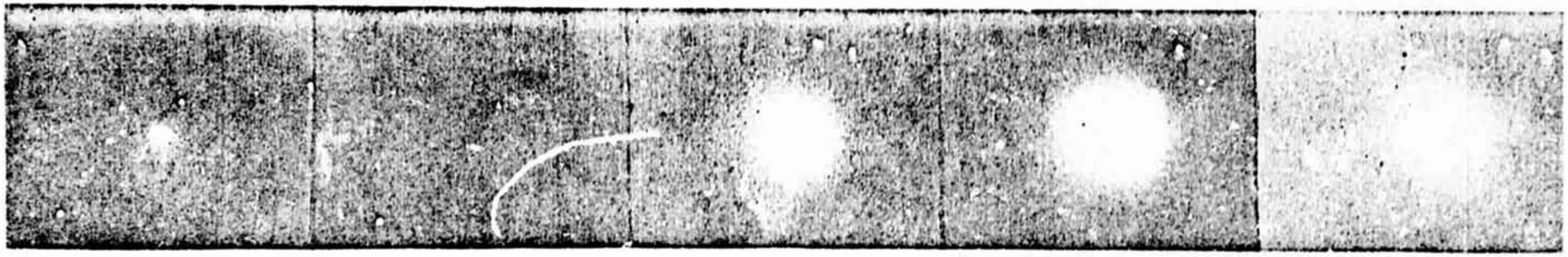


Figure 3.

COMET KOHOUTEK 1973f

JAN. 11, 1974



CN 3854-3900 Å | CO^+ 3966-4034 Å | Continuum 4763-4977 Å | C_2 5094-5186 Å | Na 5886-5900 Å

61" CATALINA OBS.

Figure 4.

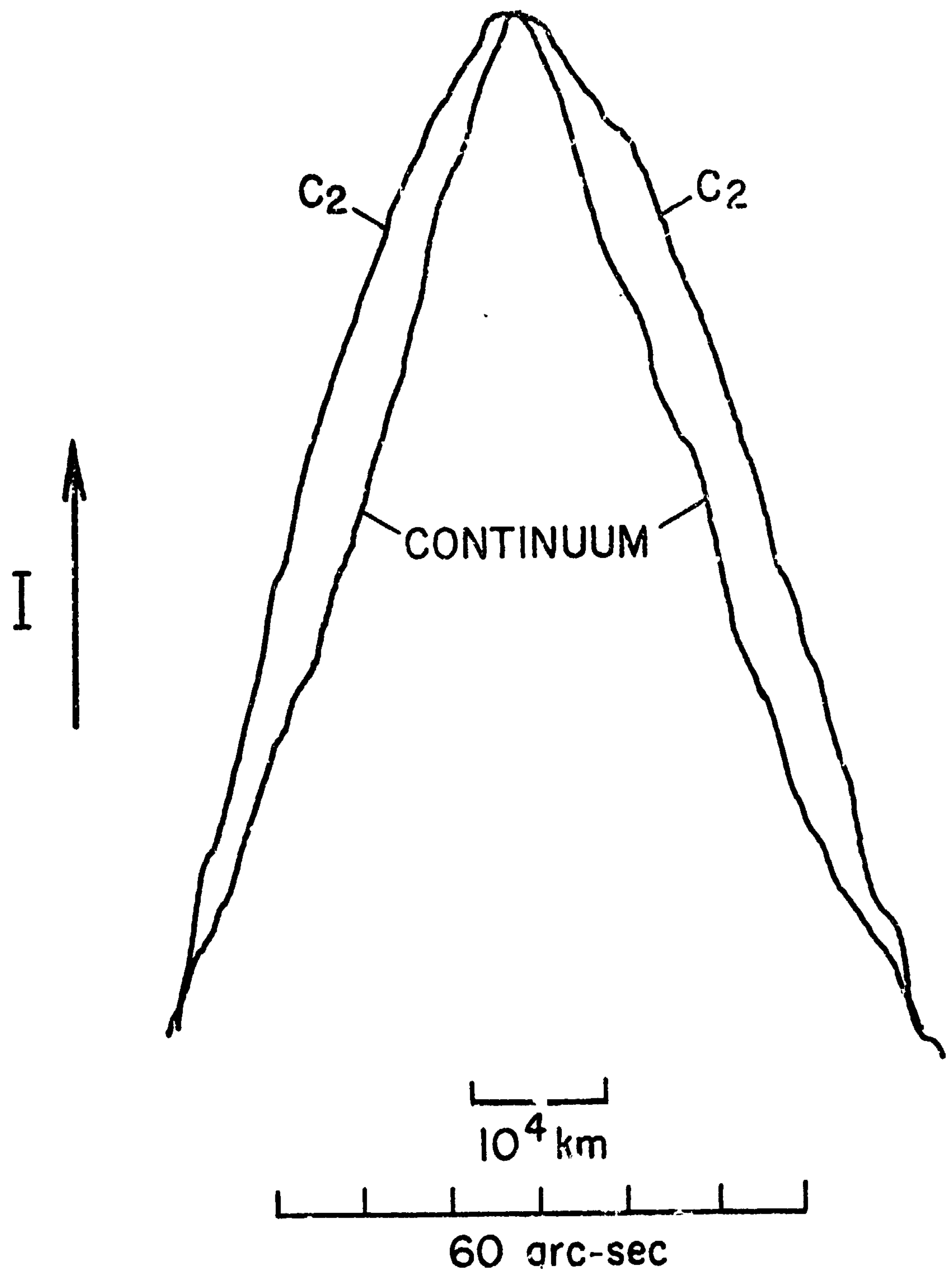
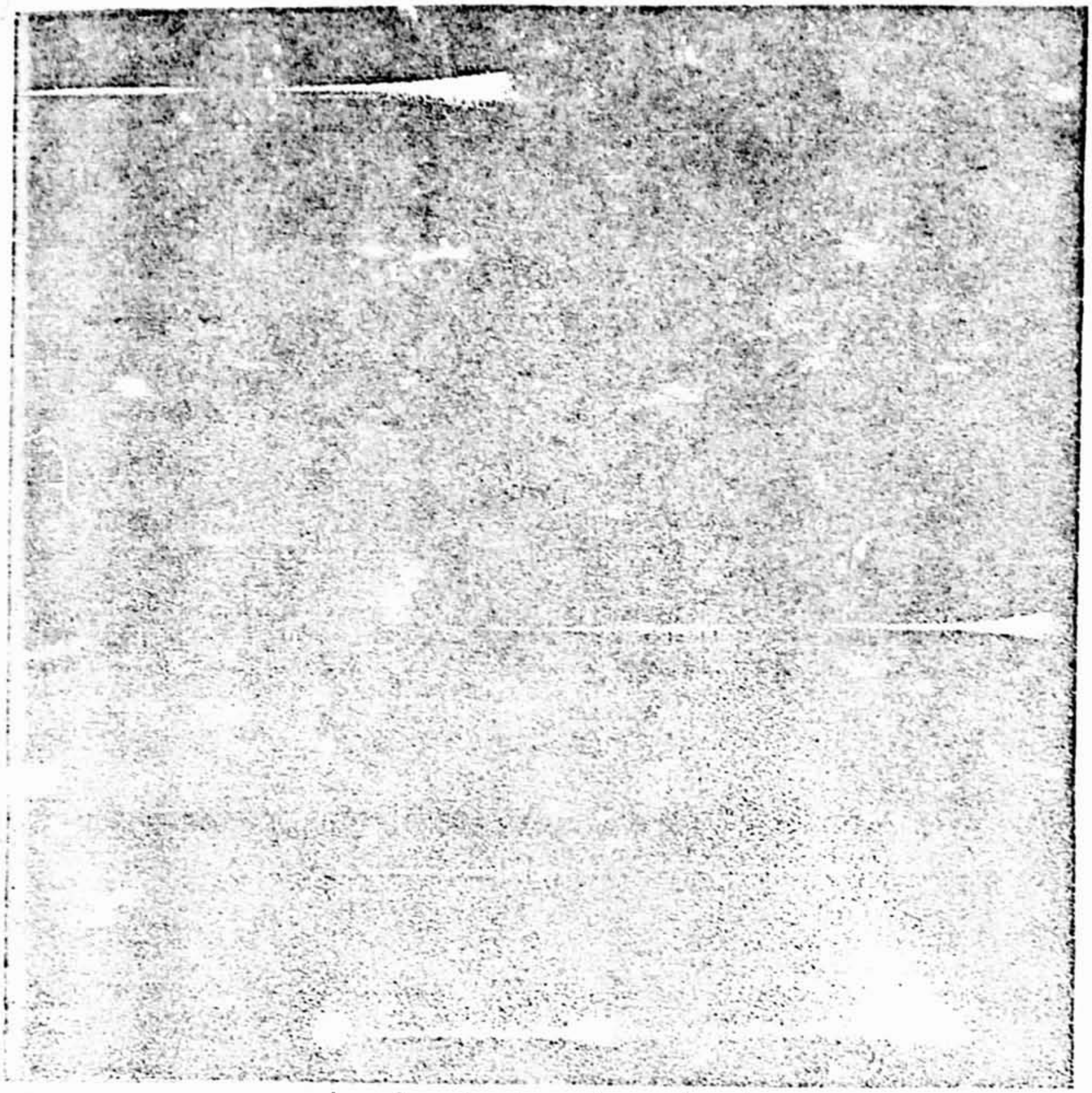


Fig. 5. Intensity profiles of C_2 and continuum in the coma of comet Kohoutek (1973f) traced perpendicular to the solar radius vector through the nucleus. The slower dropoff of C_2 with distance from the nucleus is due in part to the relative lack of solar radiation pressure that causes the continuum reflecting dust to be drawn away from the coma.



OBJECTIVE PRISM SPECTRUM

COMET KOHOUTEK 1973f

JAN. 11, 1974

Figure 6.
LPL

COMET KOHOUTEK 1973f

JAN. 11, 1974

A. Blue ,~3800-4800Å

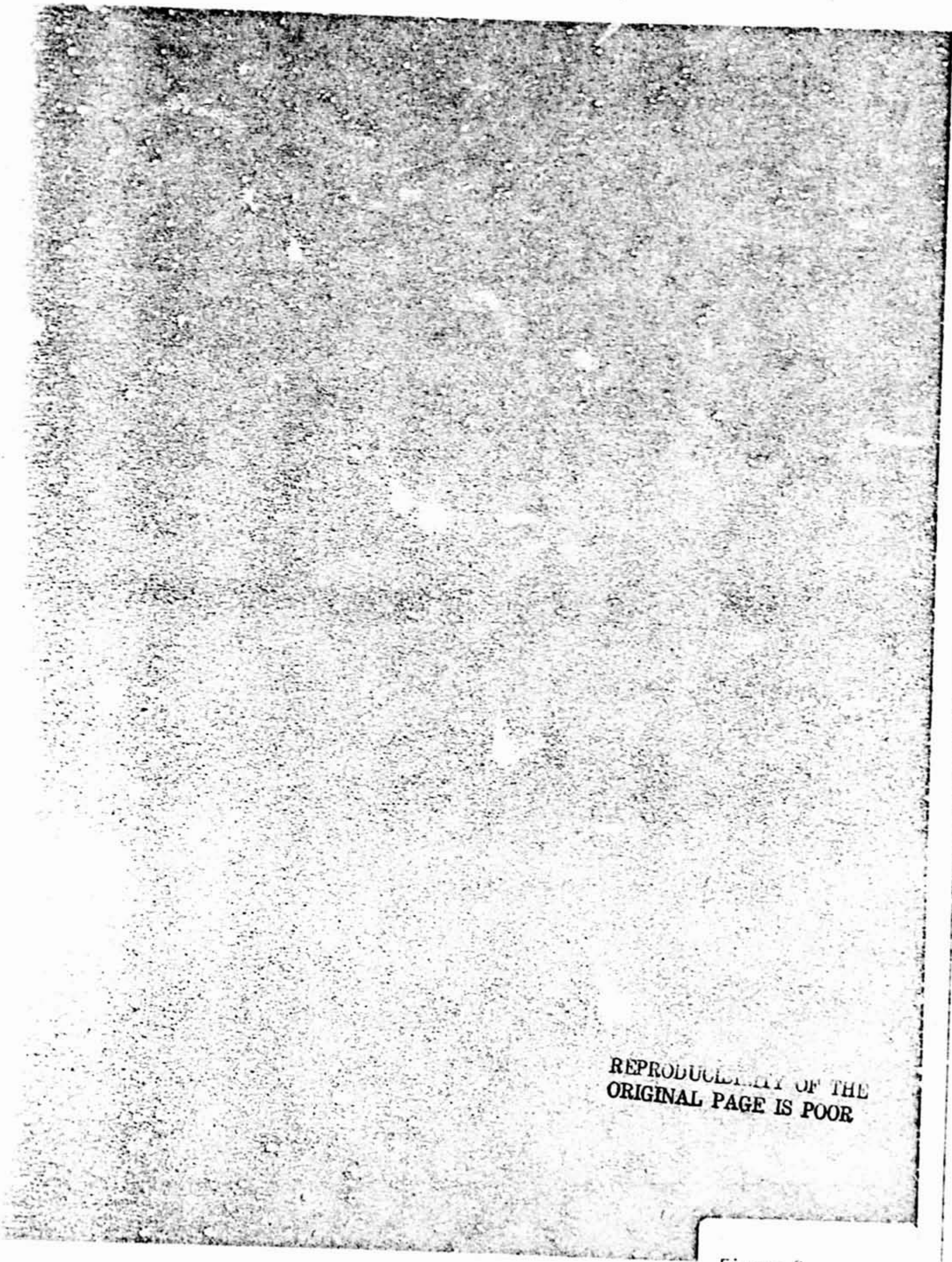
B. Red, ~6000-6700Å

A minus B leaving CO^+ and CN emissions

From color Ektachrome-EF

Figure 7.

LPL



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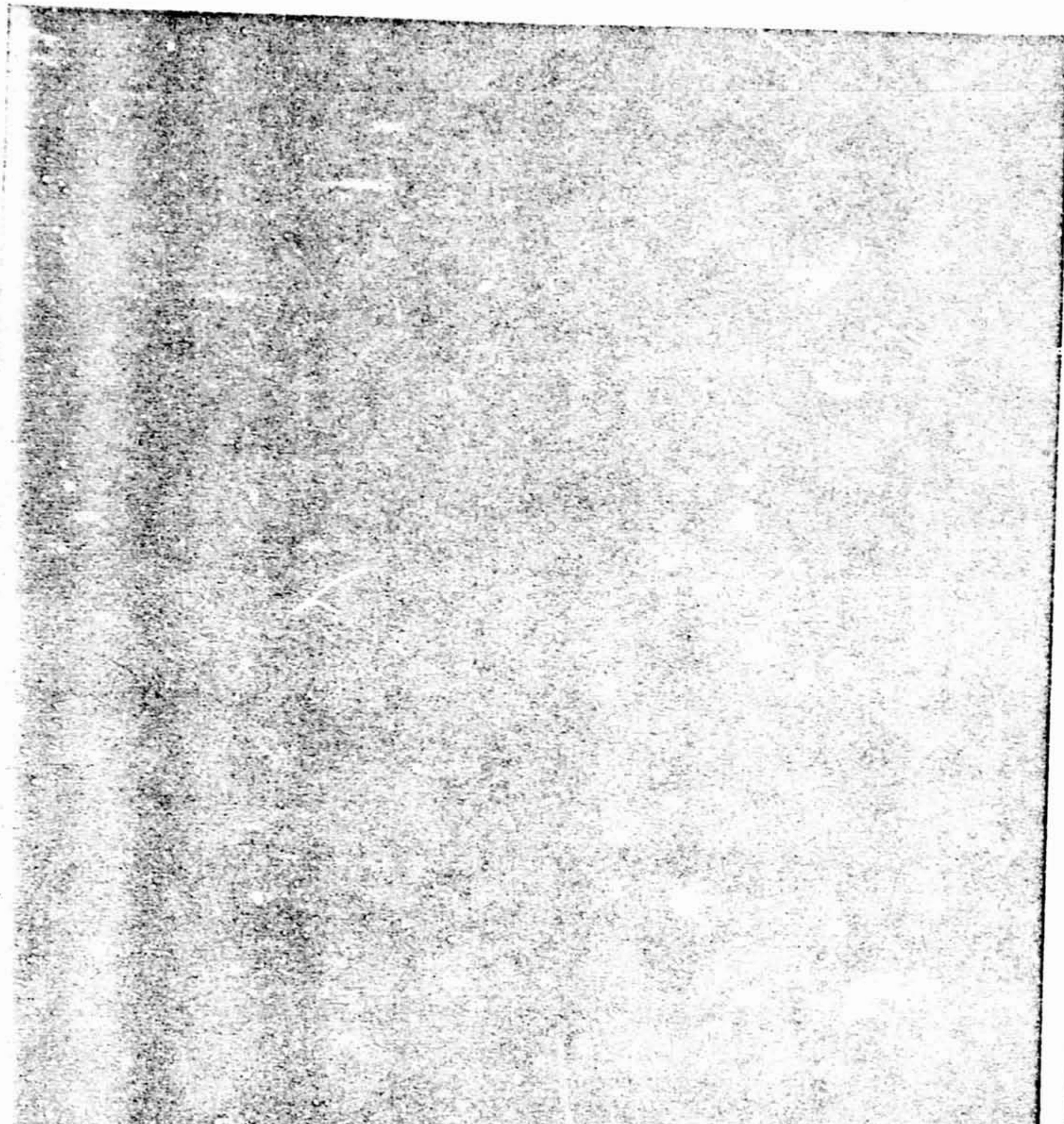

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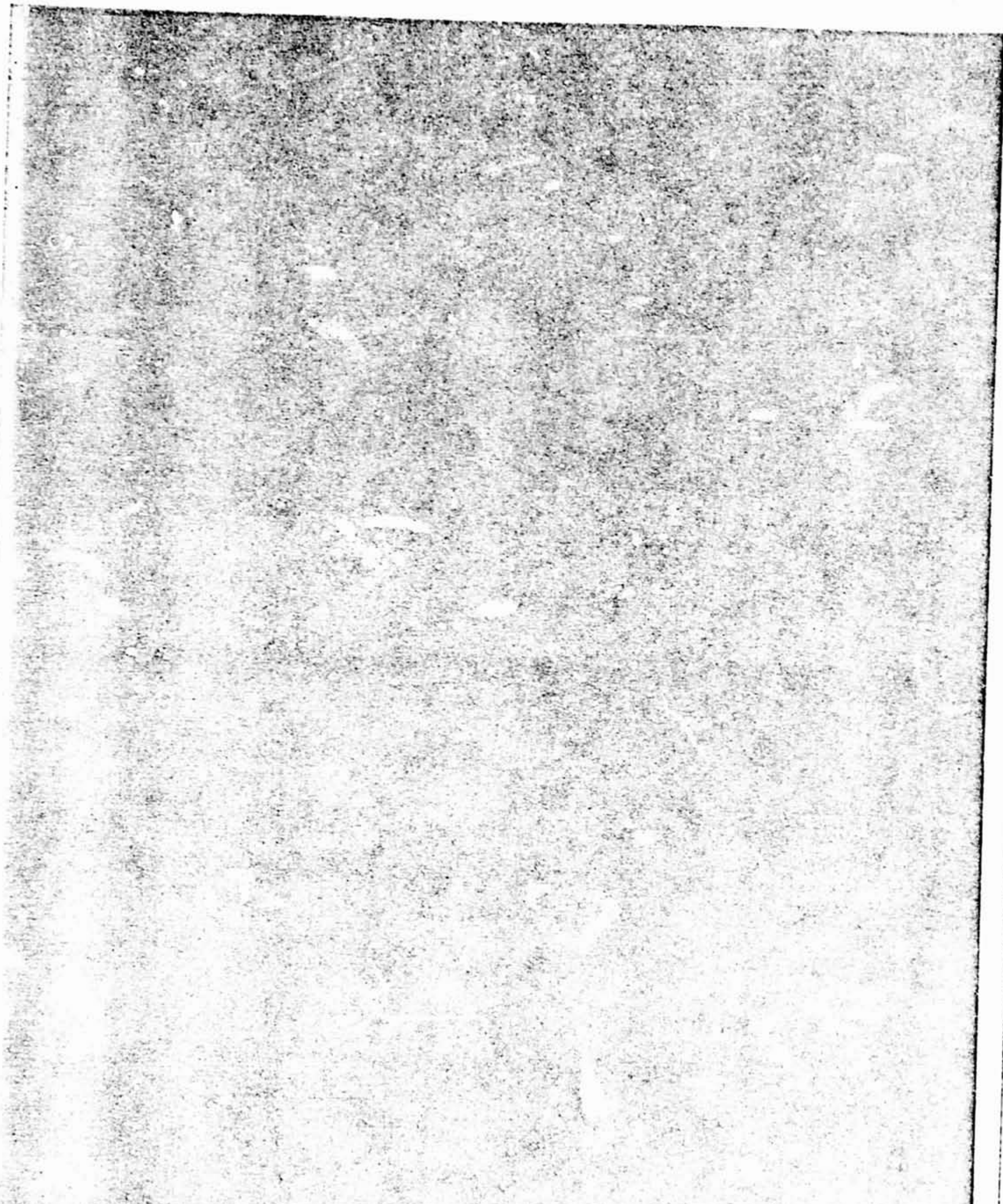

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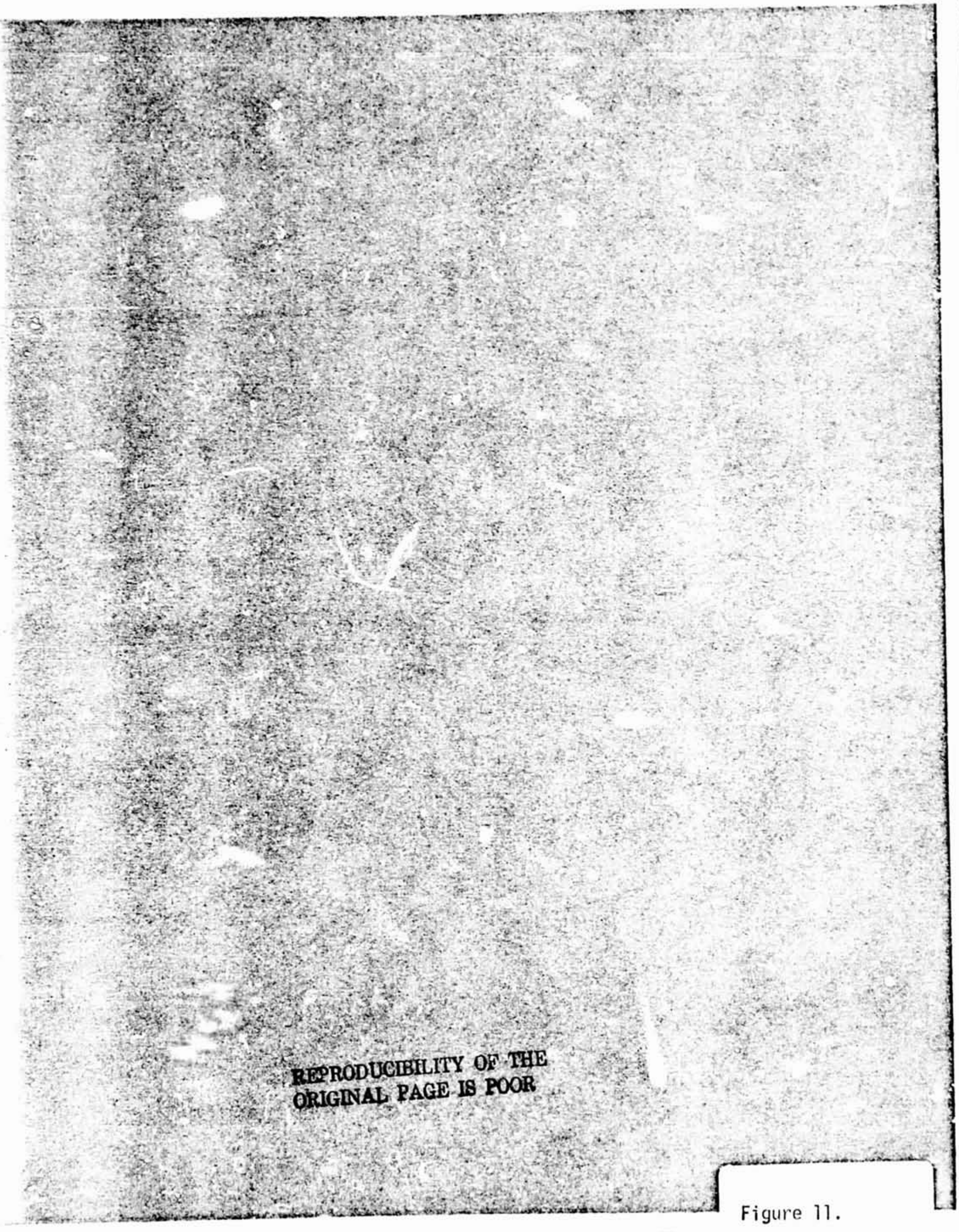
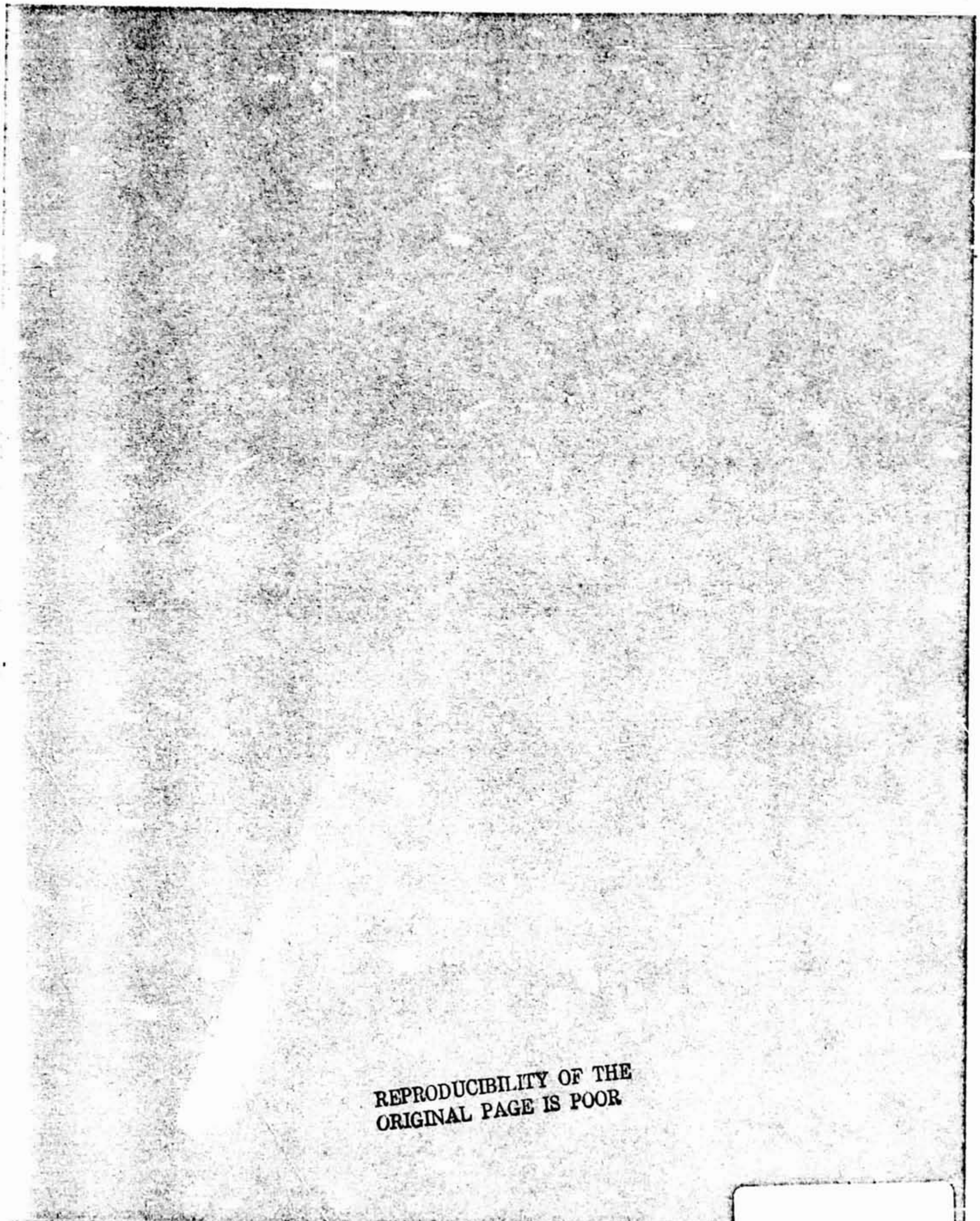


Figure 11.



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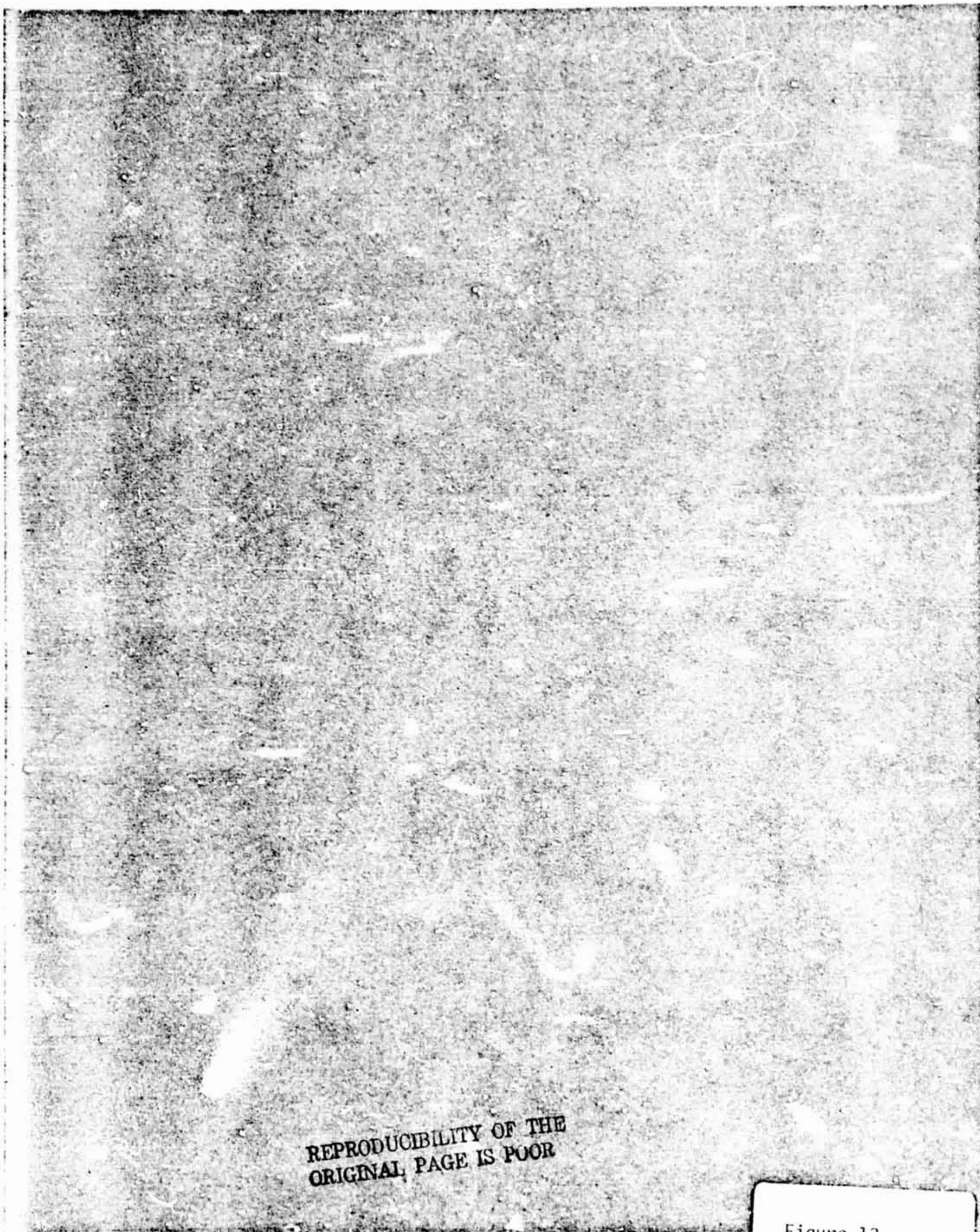

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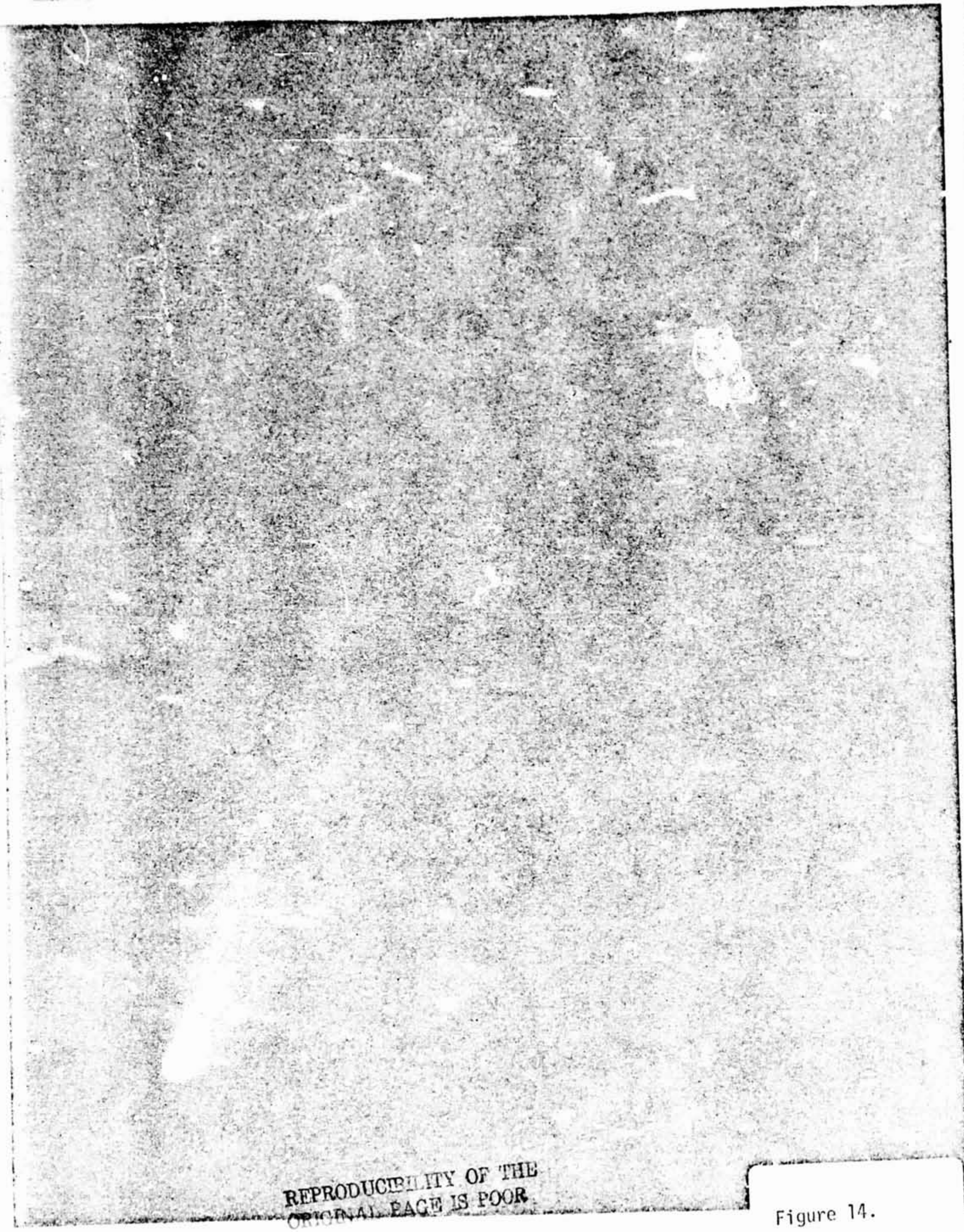

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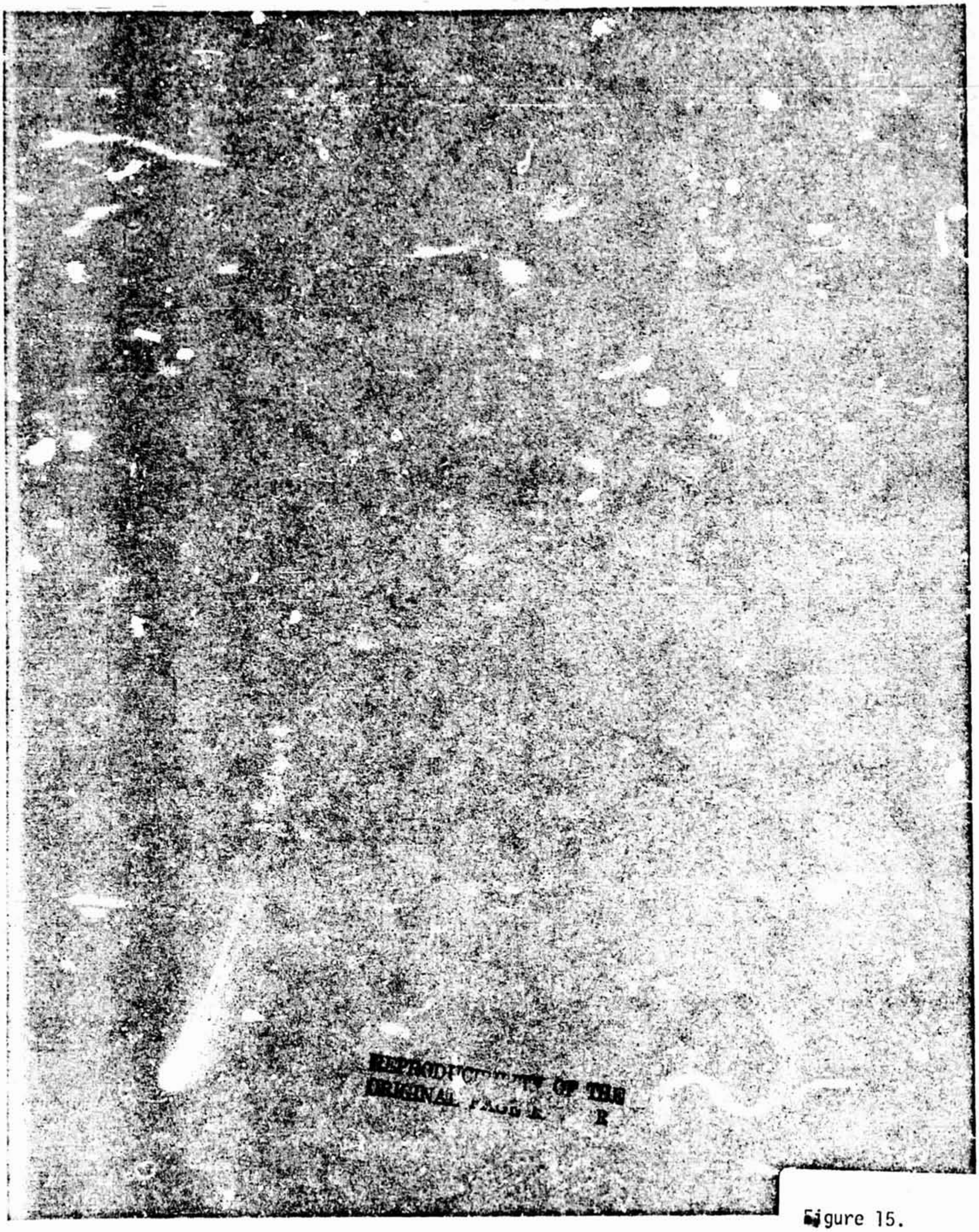

Figure 15.