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RADIATION DEGRADATION OF SELECTED FILMS

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Space Sciences Laboratory

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The change in base fog caused by radiation damage was measured for the following film types: SO-180, EF 7241, EFB 7242, SO-246, SO-267, 2475, Plus-X, Tri-X, and 1N. The films were exposed to Co^{60} gamma rays in addition to 51.1- and 130.6-MeV protons. Graphs of density change versus radiation exposure are included in this report. Sensitometric curves are also given for SO-246, SO-267, 2475, 1N, Plus-X, and Tri-X films.

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EDITOR'S NOTE

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TECHNICAL MEMORANDUM X-64524

RADIATION DEGRADATION OF SELECTED FILMS

SUMMARY

The change in base fog caused by radiation damage was measured for the following film types: SO-180, EF 7241, EFB 7242, SO-246, SO-267, 2475, 1N, Plus-X, and Tri-X. These films are being considered for possible use in the Skylab I program. Graphs of density change versus radiation exposure are included in this report. The films were exposed to Co^{60} gamma rays in addition to 51.1- and 130.6-MeV protons.

The results of this investigation show that additional shielding will be required by the majority of the films for a typical 56-day mission of Skylab I.

The film degradation produced by the Co^{60} irradiation cannot indicate the film damage caused by monoenergetic protons. Similarly, the radiation damage of a film cannot be determined by its ASA.

INTRODUCTION

This experiment is a continuation of previous work which measured the change in the base fog density of film as a function of radiation dose [1].[1,2] Most film is very sensitive to radiation; hence, film badges are routinely used as integral dosimeters.

The films evaluated in this report (Table 1) are being considered for possible use in the Skylab I program. The films in the vehicle will receive from 0.1 to 0.2 rad/day in a typical orbit [2]. The thin-shield spectrum of the radiation can be approximated to some degree by a 50-MeV proton beam. Additional shielding of the film will be needed because of the high dose rate in the vehicle. Thus, higher energy proton beams are needed to simulate the radiation penetrating the additional shielding. The film was exposed not only to 51.1-MeV protons but also to 130.6-MeV protons and a Co^{60} source. The degradation of film caused by Co^{60} gamma rays is similar to the damage caused by 450-MeV protons.[3]

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1. N. T. Lamar: Determining the Effects of Radiation on Selected Films. Internal Note MSC-BA-R-67-2, Manned Spacecraft Center, National Aeronautics and Space Administration, Houston, Tex., December 1967.

2. K. E. Huff and H. M. Cleare: Effects of Proton Exposure on Several Kodak Black and White Films. Unpublished report, Eastman Kodak Co.

3. Ibid.

TABLE 1. PARAMETERS OF EVALUATED FILMS

Film Type	Developer	Time (min)	Temp. (°F)	ASA
1N (B&W)	D-19	4	68 ± 1/2	64
2475 (B&W)	D-19	2.5	68 ± 1/2	1500
Plus-X (B&W)	D-19	8	68 ± 1/2	80
Tri-X (B&W)	D-19	3	68 ± 1/2	100
SO-246 (B&W)	D-19	10	68 ± 1/2	125
SO-267 (B&W)	D-19	8	68 ± 1/2	400
EF 7241	← ME-4 Process[a] →		98 ± 1/4	160
EFB 7242	← ME-4 Process[a] →		98 ± 1/4	100
SO-180	← E-3 Process[a] →		75 ± 1/4	100

a. The ME-4 and E-3 processes specify standard developers and developing times.

Our results show that for the same dose, high-energy protons damage the film more than low-energy protons. The radiation degradation of a film cannot be determined solely by its ASA, although the higher ASA films are usually more sensitive to radiation.

RADIATION EXPOSURES

The film was exposed to a 2.5-millicurie Co^{60} source. Filmstrips were placed from 5.8 cm to 58 cm from the source and irradiated for 24 hours.

The proton exposures were made in December 1969 at the Harvard University cyclotron. The beam flux was monitored with an ionization chamber located upstream from the film. The ionization chamber was calibrated with a Faraday cup. The beam profile was measured with a radiation-sensitive diode; the profiles were flat with a steep dropoff. Effective cross-sectional areas of 4.07 cm^2 and 3.79 cm^2 were measured at beam energies of 51.1 MeV and 130.6 MeV.

The beam energies were determined with absorbers and with the range and energy relations of Janni [3]. The beams were obtained by degrading the main 159-MeV beam with absorbers. The beam spread (full width at half maximum) was 3.5 MeV at 130.6 MeV and 9.2 MeV at 51.1 MeV.[4]

4. A. M. Koehler: Private communication. Harvard University, Cambridge, Mass., December 1969.

FILM PROCESSING

The development conditions for each film are given in Table 1. The black-and-white films were developed in a Jarrill Ash laboratory processor. The film was placed directly in the developer and agitated with a linear sinusoidal motion at 30 cpm with a maximum amplitude of one-half inch. The film was then stopped in a water bath for 1 minute and fixed in Rapid Fixer for 3 minutes. This was followed by a 3-minute rinse in clear water. The temperature in the developer was maintained with a thermostat at 68° ± 1/2°F.

The color films were developed at the Marshall Space Flight Center Photographic Division using commercial processing with nitrogen-burst agitation. Fresh chemicals were used. The temperature of the first developer was monitored; it remained within ± 1/4°F of the desired value.

The Co^{60}-irradiated films were processed within 3 days after exposure; however, a portion of the proton-irradiated film was not processed for 3 weeks. All the film not immediately developed was stored in a refrigerator at 45°F. The gammas of the black-and-white film processed with the Jarrill Ash system were measured. The Co^{60}-irradiated films were exposed uniformly on a sensitometer with white (3500°K) light.

DATA

Figures 1 through 13 show the density change in base fog as a function of radiation dose. Density is defined as $\log_{10}(1/T)$, where T is the fraction of transmitted light. Since color films have a maximum base fog with no exposure, the density change as shown in Figures 7 through 13 is negative. The radiation degradation of EFB 7242 is nearly identical to that of EF 7241. As can be seen (Figs. 12-13) 7242 has more damage in the blue region and less damage in the green than 7241. Figures 14 through 19 give the results of the sensitometric exposures of the black-and-white films.

The damage recorded by the film is very sensitive to processing conditions. Figure 20 shows the change in radiation degradation of Tri-X film as a function of different developing times.

A scattering of data was observed for film processed under "identical" conditions. Thus, there can be an error in the density change of ± 7 percent or ± 0.01, whichever is greater. A greater scattering of data was observed for 1N film, probably because of its unprotected surface. The density change of 1N is estimated to be in error by ± 20 percent or ± 0.01, whichever is greater.

The doses produced by the Co^{60} can be in error by ± 10 percent as a result of the uncertainty of the source strength. The proton-beam doses are estimated to be in error by ± 3 percent.

DISCUSSION

At the same dose, the higher-energy protons damage the film more than the low-energy ones. The ionization of the protons in the nonrelativistic region is inversely proportional to their energy. At the lower beam energies, a portion of the ionization is wasted. A proton will impart more energy to grains than is needed to make them developable. Thus, there is a decrease in damage efficiency as the proton energy decreases.

The SO-180 film is more damaged at a given dose than is the 2475 film, which has 15 times the ASA. It appears, therefore, that the ASA is not a good indicator of the radiation degradation of a film.

The film degradation is a different function of proton energy for different films. The three proton curves in Figure 2 (SO-267) have a greater separation than the three curves in Figure 4 (Tri-X). Therefore, the proton damage to a film cannot be determined by observing the Co^{60} damage alone.

CONCLUSIONS

The following conclusions were reached as a result of this investigation:

1. The majority of the films evaluated in this report will need additional radiation shielding for a typical 56-day mission of Skylab I.

2. In the nonrelativistic region and at the same dose, the higher energy protons will damage the film more than the lower energy protons.

3. The radiation damage to a film cannot be ascertained by the ASA alone.

4. The film damage produced by Co^{60} radiation cannot be used to determine the degradation of film caused by proton irradiation.

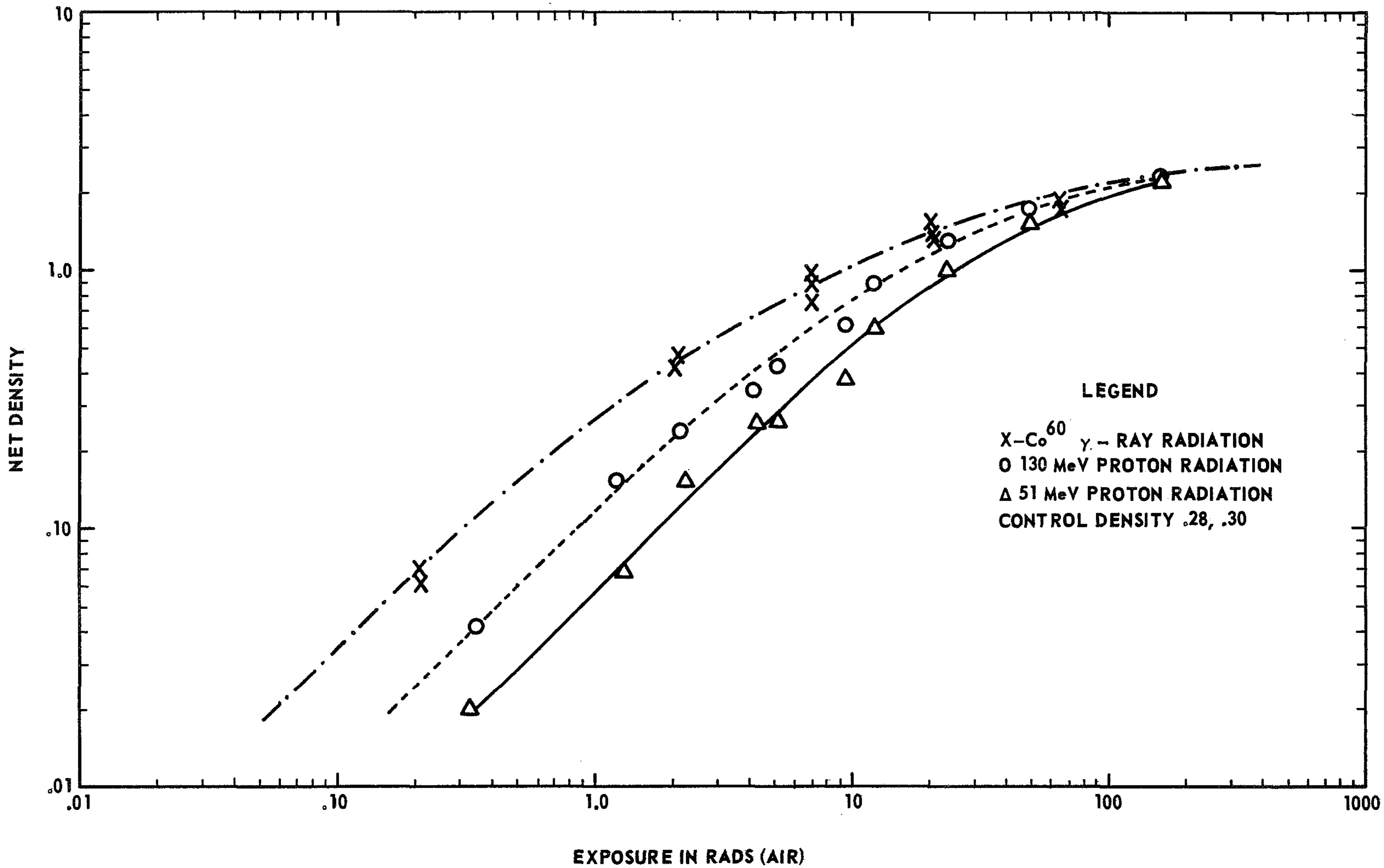

Figure 1. Change in base fog with radiation dose for Plus-X. (Film developed in D-19 at 68° for 8 min.)

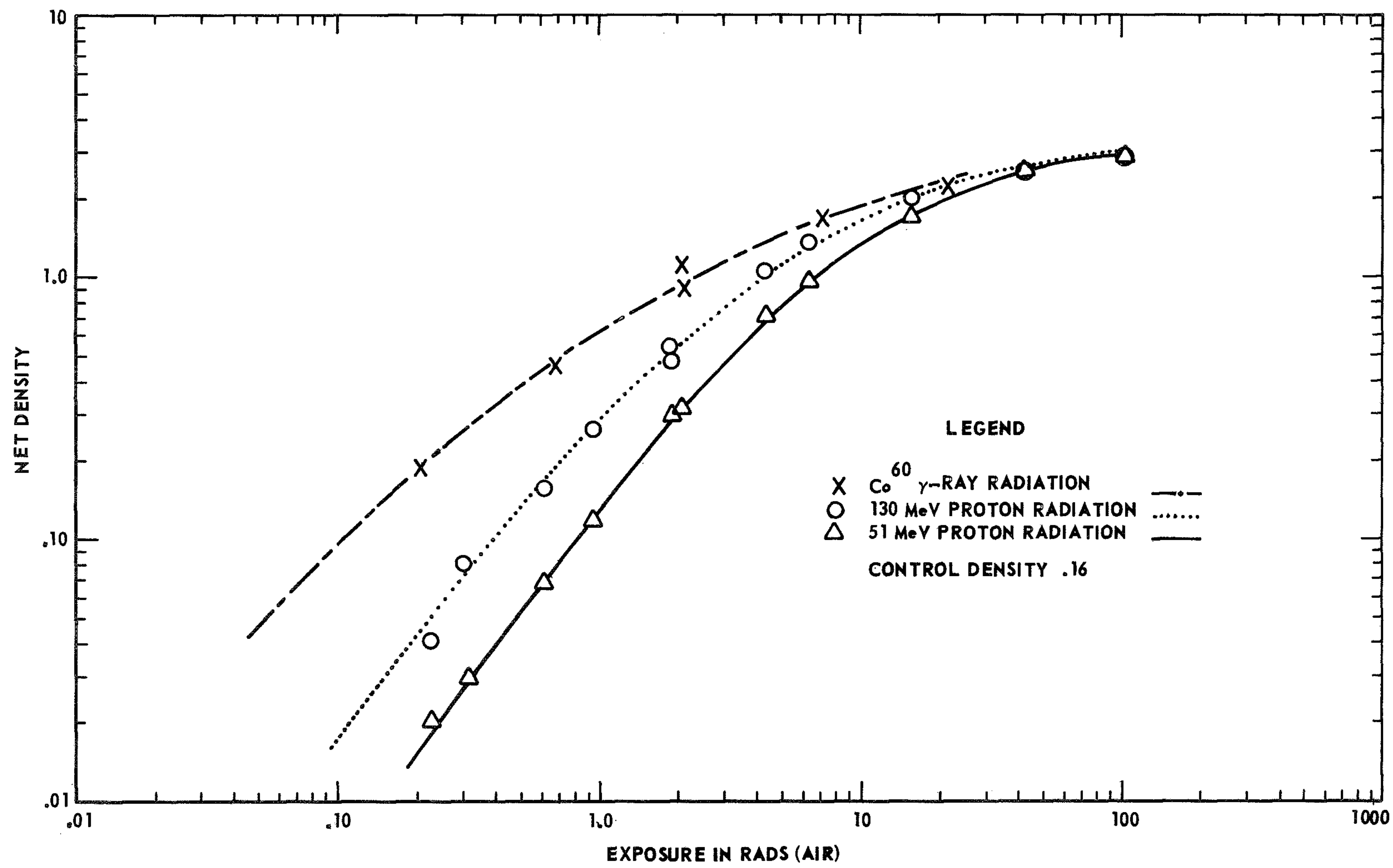

Figure 2. Change in base fog with radiation dose for SO-267. (Film developed in D-19 at 68°F for 8 min.)

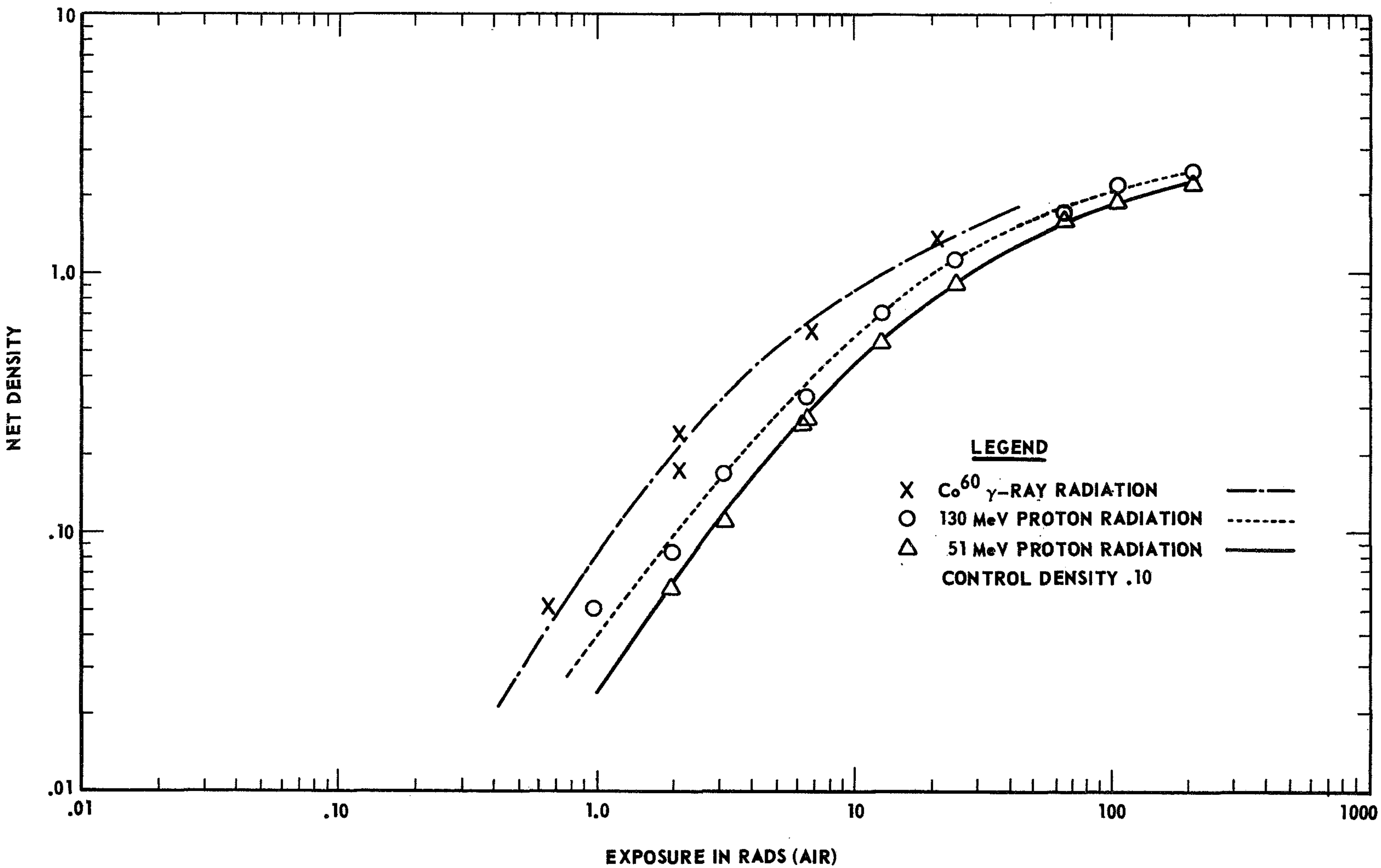

Figure 3. Change in base fog with radiation dose for 1N. (Film developed in D-19 at 68°F for 4 min.)

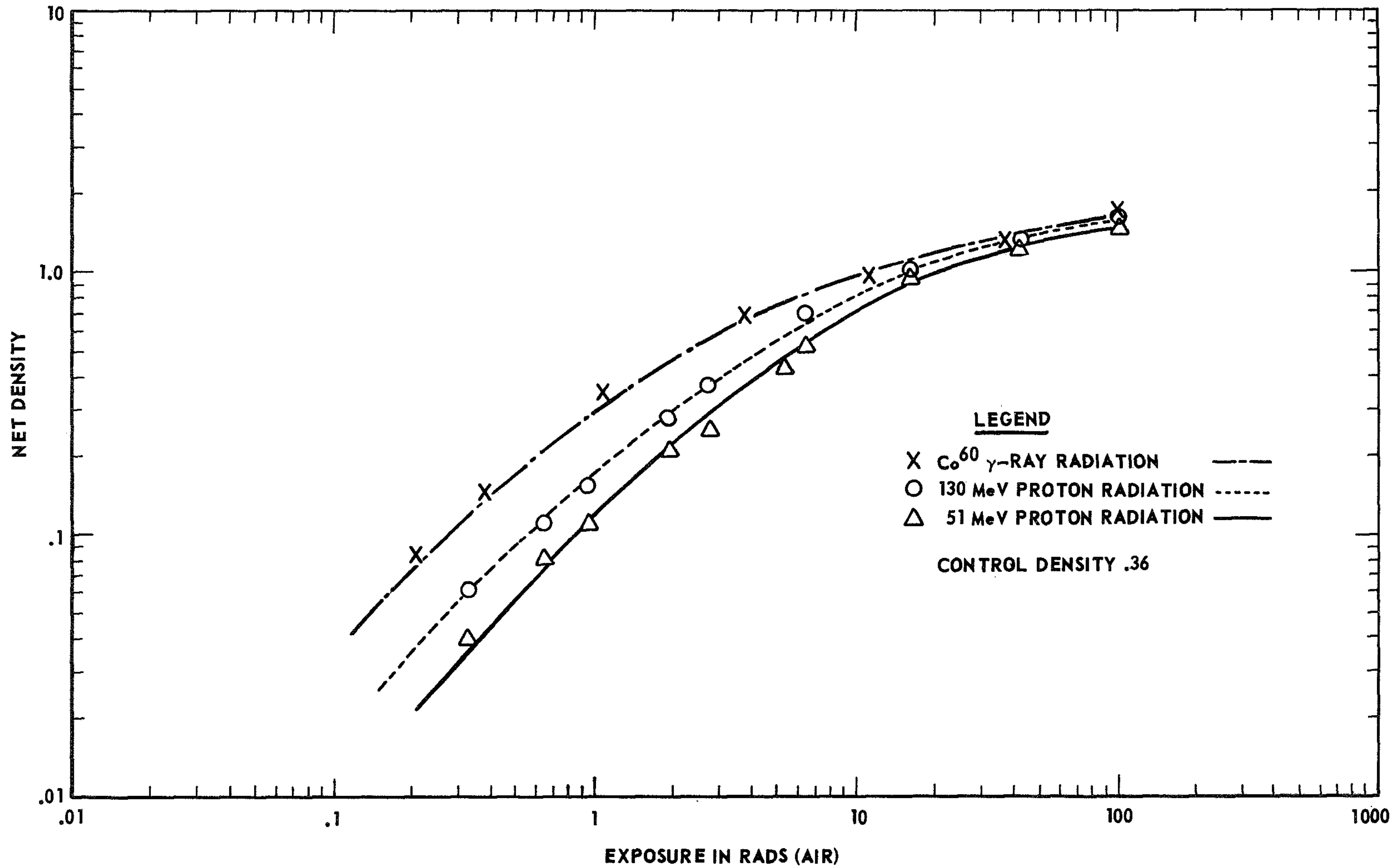

Figure 4. Change in base fog with radiation dose for Tri-X. (Film developed in D-19 at 68°F for 3 min.)

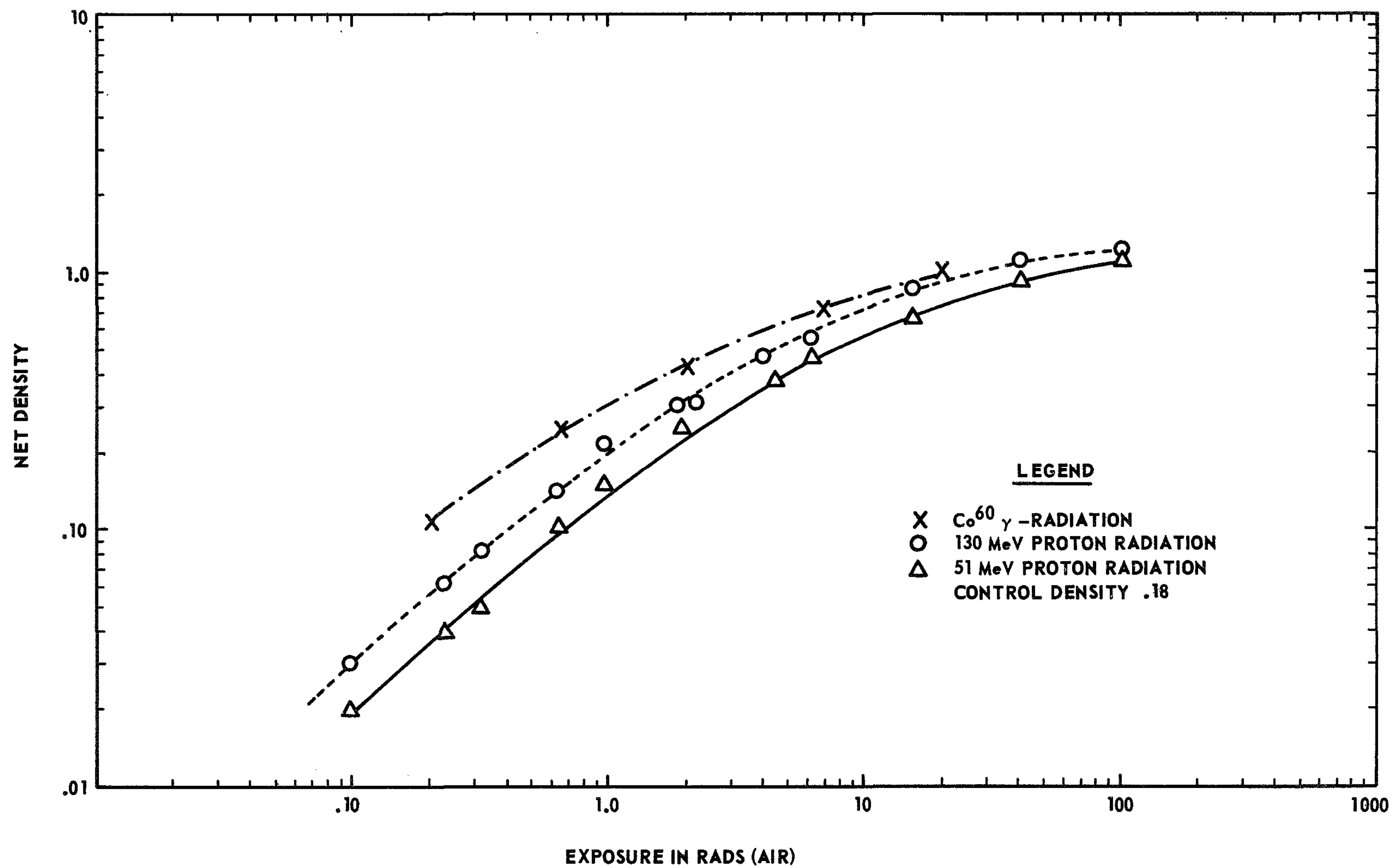

Figure 5. Change in base fog with radiation dose for 2475. (Film developed in D-19 at 68°F for 2.5 min.)

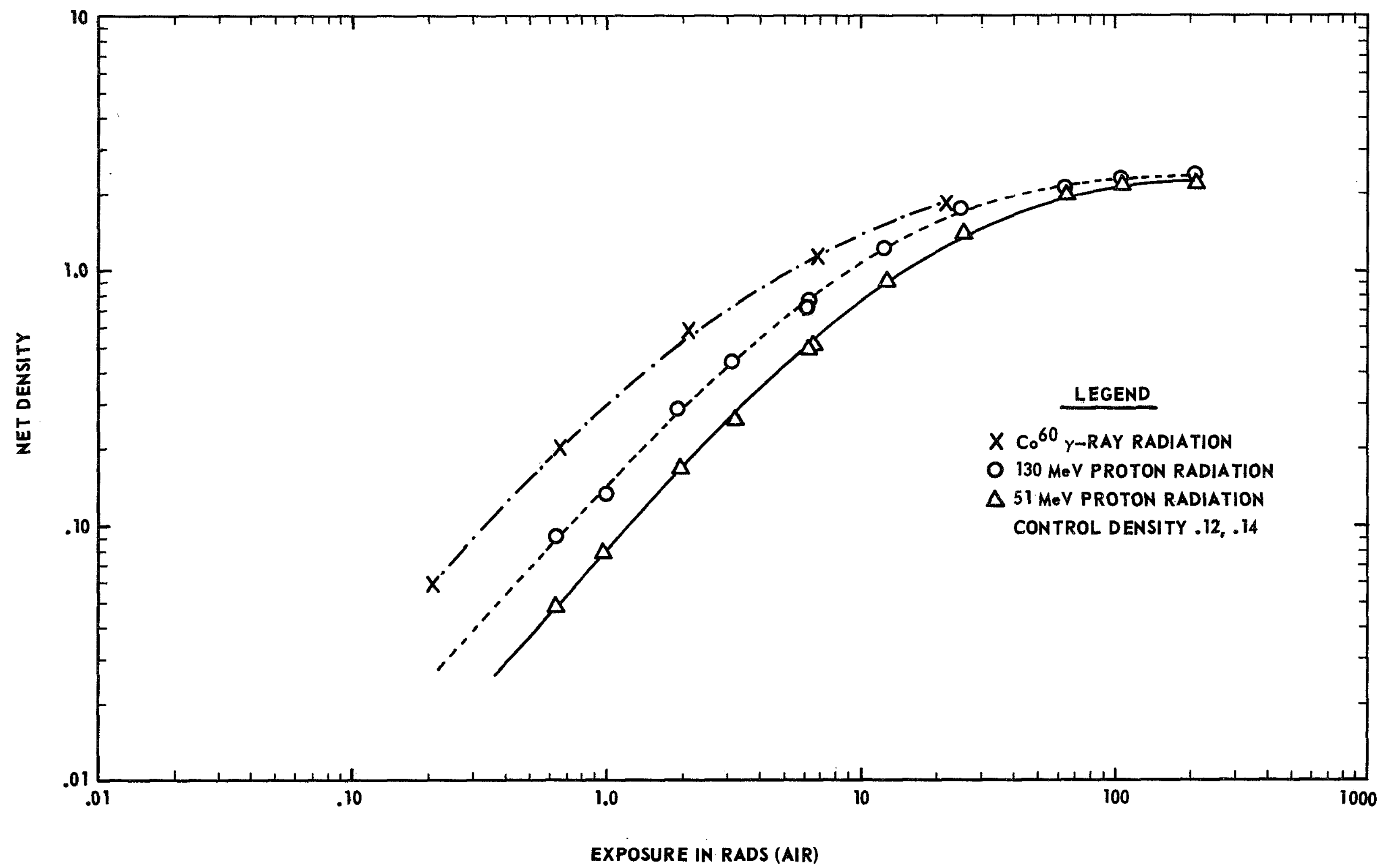

Figure 6. Change in base fog with radiation dose for SO-246. (Film developed in D-19 at 68°F for 10 min.)

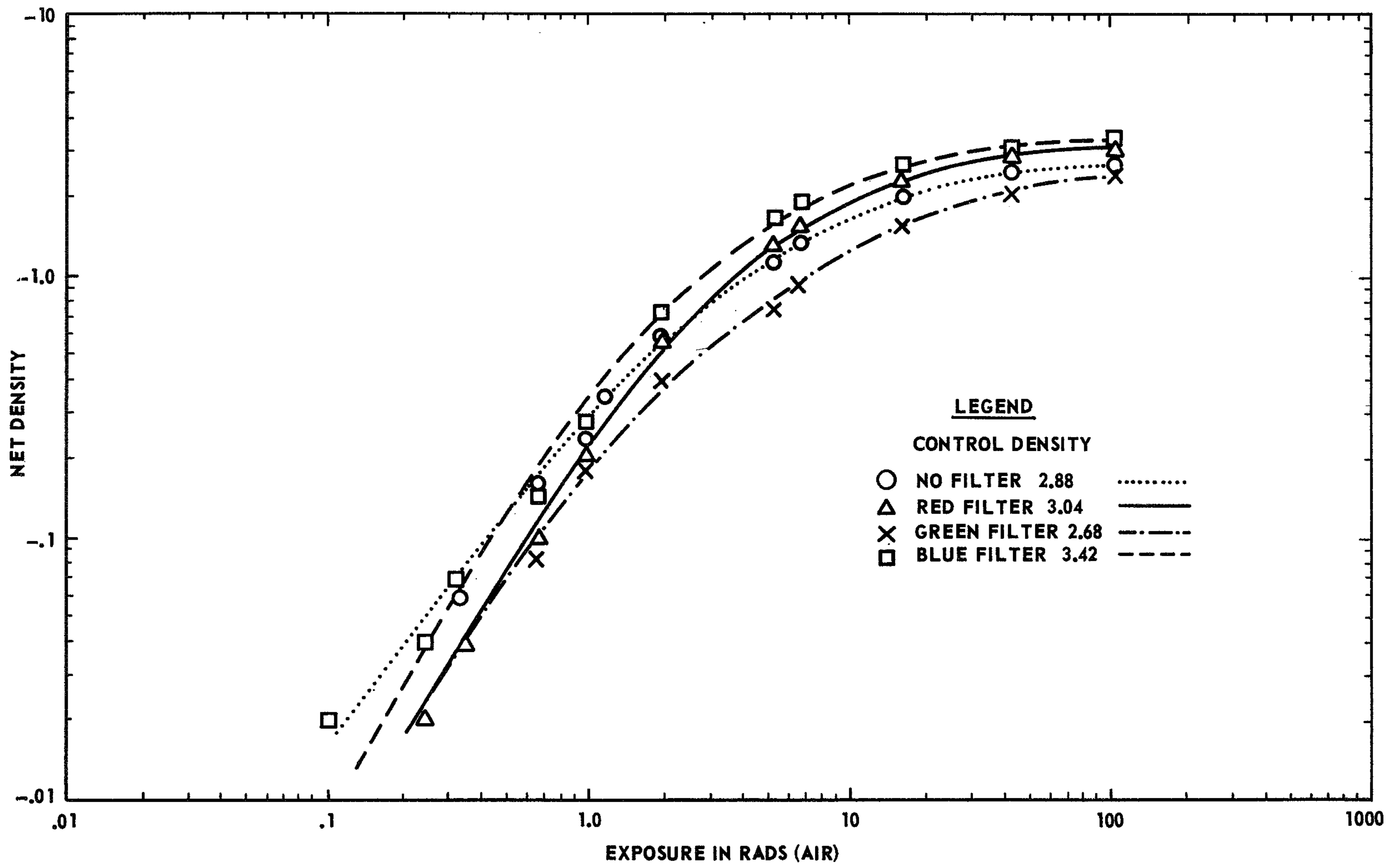

Figure 7. Change in base fog for SO-180 at different radiation doses of 51.1-MeV protons.
(Film developed with E-3 process at 75°F.)

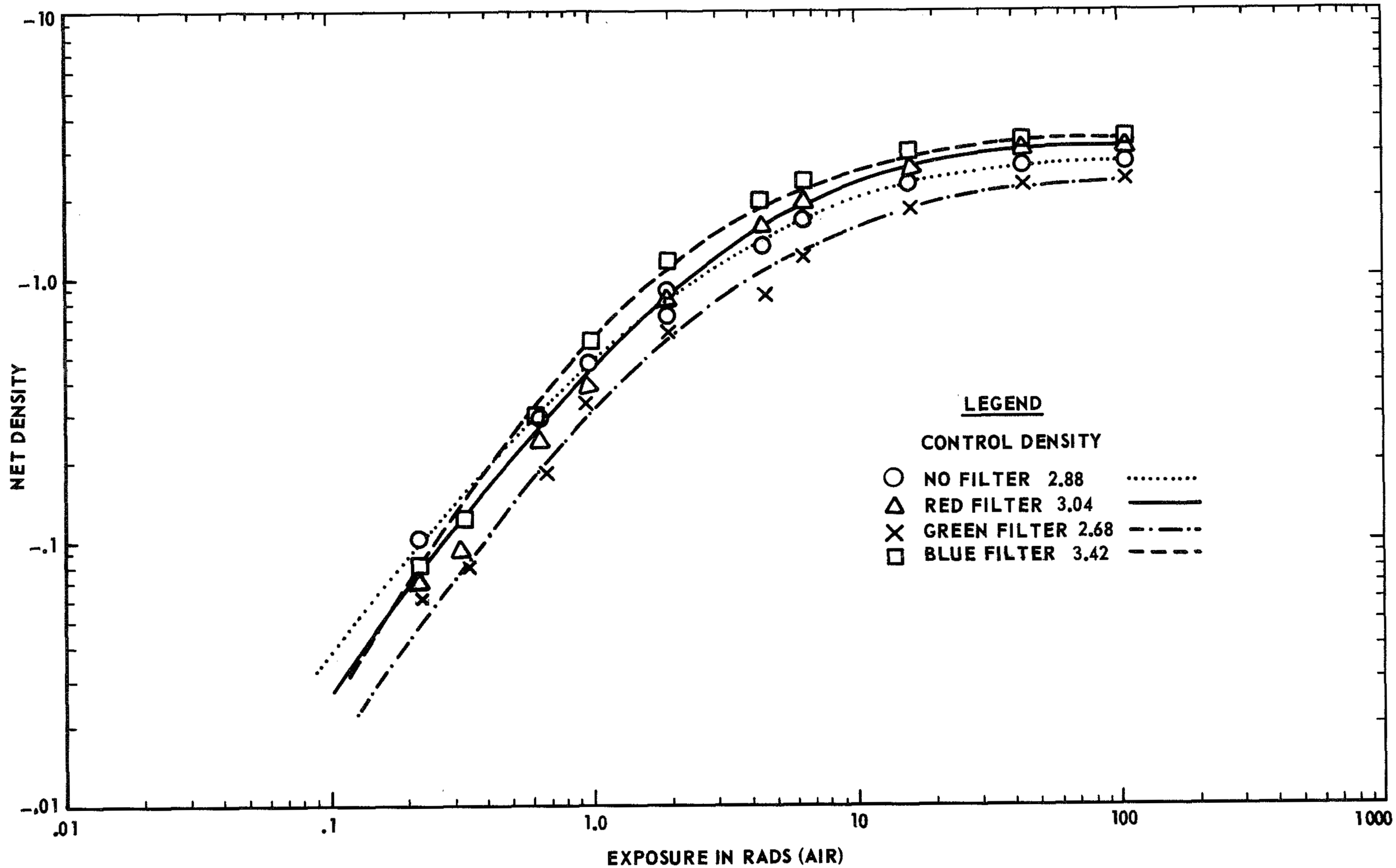

Figure 8. Change in base fog for SO-180 at different radiation doses of 130.6-MeV protons.
(Film developed with E-3 process at 75°F.)

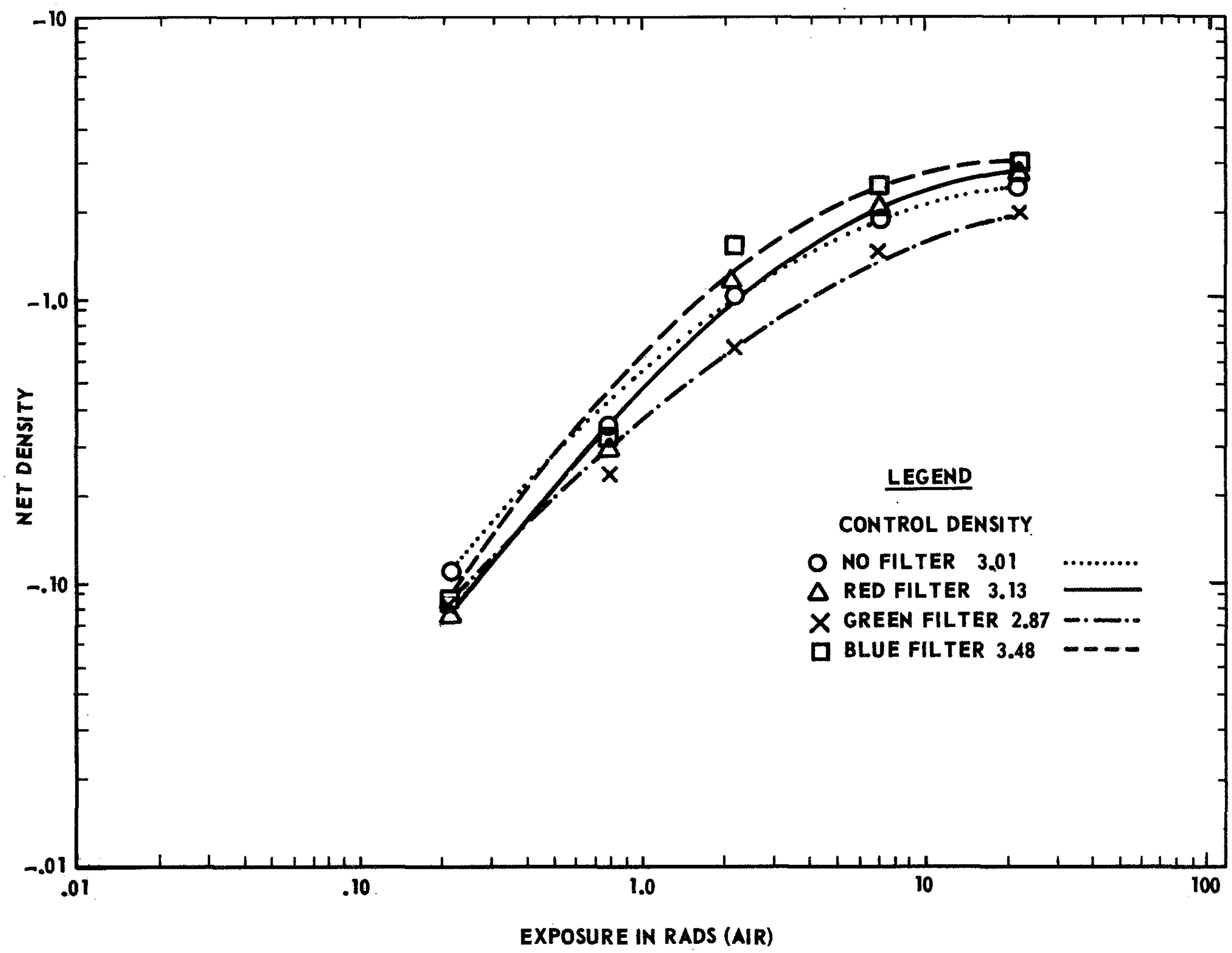

Figure 9. Change in base fog for SO-180 at different radiation doses of Co^{60} gamma rays. (Film developed with E-3 process at 75°F.)

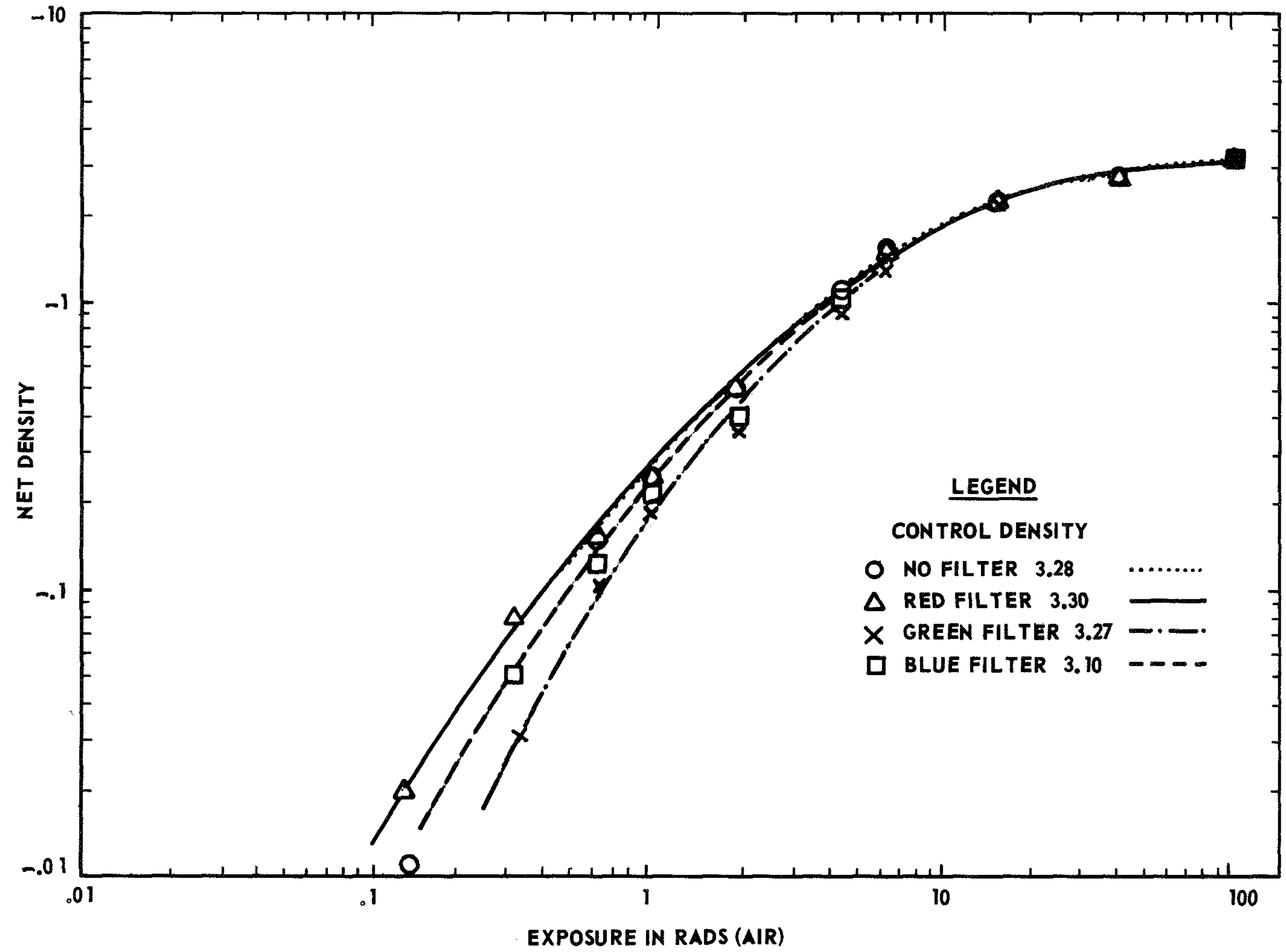

Figure 10. Change in base fog for EF 7241 at different radiation doses of 51.1-MeV protons. (Film developed with ME-4 process at 98°F.)

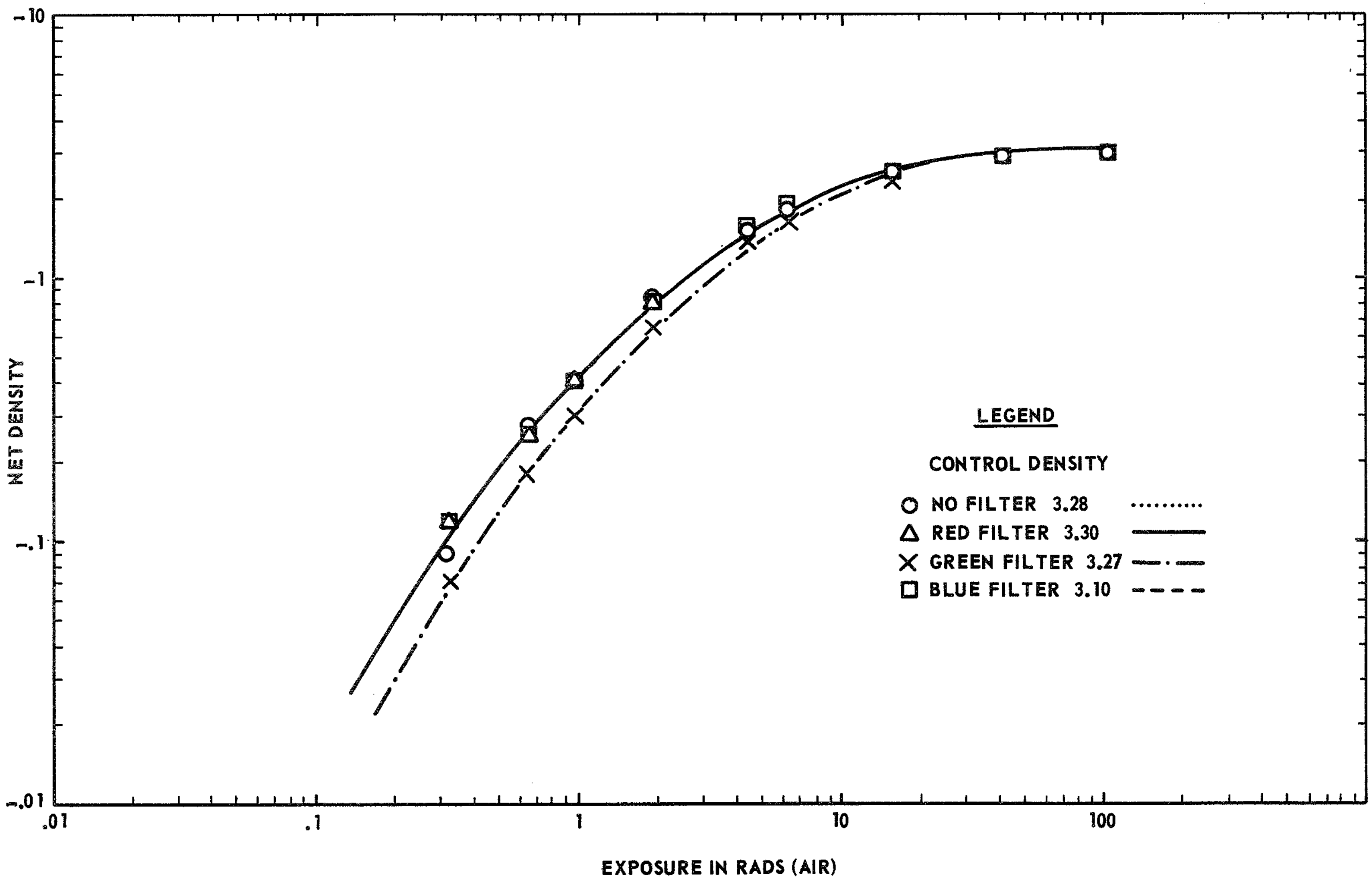

Figure 11. Change in base fog for EF 7241 at different radiation doses of 130.6-MeV protons.
(Film developed with ME-4 process at 98°F.)

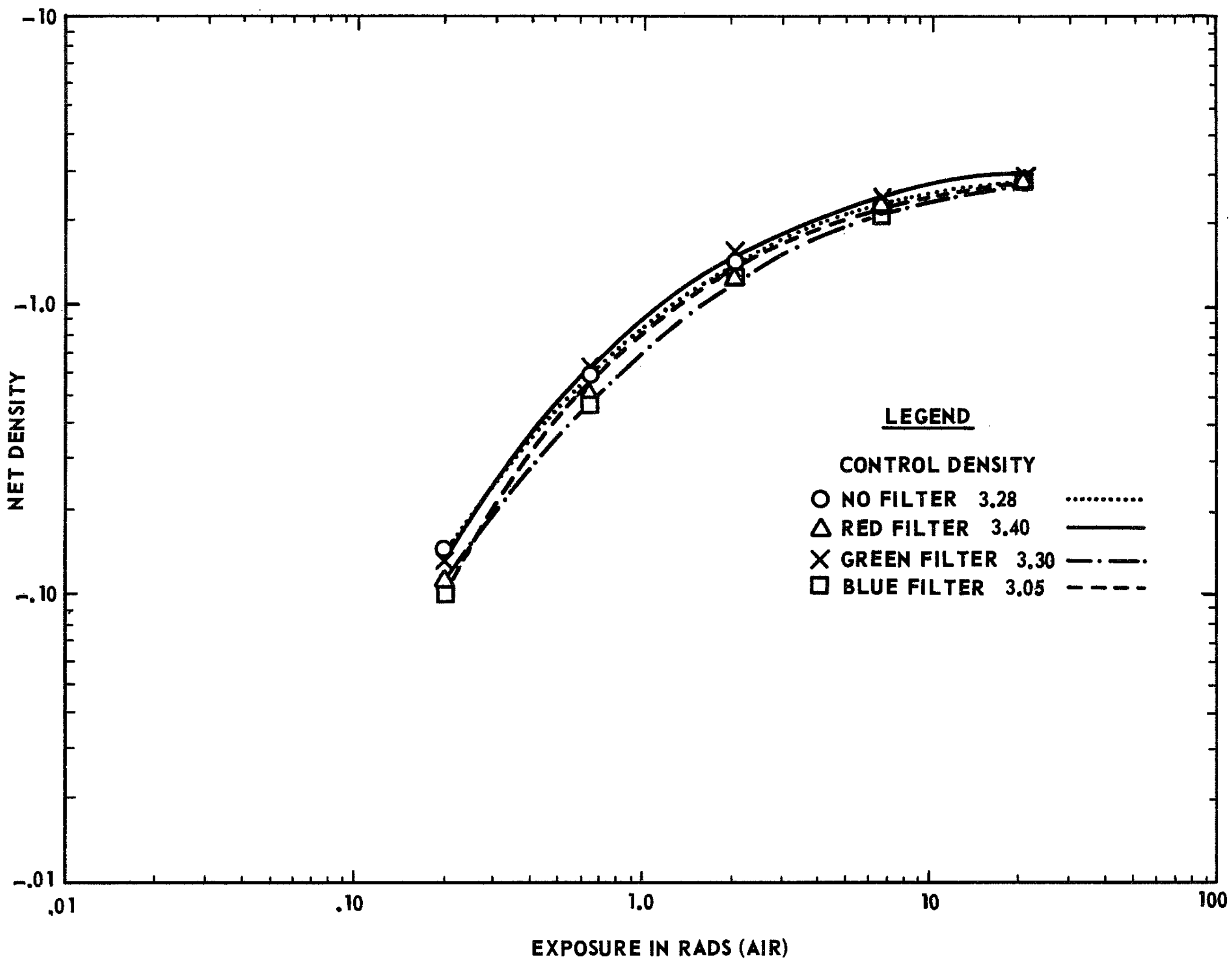

Figure 12. Change in base fog for EF 7241 at different radiation doses of Co^{60} gamma rays. (Film developed with ME-4 process at 98°F.)

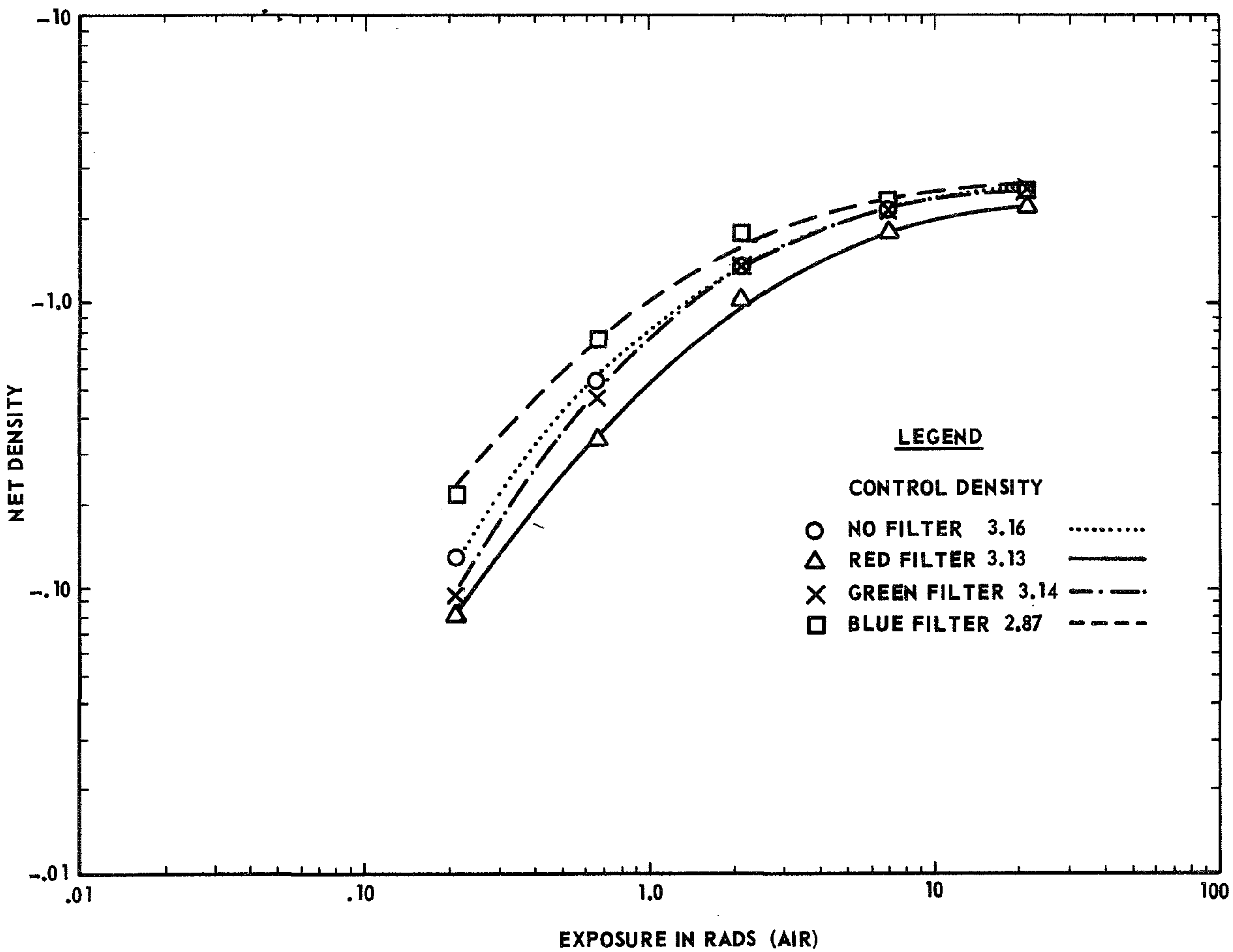

Figure 13. Change in base fog for EFB 7242 at different radiation doses of Co^{60} gamma rays. (Film developed with ME-4 process at 98°F.)

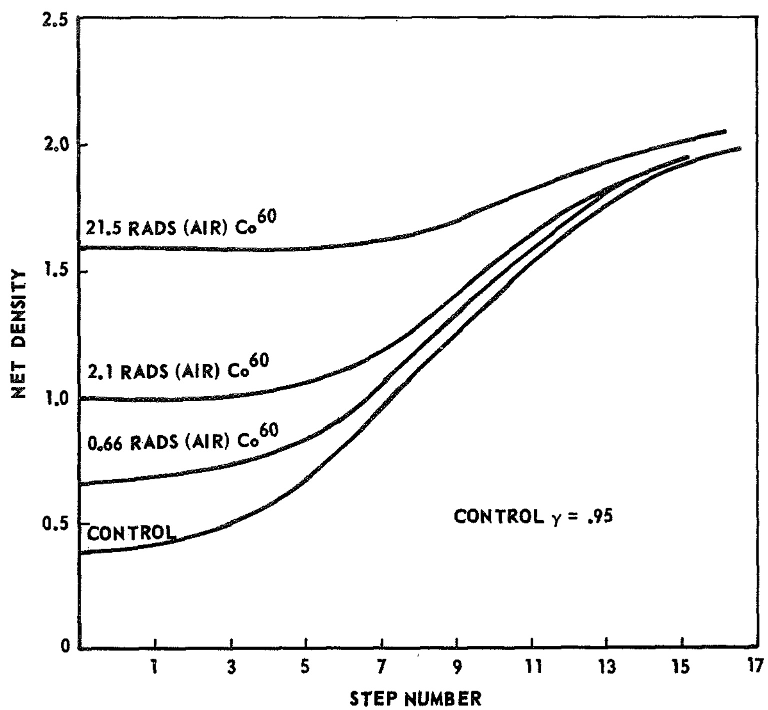

Figure 14. Sensitometric curves for Tri-X at different radiation doses.

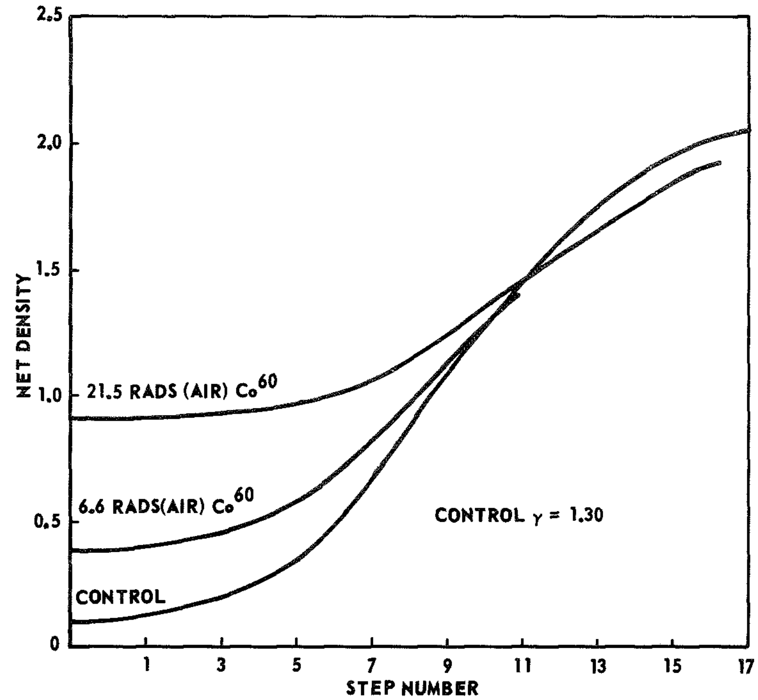

Figure 15. Sensitometric curves for 1N at different radiation doses.

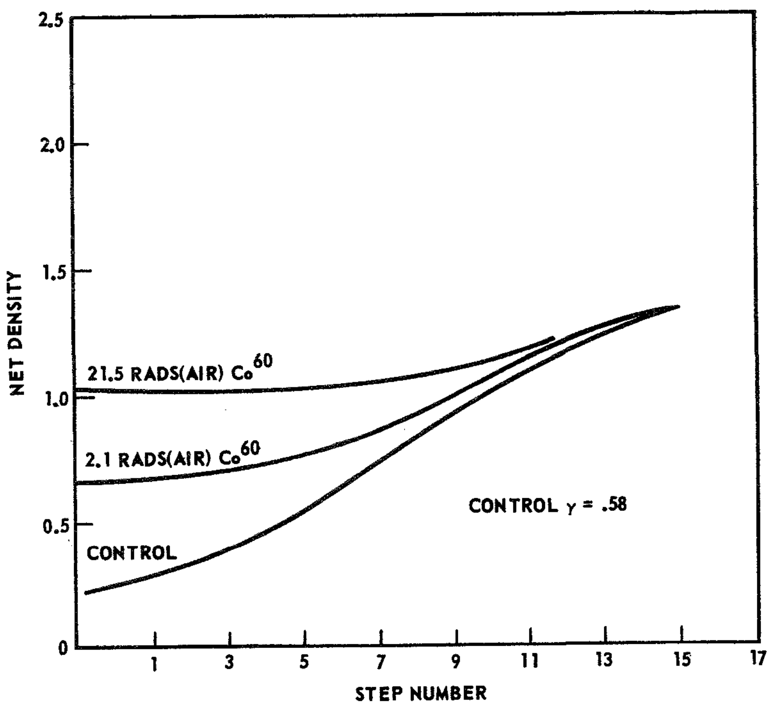

Figure 16. Sensitometric curves for 2475 at different radiation doses.

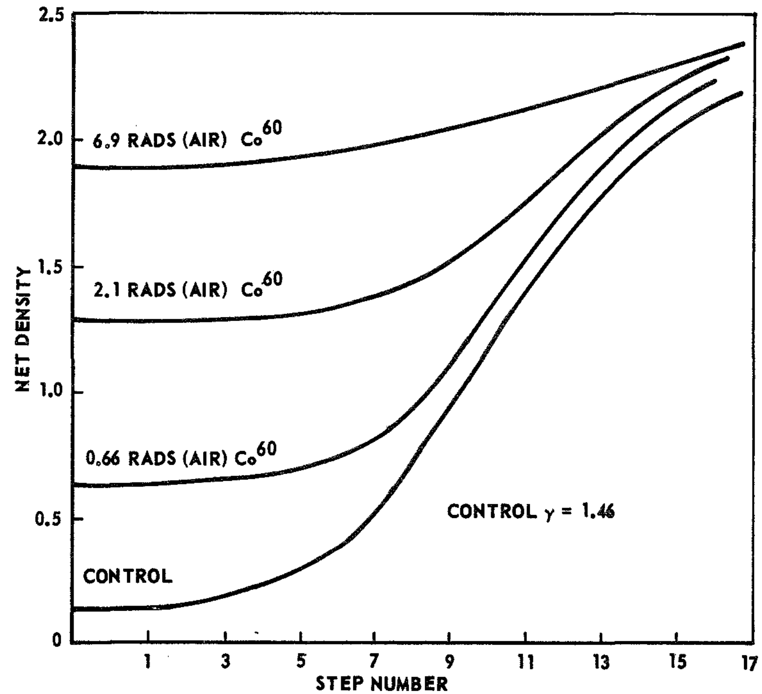

Figure 17. Sensitometric curves for SO-267 at different radiation doses.

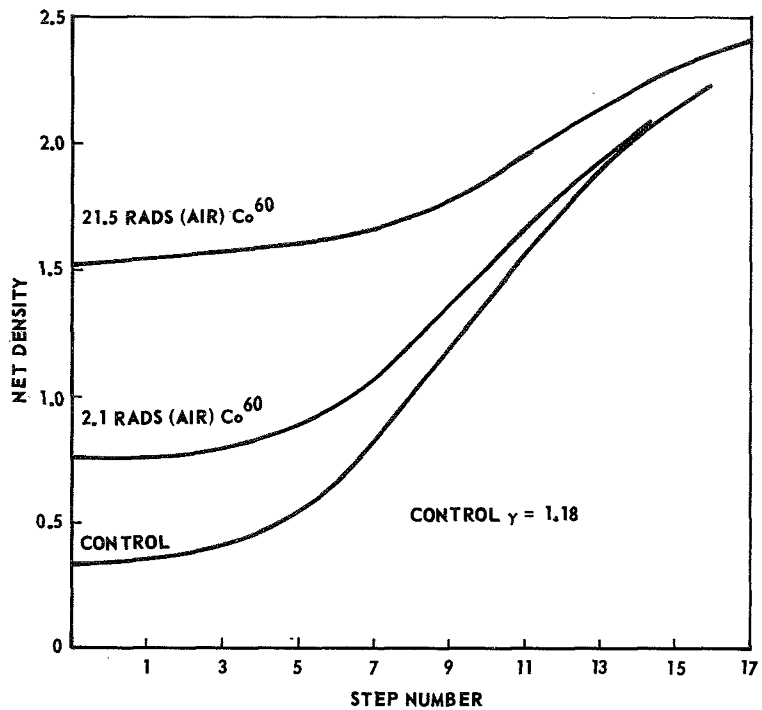

Figure 18. Sensitometric curves for Plus-X at different radiation doses.

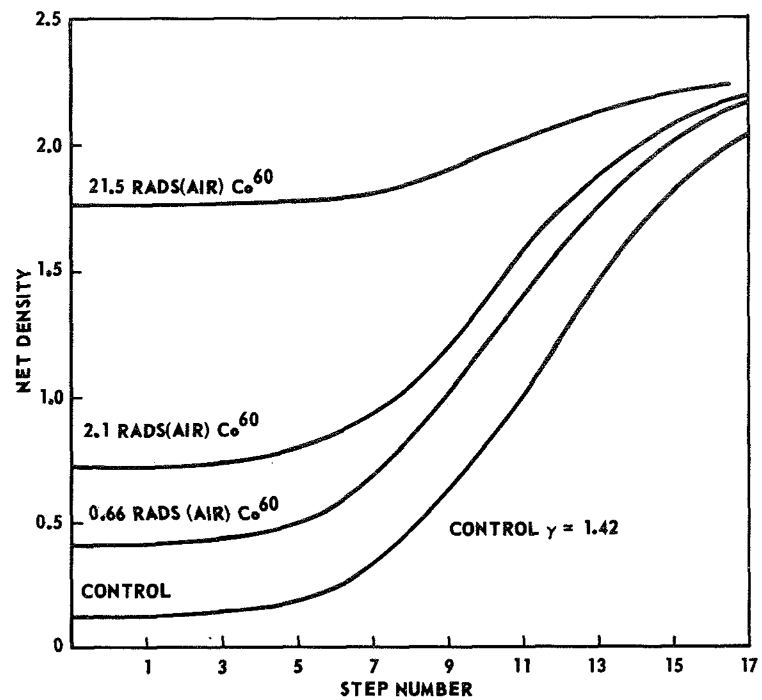

Figure 19. Sensitometric curves for SO-246 at different radiation doses.

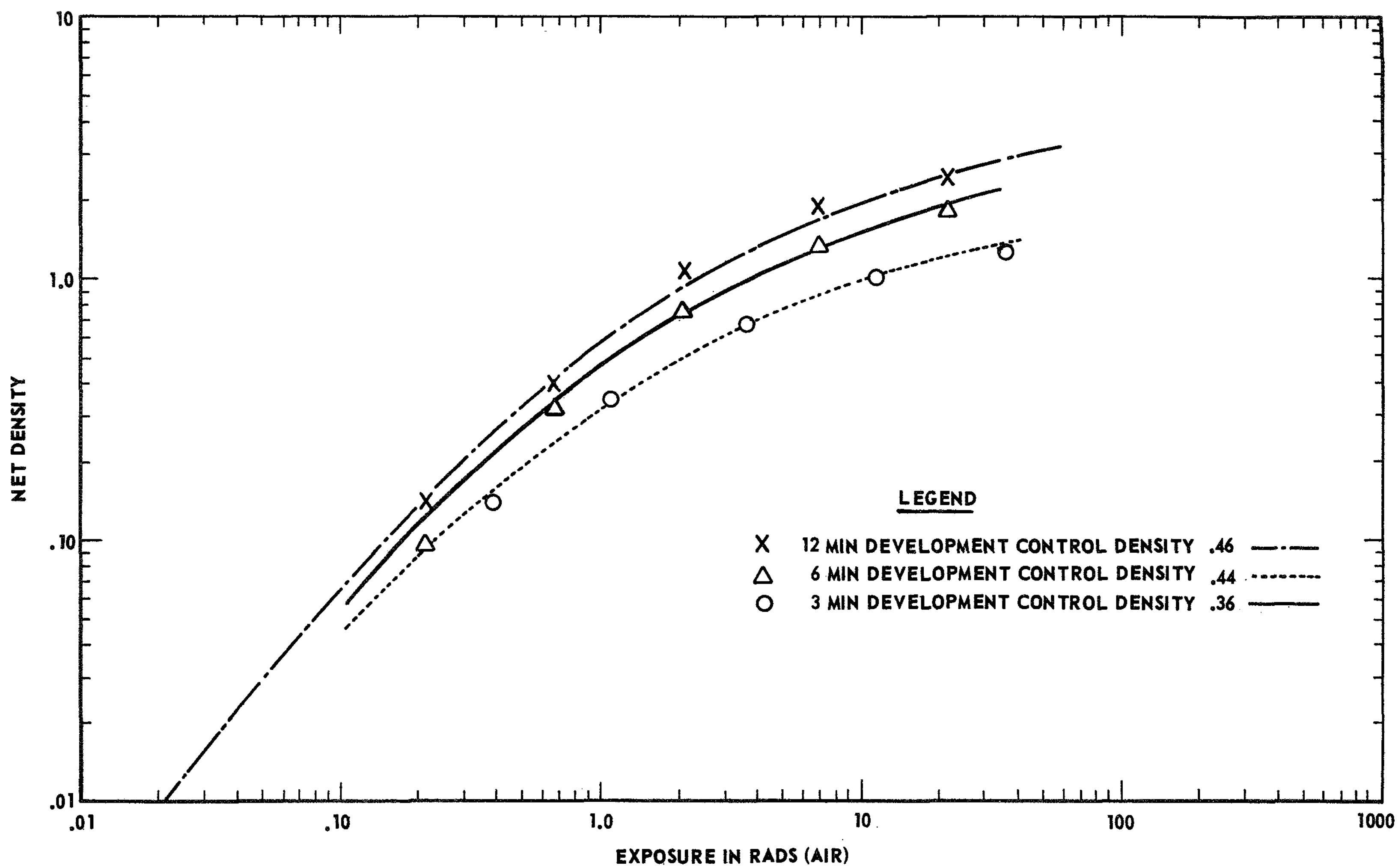

Figure 20. Change in base fog with radiation dose for Tri-X.
(Film developed in D-19 at 68°F for the indicated times.)

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APPROVAL

RADIATION DEGRADATION OF SELECTED FILMS

By William Oran

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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