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SUMMARY

An experimental study of the transmission and backscatter coefficients for aluminum and stainless steel irradiated with 75-keV to 1-MeV electrons at normal and 45° incidence is reported. The transmission coefficients were greater and the backscatter coefficients were smaller at normal beam incidence than they were at 45° beam incidence for both materials. In all cases the aluminum had higher transmission coefficients and lower backscatter coefficients than did stainless steel. It was determined that the transmission and backscatter coefficients for both aluminum and stainless steel were independent of the number of layers of foils used to attain a given thickness. The ratio of the thickness for maximum backscatter to the extrapolated range was found to be nearly a constant for each material. Transmission curves independent of energy were constructed for aluminum and stainless steel for normal and 45° beam incidence.

INTRODUCTION

It is well known that the radiation belts surrounding the earth pose a hazard to many components of satellites. These components require enough radiation shielding to enable a space mission to achieve its goals. Since one of the prime constituents of the radiation belts is energetic electrons (refs. 1 and 2), shielding against them is of interest. In order to provide effective shielding with a minimum weight penalty it is necessary to know the transmission and backscatter coefficients for different materials subjected to energetic electrons.

The present investigation was made to determine the transmission and backscatter coefficients for aluminum and stainless-steel foils irradiated with electrons. These materials were chosen because they are used extensively in space engineering applications.

To accomplish the objectives of the experiment, aluminum and stainless-steel foils were subjected to energetic electrons (energy range from 75 keV to 1 MeV). All tests were conducted in a vacuum at room temperature with the target foils perpendicular to the electron beam or at an angle of 45° with respect to the beam. The parameters which were varied were the number of foils exposed to the beam, foil thickness, and electron-beam energy. More specifically, tests were conducted on each individual target thickness and multiple layers of each target thickness at the various bombarding energies and incidence angles. Transmission and backscatter coefficients were determined over the entire range of thicknesses for each incident energy. Individual target thickness varied from nominal 1 mil to nominal 10 mils for the aluminum targets and nominal 1 mil to nominal 7.5 mils for the stainless-steel targets. (One mil = 2.54×10^{-5} m.) The results of the tests are presented in graphic form. Also, wherever applicable the results are compared with calculations and with results of other experiments. The results for aluminum were compared with Monte Carlo electron-transmission calculations recently made available (ref. 3).

APPARATUS AND TESTS

Accelerator

A 1-MeV cascaded-rectifier accelerator, described in reference 4, was used for these tests. The beam-energy calibration was conducted in a vacuum of 1 to 2×10^{-6} mm Hg by employing solid-state detectors and suitable nuclear sources. The calibration was accurate to within the resolution of the solid-state detector, which was approximately 18 keV (full width at half maximum). The electron beam from the accelerator was steered to the center of the drift tube where it was focused and collimated to a diameter of approximately 1/4 inch (6.4 mm) at the target position. The size of the beam was determined by irradiating polyvinyl chloride at the target location.

Experimental Procedures

After positioning and collimating, the electron beam was introduced into the experimental arrangement shown in figure 1. This arrangement consisted of a 2-foot-long (0.6-m) aluminum backscatter tube, the target being investigated, and a transmission tube which was also used as a Faraday cup. The backscatter tube, target, and transmission tube were electrically insulated from each other and from ground with teflon insulators. With a target in place and the electron beam on, the signals from the backscatter tube, target, and transmission tube were fed into a summing circuit and the accumulated total was displayed on an electrometer. When the total flux desired, usually 0.5 microampere, was attained the summing circuit was switched to display the backscatter tube, target, and transmission tube independently. All tests were conducted in a vacuum of 1 to 2×10^{-6} mm Hg at room temperature.

Each sample was exposed to electron energies of 250 keV, 500 keV, 750 keV, and 1 MeV. Also, the 1-mil aluminum samples were exposed to 75-keV and 125-keV electrons. Irradiations were conducted with the samples normal to the electron beam (fig. 1) or at an angle of 45° to the beam. For the 45° tests the samples were held in position between the backscatter tube and the transmission tube with a set of specially machined flanges that kept the samples at a constant 45° with respect to the electron beam.

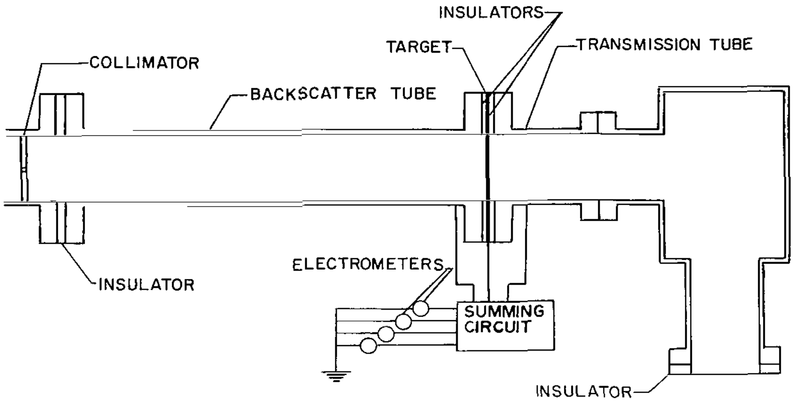

Figure 1.- Experimental arrangement.

In order to investigate the influence of multiple surfaces on the transmission and backscatter coefficients, the samples were stacked. That is, the results obtained from ten 1-mil samples were compared with the results from five 2-mil samples. In addition, other combinations were tested as well as each sample individually. The results contain transmission and backscatter percentages only; no energy-spectra information is presented in this report.

Test Samples

The samples used for these tests were foils of aluminum and stainless steel. For aluminum the nominal thicknesses used were 1 mil (approximately 6.7 mg/cm^2), 2 mils (approximately 14.0 mg/cm^2), 3.5 mils (approximately 26.5 mg/cm^2), 8 mils (approximately 55 mg/cm^2), and 10 mils (approximately 66.2 mg/cm^2). For stainless steel the nominal thicknesses used were 1 mil (approximately 21.5 mg/cm^2), 2 mils (approximately 40.2 mg/cm^2), 4 mils (approximately 78.5 mg/cm^2), and 7.5 mils (approximately 140.0 mg/cm^2). In discussing the samples, they are referred to by their nominal thickness for identification purposes only. The main parameter of interest is the thickness in mg/cm^2, which was determined for each sample and plotted accordingly.

The sample designation, U.S. alloy designation, and chemical composition of the samples used for these tests are shown in table I.

Before irradiation, each sample was cut into a 4-inch-diameter (10.2-cm) circle and inspected to insure that there were no cracks in the sample. After cleaning, the samples were mounted in a frame for irradiation. When the irradiation of a sample was completed, the 2-inch-diameter (5.1-cm) center portion was stamped out and weighed on an analytical balance which was accurate to within 0.1 milligram.

TABLE I.- IDENTIFICATION OF SAMPLES

Sample designation	U.S. alloy designation	Chemical composition
1 mil aluminum	1100	99.0% Al, 1.0% Si and Fe
2 mil aluminum	6061	96.45% Al, 1.3% Si and Fe, 1.0% Mg, 1.25% others
3.5 mil aluminum	1145	99.35% Al, 0.55% Si and Fe
8 mil aluminum	1100	99.0% Al, 1.0% Si and Fe
10 mil aluminum	None	99.999% Al
1 mil stainless steel 2 mil stainless steel 4 mil stainless steel 7.5 mil stainless steel	Type 304	65-71% Fe, 18-20% Cr, 8-12% Ni, 2% Mn, 1% Si

Errors

Backscatter from the transmission tube.- The largest error in the backscatter would be for a concentrated beam on the transmission tube. A beam of electrons was directed to the transmission tube, without a sample in the system, and the electrons which were backscattered to the backscatter tube were measured. This procedure was carried out for all test conditions employed. The maximum current measured on the backscatter tube varied from a low of less than 1 percent of the total beam at 250 keV and lower, to a high of approximately 1.5 percent of the total beam at 1 MeV. This error would tend to make the backscatter measurements high and the transmission measurements low. However, with a sample in place the error in the backscatter measurements would rapidly diminish and totally disappear before the maximum backscatter point was reached. The introduction of samples into the system would also reduce the error in the transmission measurements by spreading the transmitted beam. Therefore, the measurements made on the thin targets (less than 30 or 40 mg/cm^2) at 1 MeV incident energy would have a small error; as the target thickness was increased, the error would vanish for the backscatter measurements and would rapidly decrease and become small compared with 1.5 percent of the total beam for the transmission measurements. For all other incident energies, this error was negligible.

Loss on insulators around the target.- The solid angle subtended by the insulators on either side of the target was 15 percent of the 2π geometry. However, since the transmitted electrons fall between a cosine-square law and a cosine law, and the backscattered electrons follow a cosine law (ref. 3), the error introduced in all cases would be less than 1 percent for the transmitted or backscattered electrons.

Current readout.- The accuracy and reproducibility of the electrometers used for these tests were better than 0.5 percent in all cases. Also, the leakage current across the samples and insulators was negligible.

Summary of errors.- For the transmission measurements, the worst errors would be introduced for 1-MeV electrons incident on thin targets. In this instance the transmission measurements could be low by less than 3 percent and high by approximately 0.5 percent. For target thicknesses greater than 30 or 40 mg/cm^2, the transmission coefficients could be low by approximately 1.5 percent of the given value or high by approximately 0.5 percent of the given value.

For the backscatter measurements, the worst case would be for 1-MeV electrons incident on thin targets. The backscatter coefficients for this case could be high by about 2 percent or low by about 1.5 percent. For targets thicker than 30 or 40 mg/cm^2, the backscatter coefficients could be high by 0.5 percent of the given value or low by 1.5 percent of the given value.

At incident energies other than 1 MeV, the transmission and backscatter coefficients could be low by 1.5 percent or high by 0.5 percent of the given values.

RESULTS AND DISCUSSION

Transmission of Electrons

Normal incidence.- The transmission curves for aluminum and stainless steel resulting from electrons normally incident on their surface in the energy range from 250 keV to 1 MeV are shown in figures 2 to 5. The curves show that when the thickness is small almost all the incident electrons are transmitted; that is, they pass through the target material without undergoing many collisions. As the thickness is increased the transmission decreases very slightly until about 80-percent transmission is reached; from this point on, the addition of more material results in an almost linear decrease in transmission until about 30-percent transmission is reached. The extrapolation of this straight-line descent to zero-percent transmission yields the extrapolated range, sometimes called the practical range. From about 30-percent transmission out to the maximum range, the addition of more material results in a small net decrease in transmission; it is in this region that the energy straggling of electrons is most pronounced.

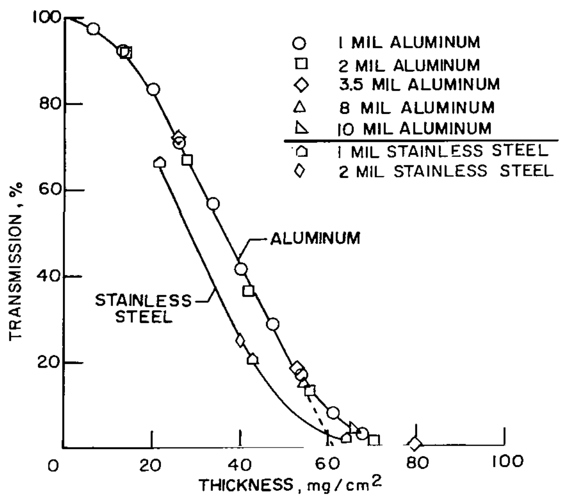

Figure 2.- Transmission for normally incident 250 keV electrons.

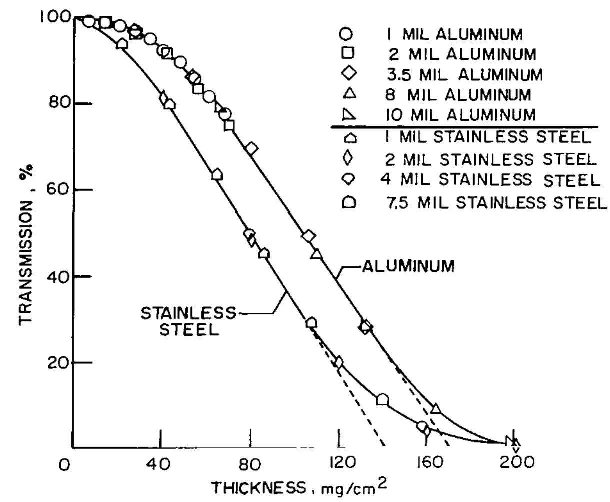

Figure 3.- Transmission for normally incident 500 keV electrons.

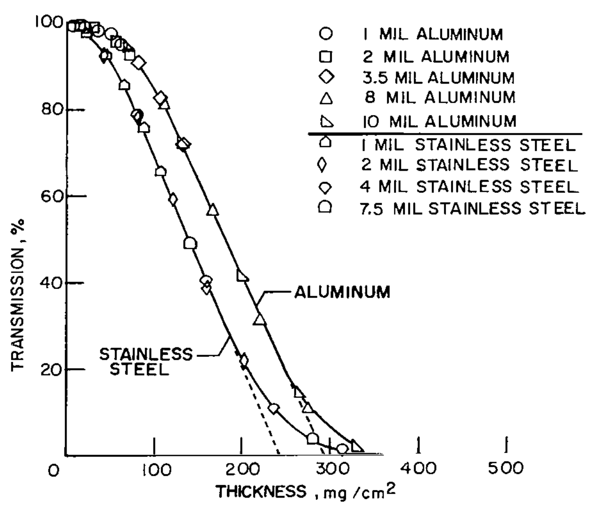

Figure 4.- Transmission for normally incident 750 keV electrons.

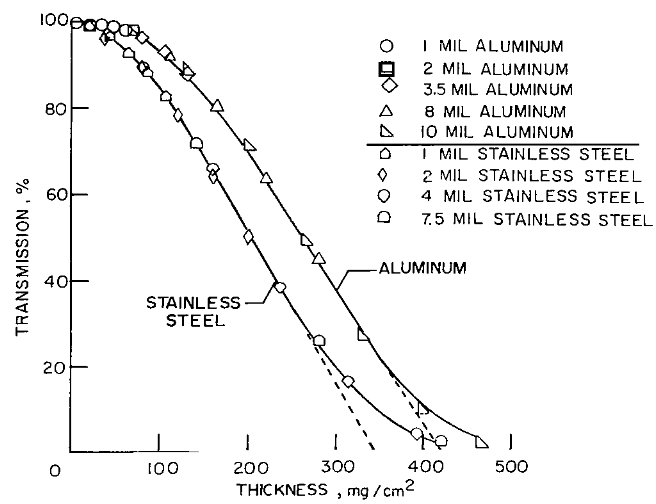

Figure 5.- Transmission for normally incident 1 MeV electrons.

Inspection of the transmission curves reveals that the transmission coefficients for stainless steel are less than those for aluminum. Closer inspection reveals that in the portion of the curves that is approximately linear (80-percent transmission to 30-percent transmission), the stainless-steel transmission coefficients are approximately 20 percent less than the aluminum transmission coefficients. This difference can be partially explained by examining the backscatter curves for normal beam incidence (discussed subsequently), which show that the backscatter coefficients for stainless steel are on the average approximately 12 percent higher than those for aluminum. The remaining difference indicates that the stainless steel is a better absorber of electrons than aluminum.

The net absorption can be found for any thickness (in mg/cm^2) of aluminum or stainless steel by subtracting the sum of the transmission and the backscatter from 100 percent. For example, the absorption coefficient for 1-MeV electrons normally incident on 200 mg/cm^2 of stainless steel is found by adding the transmission coefficient from figure 5, 51 percent, to the backscatter coefficient from figure 17, 21 percent, for a total of 72 percent, which yields an absorption of 28 percent for this case.

By extrapolating to zero transmission the linear portions of the transmission curves in figures 2 to 5, it is possible to determine the extrapolated range. The results of this extrapolation for aluminum are compared in table II with results obtained from an empirical formula given in reference 5. Table II also contains the experimental extrapolated range for stainless steel at the various energies tested except for 250 keV, where the thickness of the stainless steel was near the electron range.

A comparison of the experimental results with those of Agu et al. (ref. 6), who used a method similar to the one used in this report, is shown in figure 6. The transmission coefficients are presented as a function of thickness for aluminum subjected to 500-keV electrons at normal incidence. In general, the agreement between the two curves is very good, the main difference being that the extrapolated ranges are different by approximately 13 mg/cm^2.

TABLE II.- EXTRAPOLATED RANGES FOR NORMAL BEAM INCIDENCE ON ALUMINUM AND STAINLESS STEEL

Energy, keV	Experimental extrapolated range for aluminum, mg/cm^2	Empirical extrapolated range for aluminum, mg/cm^2	Experimental extrapolated range for stainless steel, mg/cm^2
250	61.5	58.5	
500	168	170	140
750	295	300	240
1000	430	430	340

In figure 7 the experimental electron-transmission coefficients for aluminum irradiated with a 1-MeV beam at normal incidence are compared with electron-transmission coefficients calculated by the Monte Carlo method. For purposes of comparison with the experimental data, the abscissas of the calculated curves from references 7 and 8 were converted from the ratio of the target thickness to the maximum range (550 mg/cm^2) to target thickness in mg/cm^2. The agreement between the experimental results and the calculations is very good.

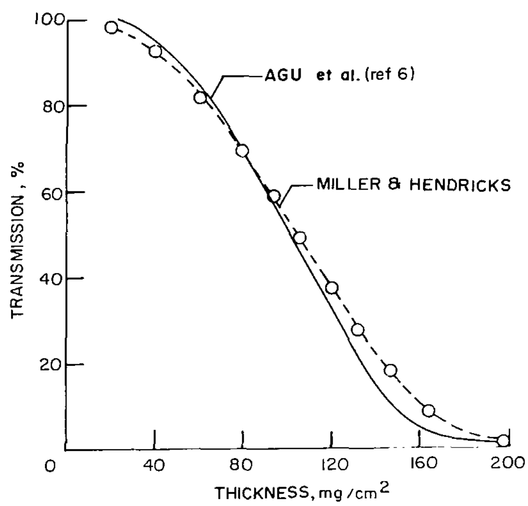

Figure 6.- Comparison with the experimental results of reference 6 for normally incident 500 keV electrons on aluminum.

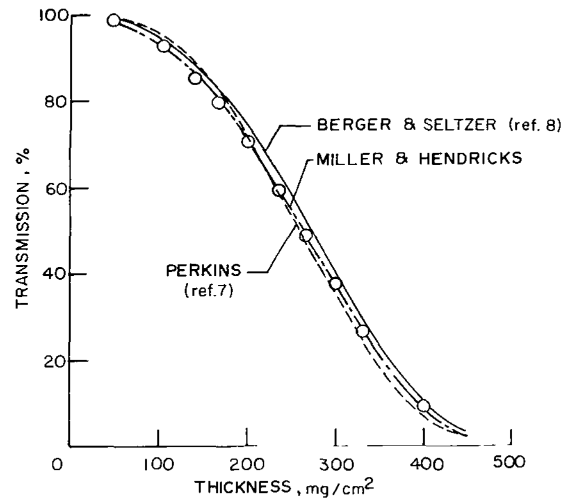

Figure 7.- Comparison with theoretical results for normally incident 1 MeV electrons on aluminum.

Incidence of 45°.- Transmission curves for aluminum and stainless steel resulting from electrons incident at 45° on their surface in the energy range from 250 keV to 1 MeV are shown in figures 8 to 11. In the low-thickness portion of their spectra the shape of the transmission curves for 45° incidence differs from that for normal incidence. The following explanation is offered. For a thin target in a beam of electrons – for instance, a 1-mil aluminum foil in a 1-MeV beam – the predominant occurrence is a spread of the transmitted beam. When the target is turned at an angle with respect to the beam, the effect is not so much to change the spread of the beam by an equal amount, but to maintain the spread with respect to the initial beam direction. The result is an increase in backscatter and absorption, and consequently a decrease in transmission.

If the transmission coefficients are compared at equal thicknesses, for 45° beam incidence and normal incidence, it is apparent that the transmission coefficients for both aluminum and stainless steel are less for 45° beam incidence than for normal incidence. However, it should be noted that neither the maximum range nor the extrapolated range decreases as a simple $1/\sqrt{2}$ relationship, as would be expected from purely geometrical considerations. Recalling that the beam is spread as it passes through the target, it is easy to see that some of the particles will be scattered in a direction perpendicular to the target. Since these particles behave as if the target were normal to the beam and have a corresponding range, the range does not drastically change. This phenomenon has been noted by other investigators (ref. 9).

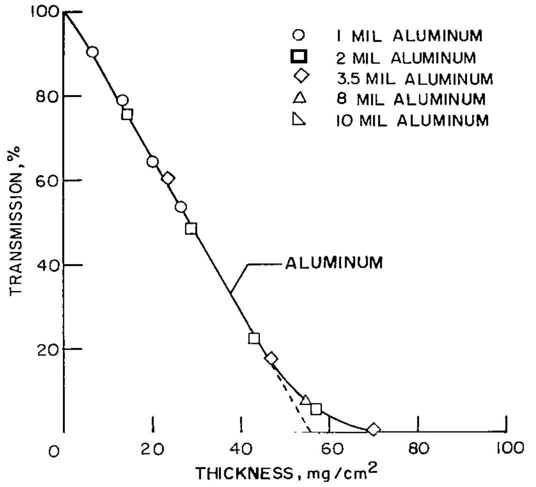

Figure 8.- Transmission for 250 keV electrons incident at 45°.

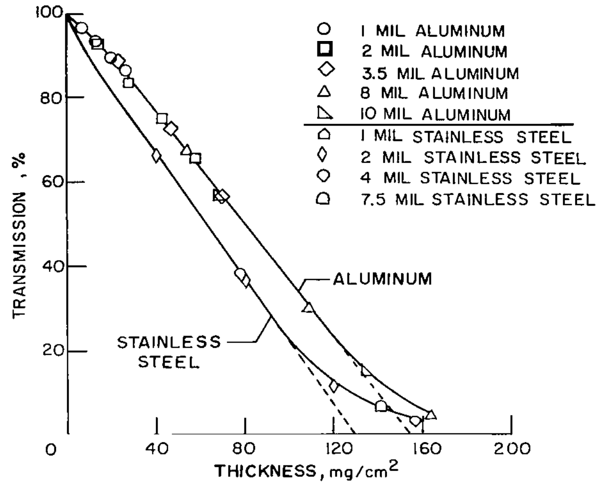

Figure 9.- Transmission for 500 keV electrons incident at 45°.

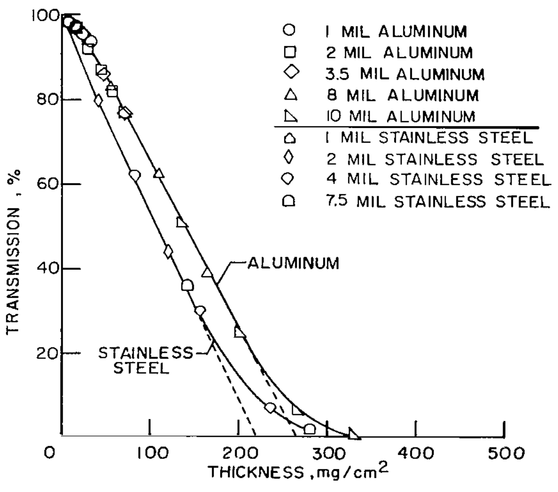

Figure 10.- Transmission for 750 keV electrons incident at 45°.

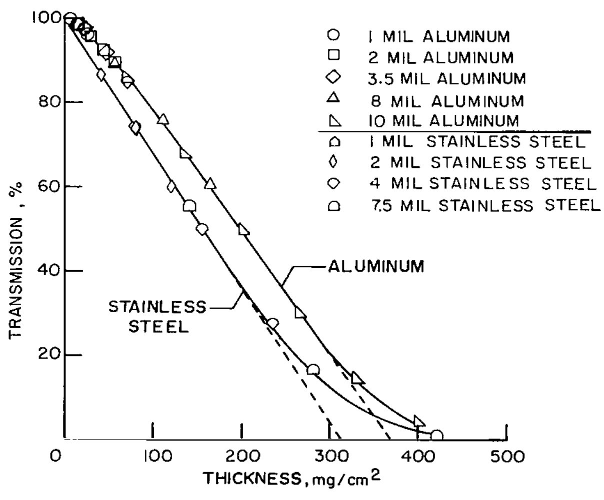

Figure 11.- Transmission for 1 MeV electrons incident at 45°.

TABLE III.- EXTRAPOLATED RANGES FOR 45° BEAM INCIDENCE

ON ALUMINUM AND STAINLESS STEEL

Energy, keV	Experimental extrapolated range for aluminum, mg/cm^2	Experimental extrapolated range for stainless steel, mg/cm^2
250	55	
500	155	130
750	265	220
1000	365	310

The experimental extrapolated ranges for 45° beam incidence are given in table III. Comparison with table II shows that they are not very different from the ranges for normal beam incidence.

Backscatter of Electrons

Normal incidence.- Backscatter curves for aluminum in the energy range from 75 keV to 1 MeV and for stainless steel in the energy range from 250 keV to 1 MeV are shown in figures 12 to 17. These curves are characterized by small values of backscatter when the targets are thin. Addition of more material causes a small increase in the amount of backscatter until a point is reached where the backscatter increases almost linearly with the addition of more material. The rate of increase then tapers off and finally ceases at some level which is characteristic of the material being investigated, the energy of the beam, and the angle of beam incidence.

The samples exposed to incident electron energies of 75 keV were not thin enough to include the portion of the backscatter curve below the saturation value. The maximum

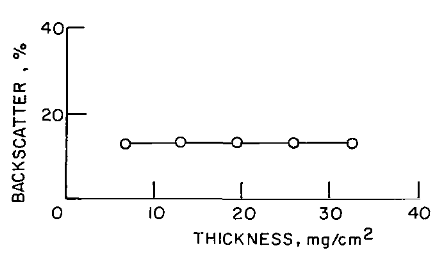

Figure 12.- Backscatter for 75 keV electrons normally incident on 1 mil aluminum.

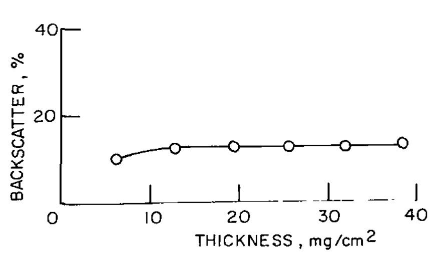

Figure 13.- Backscatter for 125 keV electrons normally incident on 1 mil aluminum.

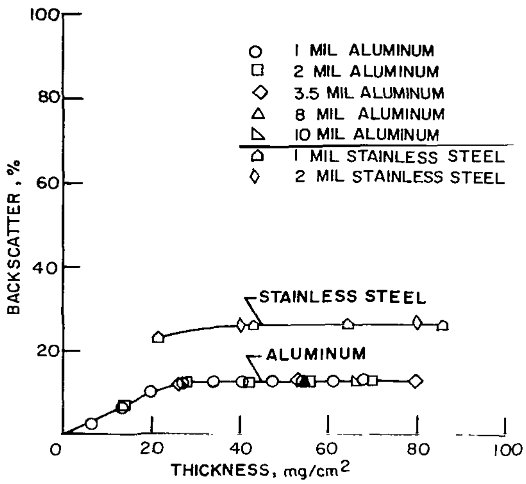

Figure 14.- Backscatter for normally incident 250 keV electrons.

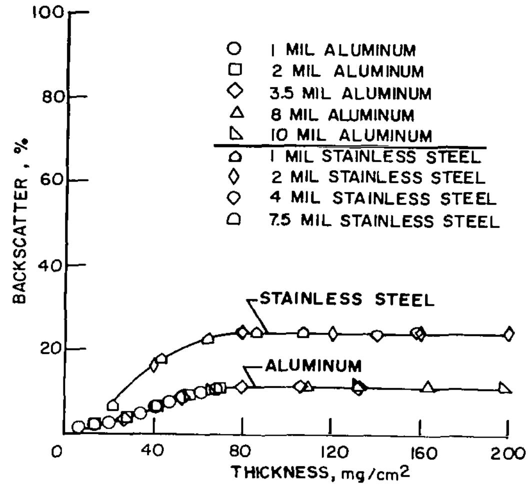

Figure 15.- Backscatter for normally incident 500 keV electrons.

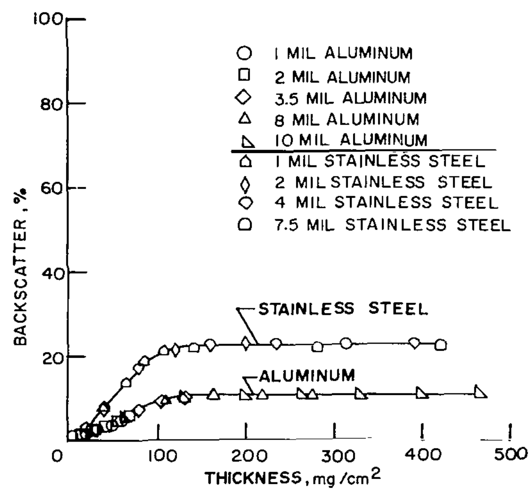

Figure 16.- Backscatter for normally incident 750 keV electrons.

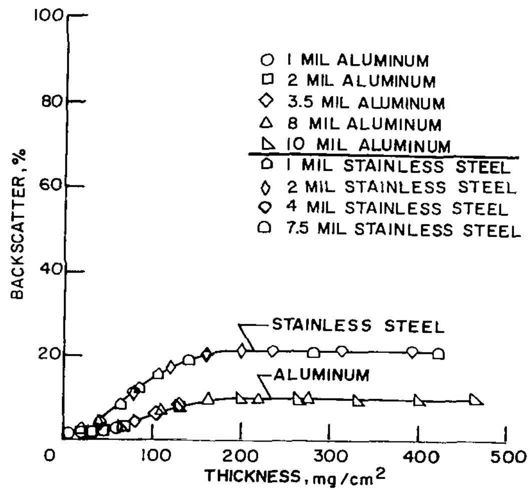

Figure 17.- Backscatter for normally incident 1 MeV electrons.

backscatter for the 75-keV and 125-keV electrons incident on aluminum was approximately 13 percent (figs. 12 and 13). For incident energies of 250 keV to 1 MeV, the samples were sufficiently thin to permit analysis of the portion of the backscatter curves that is variable with thickness (figs. 14 to 17). The maximum backscatter for these aluminum samples varied from a high of approximately 12.5 percent at 250 keV to a low of 10 percent at 1 MeV. The maximum backscatter from the stainless steel was greater than that from the aluminum in all instances, varying from a high of approximately 26 percent at 250 keV to a low of approximately 21 percent at 1 MeV.

TABLE IV.- RATIO OF THICKNESS AT MAXIMUM BACKSCATTER TO EXTRAPOLATED AND MAXIMUM RANGES FOR NORMAL BEAM INCIDENCE ON ALUMINUM

Energy, keV	Thickness for max. backscatter, mg/cm^2	Ratio of thickness at max. backscatter to extrapolated range	Ratio of thickness at max. backscatter to max. range
250	28	0.455	0.344
500	76	.45	.34
750	130	.44	.338
1000	195	.454	.355

As was the case for the transmission measurements, the current collection method used for these tests indicated that the multiple layers or the different alloys had no effect on the backscatter coefficients.

The ratio of the experimental thickness for maximum backscatter of aluminum to the experimental extrapolated range is given as a function of incident energy in table IV. The fact that this ratio is approximately constant, around 0.45, indicates that the ratio is a function of the material. Also given in table IV is the ratio of the experimental thickness for maximum backscatter for aluminum to the maximum range. The values used for the maximum range were calculated by Berger and Seltzer in reference 10. This ratio is also constant, having a value of approximately 0.34, which agrees well with the value of 0.35 at 500 keV given by Berger on page 168 of reference 3.

Table V shows the ratio of the experimental thickness for maximum backscatter for stainless steel to the experimental extrapolated range as a function of incident energy. The ratio for stainless steel is approximately 0.515 over the energy range from 500 keV to 1 MeV. There were not enough data points for 250 keV to determine a ratio.

TABLE V.- RATIO OF THICKNESS AT MAXIMUM BACKSCATTER TO EXTRAPOLATED RANGE FOR NORMAL BEAM INCIDENCE ON STAINLESS STEEL

Energy, keV	Thickness for max. backscatter, mg/cm^2	Ratio of thickness at max. backscatter to extrapolated range
500	72	0.515
750	125	.52
1000	175	.515

The maximum backscatter for normal beam incidence as a function of incident energy for aluminum and stainless steel is compared with other experiments and calculations in figure 18. The experimental results of Cohen and Koral (ref. 11) at 600 keV, 800 keV, and 1 MeV are in relatively good agreement with the experimental results of this investigation. The results of Monte Carlo calculations by Berger (p. 169 of ref. 3) for the maximum backscatter of electrons incident on aluminum are also shown in the figure. The results agree with the experimental data to within 0.5 percent except at 250 keV, where the difference is approximately 1.0 percent. This relatively good agreement of the aluminum data with results of other experiments and calculations seems to justify a high degree of confidence in the stainless-steel data, for which no direct comparisons were available.

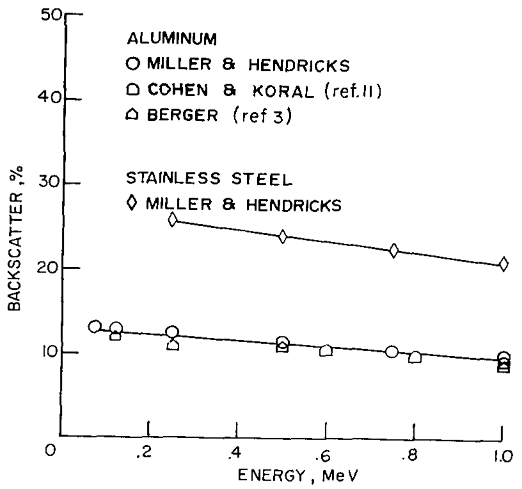

Figure 18.- Comparison of backscatter results with other experiments and theory for normally incident electrons.

Incidence of 45°.- Backscatter curves for 45° beam incidence on aluminum and stainless steel in the energy range from 250 keV to 1 MeV are shown in figures 19 to 22. The backscatter curves for 45° and normal incidences had different shapes in the low-thickness portion of their spectra. For 45° beam incidence, the slowly increasing region for the thin samples disappeared. This result is analogous to that for the transmission curves, where the slowly decreasing part of the transmission curve disappeared for 45° beam incidence. As was the case for the transmission curves, the spread of the beam was responsible for the change of shape of the low-thickness portion of the backscatter curves. (See section on transmission at 45° incidence.)

The backscatter coefficients are greater for the 45° beam incidence than for normal incidence. The maximum backscatter for the aluminum samples varied from a high of approximately 23.5 percent at 250 keV to a low of approximately 22 percent at 1 MeV. The maximum backscatter for the stainless-steel samples varied from a high of 37 percent at 250 keV to a low of approximately 33.5 percent at 1 MeV. The maximum backscatter from the stainless steel was greater than the maximum backscatter from the aluminum.

Table VI shows the ratio of the experimental thickness for maximum backscatter of aluminum to the experimental extrapolated range as a function of incident energy at 45° beam incidence. As can be seen from the table, the ratio is constant at about 0.45.

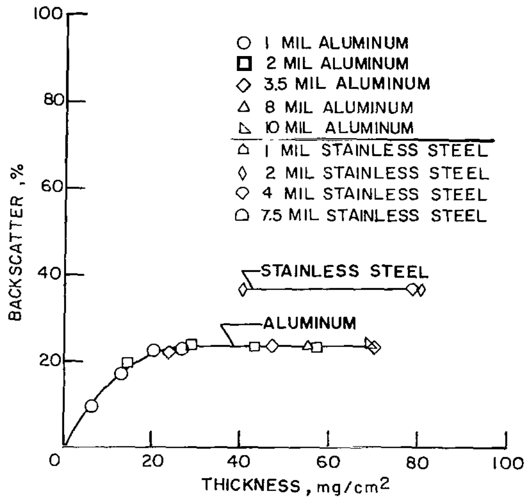

Figure 19.- Backscatter for 250 keV electrons incident at 45^{o}.

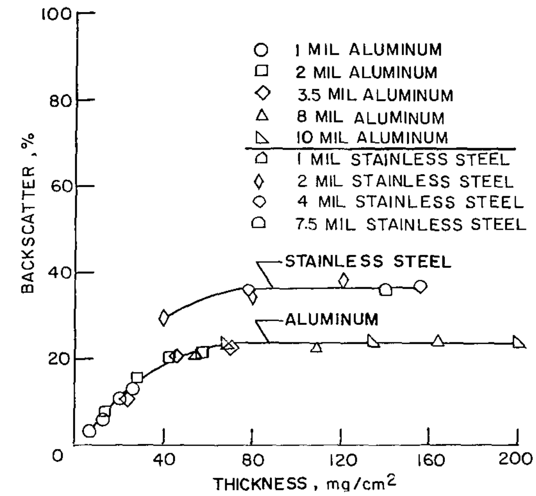

Figure 20.- Backscatter for 500 keV electrons incident at 45^{o}.

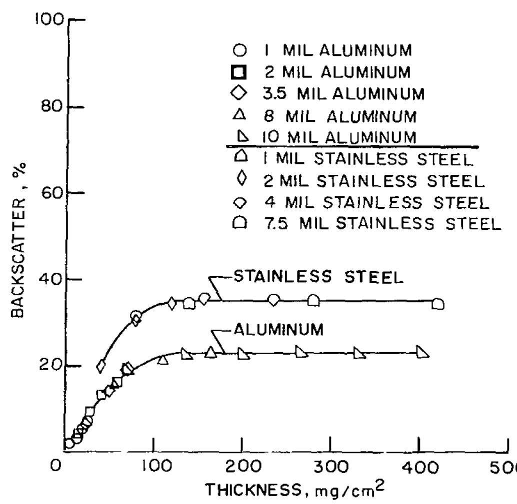

Figure 21.- Backscatter for 750 keV electrons incident at 45^{o}.

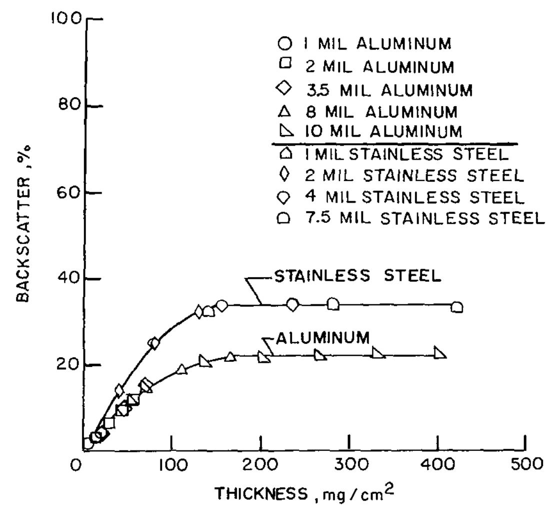

Figure 22.- Backscatter for 1 MeV electrons incident at 45^{o}.

The fact that this is the same ratio that was found for aluminum at normal beam incidence (see table IV) lends support to the earlier statement that the ratio of the thickness for maximum backscatter to the extrapolated range is constant and is a function of the material being investigated.

The ratio of the thickness at maximum backscatter to the measured extrapolated range for the stainless steel at 45^{o} beam incidence is shown in table VII. The data for the stainless steel are centered around approximately 0.52.

TABLE VI.- RATIO OF THICKNESS AT MAXIMUM BACKSCATTER TO EXTRAPOLATED RANGE FOR 45° BEAM INCIDENCE ON ALUMINUM

Energy, keV	Thickness for max. backscatter, mg/cm^2	Ratio of thickness at max. backscatter to extrapolated range
250	25	0.45
500	70	.45
750	120	.45
1000	165	.45

The data for maximum backscatter as a function of energy at 45° incidence are summarized and compared with experimental and calculated results of other investigations in figure 23. The experimental point for aluminum at 800 keV is from the work of Cohen and Koral (ref. 11). The results of the present investigation are higher by approximately 1.5 percent. The agreement of the present results with the Monte Carlo calculations of Berger (ref. 12) at 250, 500, and 1000 keV is excellent. Direct comparisons for the stainless-steel data were not available; however, because of the good agreement for the aluminum data, they are believed to be very near the true values.

A useful feature of the ratio of maximum backscatter to the extrapolated range is that it can be used with figure 26 to predict what thickness (in mg/cm^2) of aluminum or stainless steel is necessary for maximum backscatter for any given electron energy from 250 keV to 1 MeV for aluminum and 500 keV to 1 MeV for stainless steel. For example, find the amount of stainless steel necessary to give the maximum backscatter for normally incident 600-keV electrons. From table V the ratio of the thickness (in mg/cm^2) at maximum backscatter to the extrapolated range is approximately 0.515. From figure 26 the extrapolated range is 180 mg/cm^2. Therefore, the ratio (0.515) times the extrapolated range (180 mg/cm^2) yields 92.7 mg/cm^2 as the desired thickness. Examination of figure 18 reveals that the backscatter would be 23.5 percent of the total incident electrons.

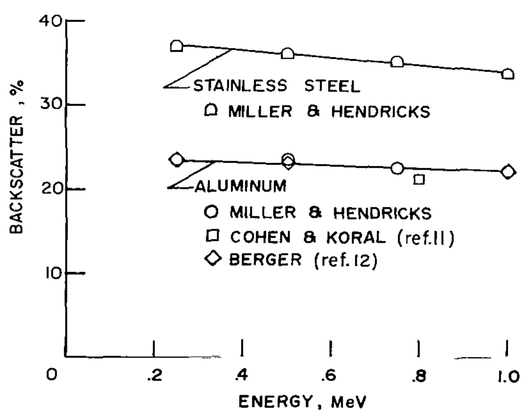

Figure 23.- Comparison of backscatter results with other experiments and theory for electrons incident at 45°.

TABLE VII.- RATIO OF THICKNESS AT MAXIMUM BACKSCATTER TO EXTRAPOLATED RANGE FOR 45° BEAM INCIDENCE ON STAINLESS STEEL

Energy, keV	Thickness for max. backscatter, mg/cm^2	Ratio of thickness at max. backscatter to extrapolated range
500	70	0.54
750	120	.54
1000	155	.50

Energy Independent Transmission Curves

It has been proposed by Berger and Seltzer (ref. 8) that electron transmission coefficients for aluminum are insensitive to energy in the range from 100 keV to 1 MeV. To determine whether the transmission data of this report followed Berger's proposal, energy-independent transmission curves were constructed for aluminum and stainless steel for normal and for 45° electron beam incidence. The resulting energy-independent transmission curves are shown in figures 24 and 25. The curves were constructed as follows: A given extrapolated range (for instance, 61.5 mg/cm^2 for normally incident 250-keV electrons on aluminum) was divided into the thickness (in mg/cm^2) of aluminum necessary to give a ratio of 0.1; the transmission coefficient for this ratio was then

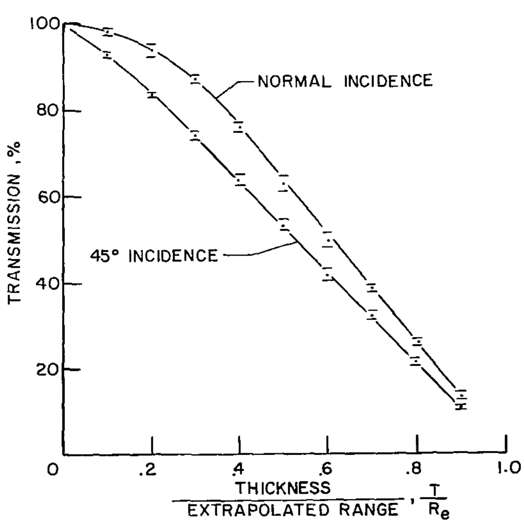

Figure 24.- Energy-independent transmission curves for aluminum.

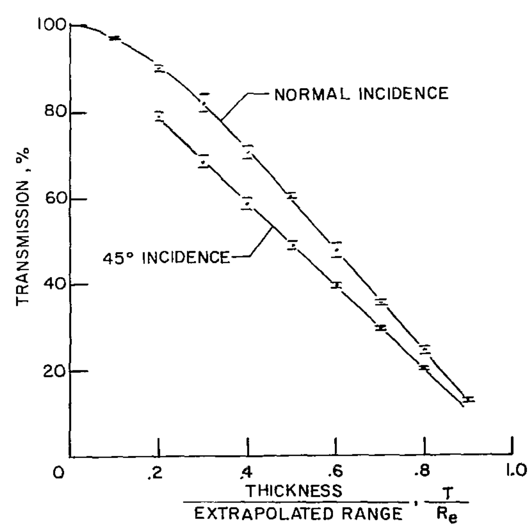

Figure 25.- Energy-independent transmission curves for stainless steel.

determined from the appropriate figure (for this example, fig. 2). This exercise was repeated for the thicknesses necessary to give a ratio of 0.2, 0.3, and so forth; the entire procedure was then repeated for the extrapolated ranges for 500 keV, 750 keV, and 1 MeV. Next, the transmission coefficient at the same ratio for each incident electron energy was added and the average was taken. The procedure was repeated for another ratio until the entire range of T/R_e as a function of transmission was covered (where T is thickness in mg/cm^2 and R_e is the extrapolated range for a given incident energy). The results of the averaging process are shown on the energy-independent transmission curves. For any given point the bars represent the maximum and minimum transmission coefficients from the experimental data and the dot between the bars is the average of the transmission coefficients. The small amount of spread in the data suggests that the electron transmission curves are independent of energy in the range from 250 keV to 1 MeV, and thus supports the proposal of Berger. By using figures 24 and 25 in conjunction with figure 26, it is possible to determine the electron transmission coefficients for any given thickness (in mg/cm^2) of aluminum or stainless steel if the incident electron energy in MeV is known. For example, find the transmission coefficient for 600-keV electrons incident normally on a thickness T of 75 mg/cm^2 of aluminum. From figure 26 the extrapolated range R_e is 220 mg/cm^2. The ratio T/R_e equals 0.34. From figure 24 the transmission coefficient is found to be 84 percent.

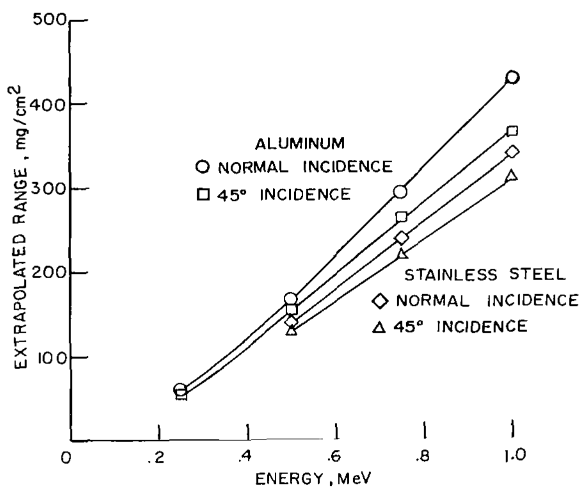

Figure 26.- Extrapolated ranges for electrons in aluminum and stainless steel.

SUMMARY OF RESULTS

1. Energy-independent electron transmission curves were constructed for aluminum and stainless steel exposed to electrons at normal and 45° incidence. These curves used in conjunction with the extrapolated-range curves give transmission coefficients for aluminum and stainless steel as a function of the ratio of material thickness to extrapolated range in the energy range from 250 keV to 1.0 MeV for aluminum and 500 keV to 1.0 MeV for stainless steel.

2. The ratio of the minimum thickness for maximum backscatter to the measured extrapolated range for aluminum and stainless steel is a constant for each material,

independent of energy, in the range from 250 keV to 1.0 MeV. For aluminum the constant is 0.45 and for stainless steel the constant is approximately 0.52. These constants may be employed to find the minimum material thickness that yields maximum backscatter.

3. The current-collection technique employed for these tests revealed no layer or interface effect on the transmission or backscatter coefficients for either of the materials investigated.

4. The experimental transmission curve for 1.0-MeV electrons incident normally on aluminum shows excellent agreement with Monte Carlo electron transmission calculations.

5. The transmission coefficients for stainless steel are approximately 15 to 20 percent less than the transmission coefficients for aluminum for both normal and 45° electron incidence in the energy range from 250 keV to 1.0 MeV. The maximum backscatter coefficients for stainless steel are approximately 10 to 15 percent greater than the maximum backscatter coefficients for aluminum for both normal and 45° electron incidence in the energy range from 250 keV to 1.0 MeV.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., August 15, 1967,
124-09-11-01-23.

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