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ABSTRACT

Adhesion, friction and Auger spectroscopy analysis of a commercially used cast cobalt base alloy as a turbine shroud material has revealed a surface enriched with tungsten and carbon suggesting a surface layer of tungsten carbide. Adhesion and friction of this segregated surface layer are higher than for the bulk cobalt base alloy composition. Auger spectroscopy analysis of the segregation of tungsten in the alloy indicates that it occurs between 850 and 1000°C.

INTRODUCTION

The wear of turbine blade tips by shrouds is a problem in currently used aircraft engines. This wear results from contact of the turbine blades with the shroud of the engine as a result of thermal and mechanical growth and excursions. Such "rubs" result in adhesion, friction, wear to the blade and the need to replace or rebuild blade tips.

An alloy used for a shroud material is a high temperature cobalt base super alloy containing chromium, tungsten and nickel. It is this shroud material and not the blades that should wear. With the shroud rather than the blade tip wearing the turbine performance losses from wear are minimized.

The objective of this study was to examine the composition of the shroud material in the surficial layers using Auger emission spectroscopy to clarify the wear process and suggest means to reduce wear of the blades. The adhesion and friction behavior of the alloy were also examined while conducting Auger spectroscopy depth profiling.

Material

The alloy investigated in this study was a cast cobalt base alloy used as an aircraft turbine shroud material. The composition of the alloy is presented in Table I. It is important to note that the alloy contains seven percent tungsten. The alloy was examined in the as received condition after removal from an engine. Thus, it had been exposed to high temperatures.

Apparatus

The apparatus used in this study was an adhesion and friction device with built-in LEED (low energy electron diffraction) and Auger emission spectroscopy capabilities. The specimen configuration for adhesion and friction studies was that of a 2 mm radius pin contacting a flat disk 8 mm in diameter and 2 mm thick. Loads applied ranged from 1 to 10 grams. Strain gages mounted at right angles to each other on a beam containing the rider were used to measure load, adhesion and friction forces.

The chamber containing the specimens was capable of achieving vacuum pressures to 10^{-10} torr. Sputtering of the disk specimen to remove surface layers was accomplished by back filling the chamber with argon gas to a pressure of 10 torr.

Experimental Procedure

The as received shroud material of the composition presented in Table I was electric discharge machined to produce a tablet size specimen 8 mm in diameter. The specimen was mounted in a holder and inserted into the vacuum chamber. The system was evacuated and baked-out at 250° C. Auger spectra, adhesion forces and friction forces were measured as follows: 1) on the as received sample, 2) at five intervals, one after each one hour sputtering cycle, 3) after abrading the surface with 600 grit paper, 4) after heating the abraded surface to 850°C and 5) after heating the abraded surface to 1000°C.

Sputtering was accomplished with argon ions at a pressure of 10 torr, 1000 volts, 3 milliamperes and for a period of one hour.

RESULTS AND DISCUSSION

The Auger spectrum for the as received commercial cobalt base alloy is presented in Figure 1. The principal surface species present are carbon and oxygen. The oxygen has its origin in the surface oxides and the carbon, as will be shown, with surface carbides.

In order to probe the alloys surface chemistry profile, sputtering of the alloy surface was conducted in one hour intervals for a total period of five hours. A typical Auger spectra after just one hour of sputter removal of surface layers is presented in Figure 2. Tungsten and carbon are the principal peaks in the spectrum.

Carbon and tungsten Auger peaks have been observed together in attempts to achieve clean tungsten surfaces (ref. 1). The alloy contains only seven percent tungsten yet this is the only metallic element seen in the Auger spectrum of Figure 2.

Continued sputtering of the alloy surface for four additional hours beyond that employed in obtaining the Auger spectrum of Figure 2 resulted in the Auger trace of Figure 3. The tungsten peaks are now the principal peaks with the carbon peak decreasing considerably from that seen in Figure 2. In the spectrum of Figure 3 there is still an absence of the other metallic elements present in the bulk alloy, particularly cobalt and chromium (see Table I).

The relative Auger peak intensities for tungsten to oxygen and tungsten to carbon with sputtering are presented in Figure 4. The data of Figure 4 indicate a relatively gradual diminishing of the oxygen as surface layers are stripped away. This is as might be anticipated.

With the carbon there is a rather abrupt decrease in the carbon Auger peak intensity between four and five hours. The surficial concentration of carbon together with tungsten would suggest the presence of a tungsten carbide surface layer (ref. 2). The presence of hard tungsten carbide on the surface of the shroud alloy contributed to abrasive wear of the turbine blades. Tungsten carbide is hard and can act to abrade the blade material.

Adhesion and friction data were obtained on the alloy within successive sputtering intervals and the results obtained are presented in Figure 5. The data of Figure 5 indicate an increase in both adhesion and friction with progressive removal of surface layers. Thus, as less and less oxygen and carbon are seen in the Auger spectra leaving principally tungsten as the surface layer (Figure 4) both adhesion and friction are seen to increase.

In order to examine the bulk alloy composition the specimen was removed from the apparatus and abraded on 600 grit metallurgical paper and then placed back into the apparatus. Adhesion and friction results obtained on the abraded specimen are presented in Figure 5. Abrasive removal of the surface layers resulted in an Auger spectrum containing oxygen, carbon, chromium and cobalt but absent was tungsten. Both adhesion and friction were markedly less for the bulk alloy composition as indicated in the data of Figure 5.

The abraded alloy was heated to 850°C for forty-five minutes to determine if the tungsten would segregate to the surface. The Auger spectrum from heating is presented in Figure 6. Cobalt, chromium, carbon and sulfur peaks were detected in the spectrum but tungsten was not observed. The specimen was then heated to 1000°C and the results of Figure 7 were obtained. In Figure 7 cobalt, chromium, carbon and tungsten were now observed at the surface. These results indicate that between 850 and 1000°C the tungsten segregated from the bulk to the alloy surface.

CONCLUSIONS

Based upon the adhesion, friction and Auger spectroscopy data obtained in this study on a commercial cobalt base alloy used as an aircraft turbine shroud material the following conclusions are drawn.

1. Between 850 and 1000°C tungsten in the cobalt base alloy segregates to the surface of the alloy. Carbon is also present and the compound tungsten carbide is suggested. This material could contribute to abrasive wear of turbine blades.

2. The surface tungsten rich layer has markedly higher adhesion and friction characteristics than the bulk alloy composition. The bulk alloy friction behavior is comparable to that measured for cobalt.

3. Sputtering of the alloy surface revealed oxygen diffused into the surficial layers with a gradual diminution of the same. With carbon, however, there was a rather abrupt decrease in its intensity with surface layer removal.

4. A replacement alloy should be sought that does not contain tungsten or other carbide forming constituents with surface segregation tendencies. The new alloy should be evaluated as a potential shroud material.

REFERENCES

1. Soyner, R. W.; Rickman, J.; and Roberts, M. W.: "Preparation of Atomically Clean Tungsten Surfaces," Sur. Sci. 39, pp. 445-449 (1973).
2. Ollis, D. F.; and Boudart, M.: "Surface and Bulk Carburization of Tungsten Single Crystals," Sur. Sci. 23, pp. 320-346 (1970).

TABLE I. - COMPOSITION OF CAST COBALT ALLOY

Element	Percent
Chromium	23.4
Nickel	10.0
Tungsten	7.0
Carbon	0.6
Titanium	0.2
Tantalum and Zirconium	Additions
Cobalt	Balance

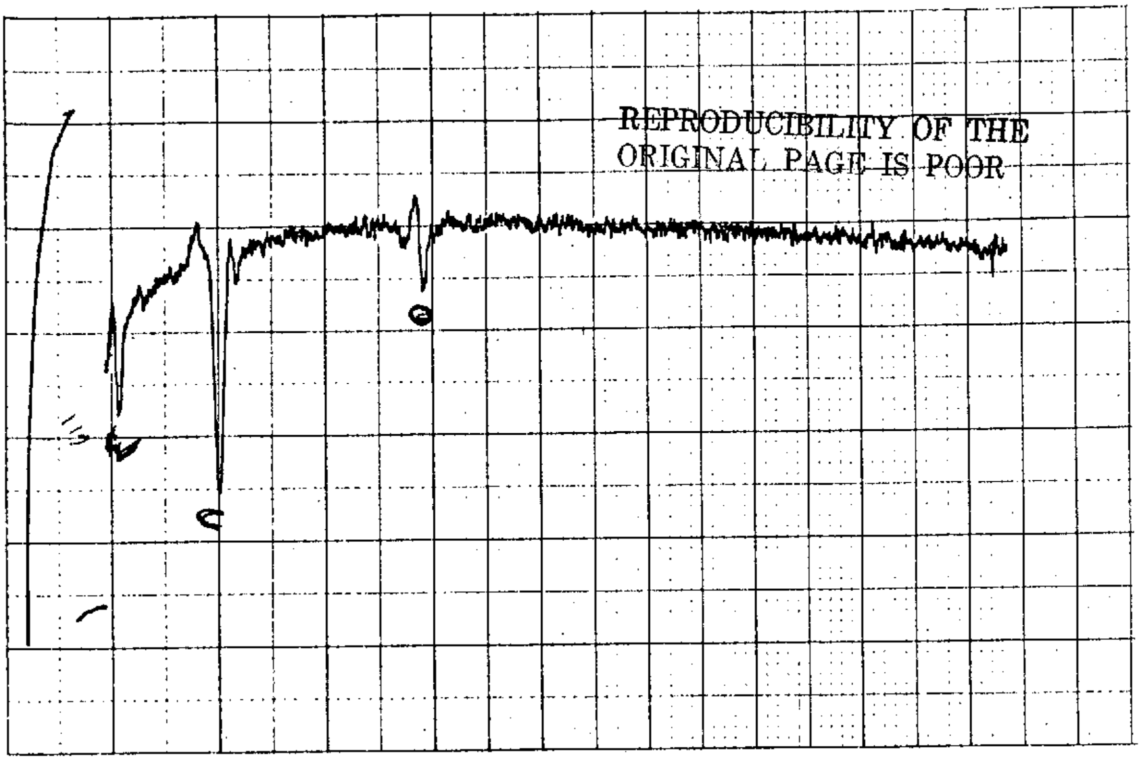

Figure 1. - Auger spectrum for a commercial cobalt base alloy in the as received condition.

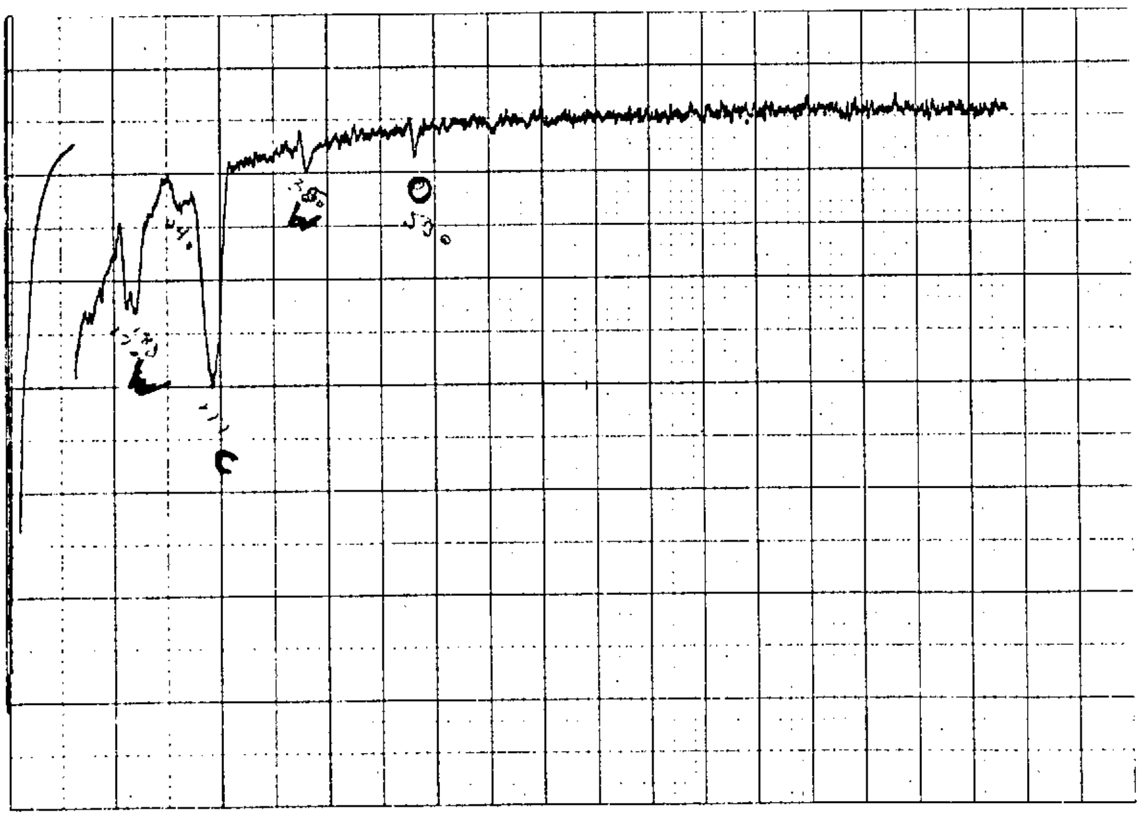

Figure 2. - Auger spectrum for a commercial cobalt base alloy after 1 hour of sputtering. Sputtering conditions 1000 volts, 3 mA, argon and a pressure of 10 torr.

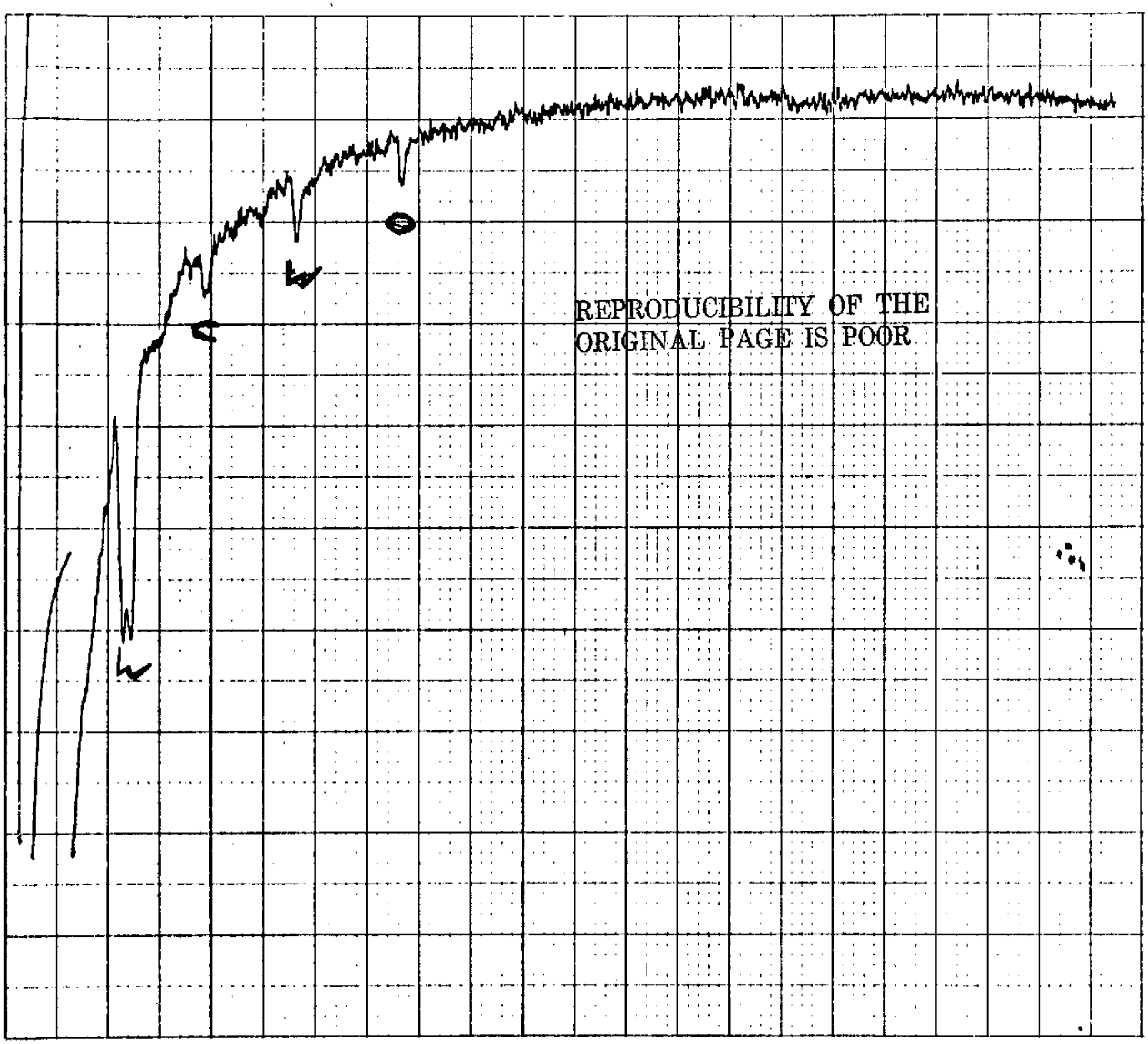

Figure 3. - Auger spectrum for a commercial cobalt base alloy after 5 hours of sputtering. Sputtering conditions 1000 volts, 3 mA, argon and a pressure of 10 torr.

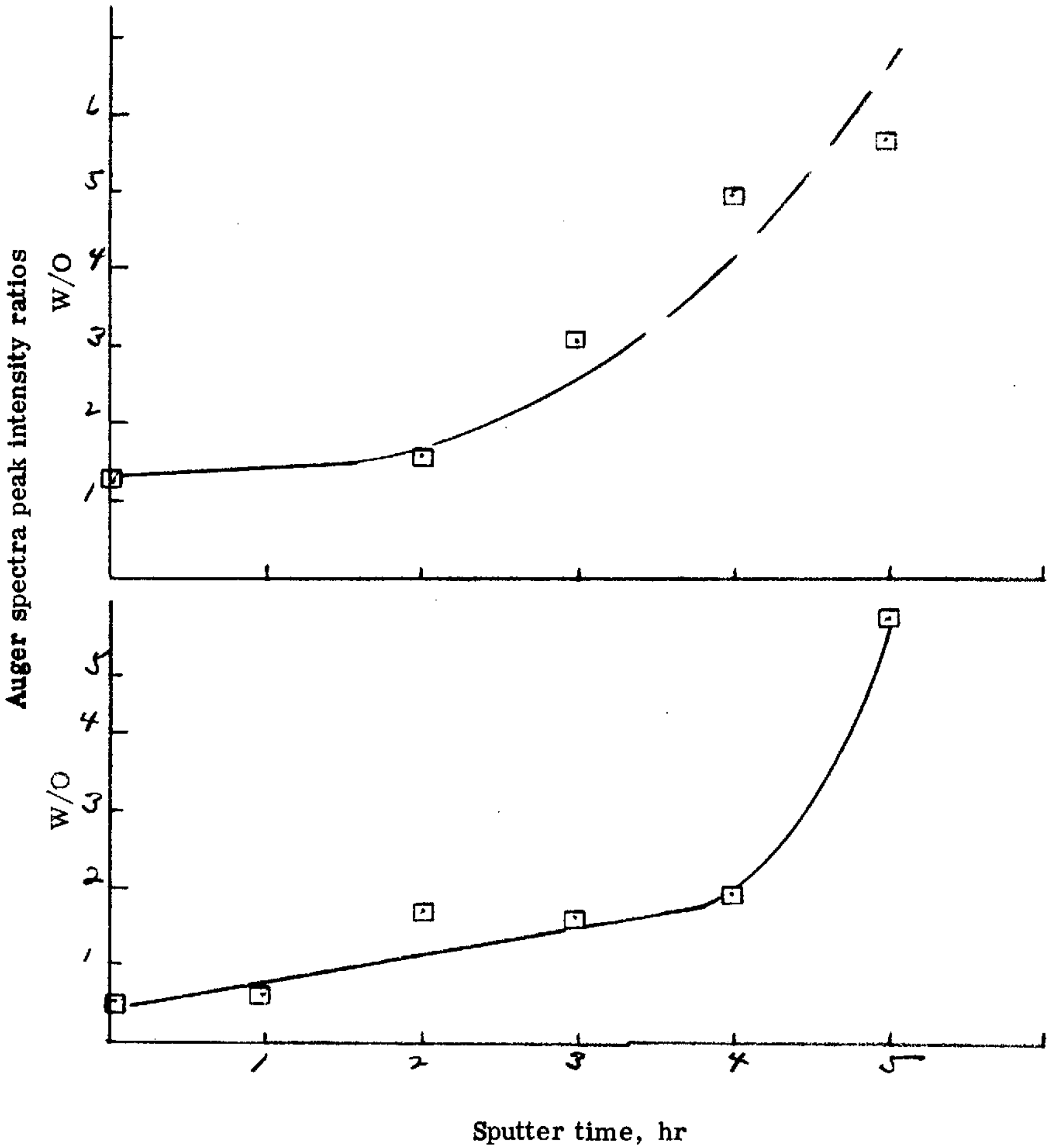

Figure 4. - Auger spectroscopy peak intensity ratios for tungsten to carbon and tungsten to oxygen as a function of surface sputter removal for a commercial cobalt base alloy. Sputter gas argon, 1000 volts, 3.0 mA and a pressure of 10 torr.

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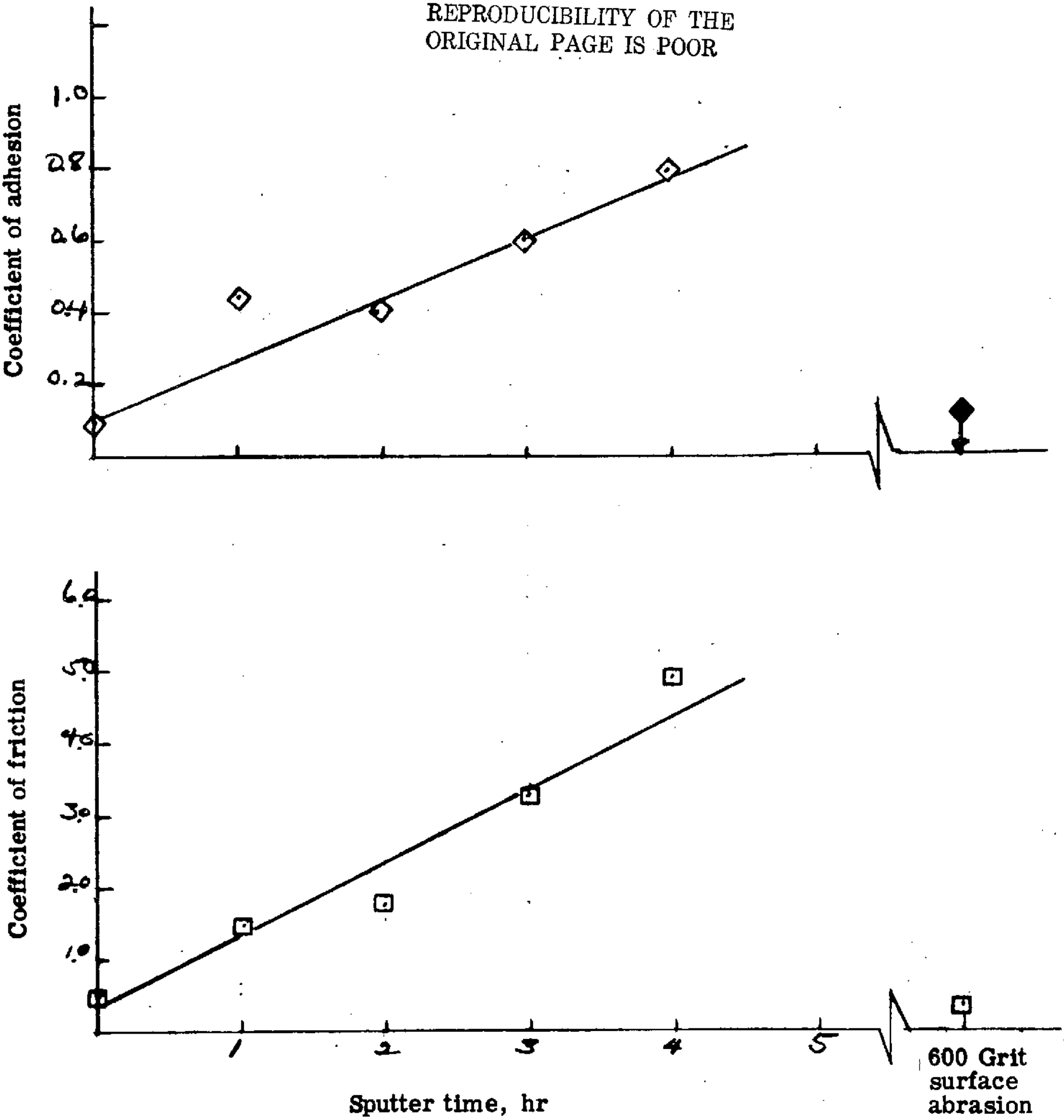

Figure 5. - Adhesion and friction coefficients for a commercial cobalt base alloy as a function of argon sputter removal of surface material. Sputter gas, argon, 1000 volts, 3 mA and 10 torr. Sliding velocity 1.5 cm/min, load 1.0 Cm, 10^{-10} torr and 23° C.

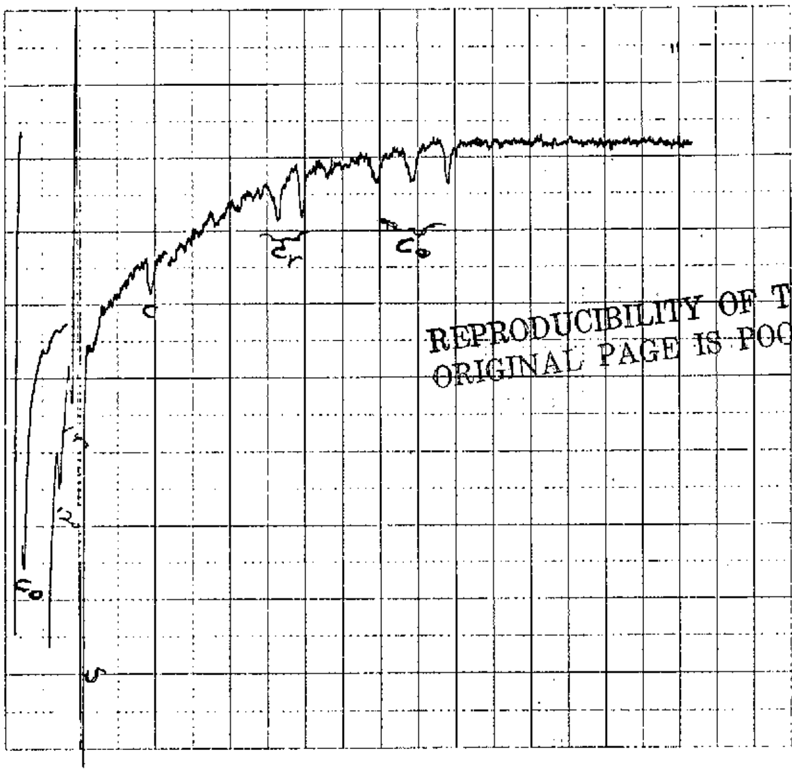

Figure 6. - Auger spectrum for a commercial cobalt base alloy sputtered, abraded and then heated for 45 minutes at 850° C.

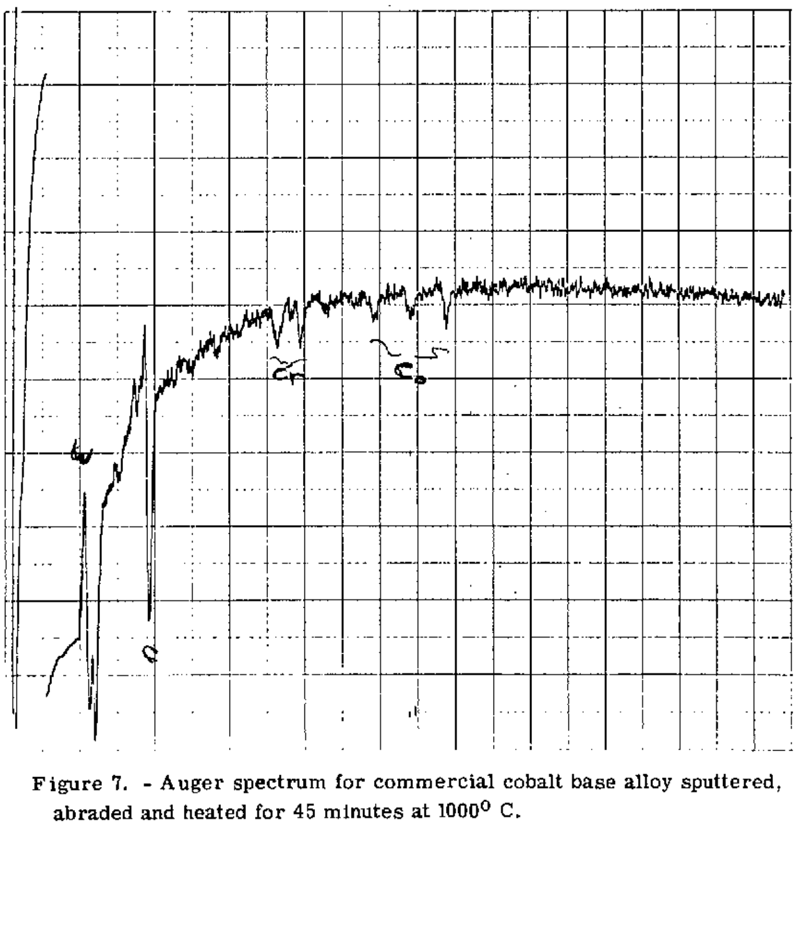

Figure 7. - Auger spectrum for commercial cobalt base alloy sputtered, abraded and heated for 45 minutes at 1000° C.