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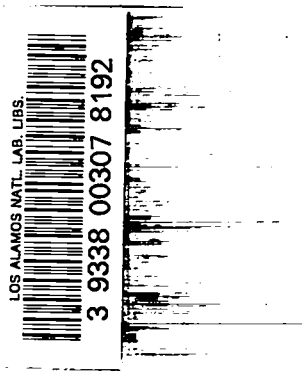

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LIOUID PLUTONIUM REACTION WITH TITANIUM

by

S. Dale Soderquist, Kaye A. Johnson

ABSTRACT

High purity plutonium penetrated into commercially pure titanium at an average rate of 0.006 inches per minute during six minutes between 970°C and 1050°C, under partial vacuum. It is believed that, due to the constrained geometry of the titanium cup and the loss of some plutonium due to penetration through an upper wall of the cup, the plutonium-titanium reaction rate was slowed and penetration stopped at 0.038 inches into the titanium. Conservative calculations based on the plutonium-titanium equilibrium phase diagram at 1050°C show that plutonium could have penetrated into the titanium cup at least 0.10 inches. Therefore, equilibrium conditions were not approached after the six minute test. A less-constrained titanium cup design with a lower titanium surface to plutonium volume ratio is being considered for further plutonium-titanium reaction studies.

I. INTRODUCTION

The original purpose of this study was to obtain reaction-rate data, at various temperatures near 1000°C, of plutonium penetration into containers made of titanium and titanium-6% aluminum-4% vanadium. A preliminary test was done with high purity plutonium in a commercially pure titanium cup, and the reaction rate was rapid. This study has since been broadened in scope to include other metals and coatings for containment of Pu at 1100°C. Also, based on the preliminary test, the containment cup configuration has been changed.

II. REPORT

The preliminary experimental test set-up included a commercially pure titanium cup machined to the dimensions shown in Fig. 1 (see Fig. 2 for microstructure). The titanium cup, nearly filled with plutonium in the center well and thermocouple inserted in the side well, was surrounded by a graphite susceptor/holding vessel, and heated inductively. The assembly was held six minutes between 970°C and 1050°C under partial vacuum. The plutonium penetrated through the upper titanium wall into the thermocouple well and through the outer wall, allowing some of the plutonium to leak out of the cup (Fig. 3). Also, a small part of the stainless steel sheathed thermocouple reacted with

the titanium (and plutonium) in the thermocouple well, possibly aiding plutonium penetration of the outer titanium wall. However, this would not have affected plutonium penetration into the bottom of the center well since the plutonium-titanium-stainless liquid flowed away from the center well. In addition, since plutonium melts first at 640°C and filled the bottom of the center titanium well, reaction of plutonium into the bottom of the titanium cup would initiate before titanium-nickel eutectic melts at 955°C. The plutonium titanium interface is shown after cooling at the bottom of the center well (Fig. 4).

Penetration measurements into the bottom of the center well show a reaction depth of 0.038 inches which averages 0.006 inches per minute penetration rate for six minutes between 970°C and 1050°C. However, it is believed that due to the constrained geometry of the original experimental titanium cup, and the loss of some plutonium by leakage, the reaction was prematurely slowed. With a new hemispherical cup design, more liquid plutonium per unit surface area of titanium will be available which should increase reaction rate and penetration for a given temperature and time.

Conservative penetration calculations based on equilibrium solubility of plutonium in titanium at 1050°C (Fig. 5)[1] show that plutonium could have penetrated into the titanium cup at least 0.10" with the geometry used. Therefore, equilibrium conditions were not approached during this test. The calculations were conservative because it was assumed that the amount of liquid plutonium in the titanium cup at the start of the experiment was at the final liquid level after some plutonium had leaked out, as measured from Fig. 2. Also, because of the steep solidus line slope in the plutonium-titanium phase diagram (Fig. 5), a change in temperature will not change solubility significantly, only kinetics. That is, with a fixed amount of plutonium, the achievable depth of penetration will not change significantly with temperature variations of 100°C or so near 1100°C. However, the rate of penetration toward equilibrium conditions will increase rapidly with a temperature rise of 100°C.

Further tests of plutonium penetration into various materials at 1100°C are intended with a hemispherical cup design, and will be the subject of future reports.

III. CONCLUSIONS

1. Equilibrium penetration of plutonium into titanium was not reached in this experiment after six minutes between 970°C and 1050°C.

2. Reaction rate of liquid plutonium with titanium is rapid, even under partial vacuum conditions where a partially protective coating of titanium oxide is expected.

3. Very clean surfaces and a good vacuum will probably increase penetration rate of liquid plutonium into titanium over that reported here.

4. A less-constrained cup design with a lower titanium surface to plutonium volume ratio would increase plutonium penetration.

REFERENCE

1. Ellinger, F. H., et al. "Constitution of Plutonium Alloys," Los Alamos Scientific Laboratory report LA-3870, P-115 (December 1968).

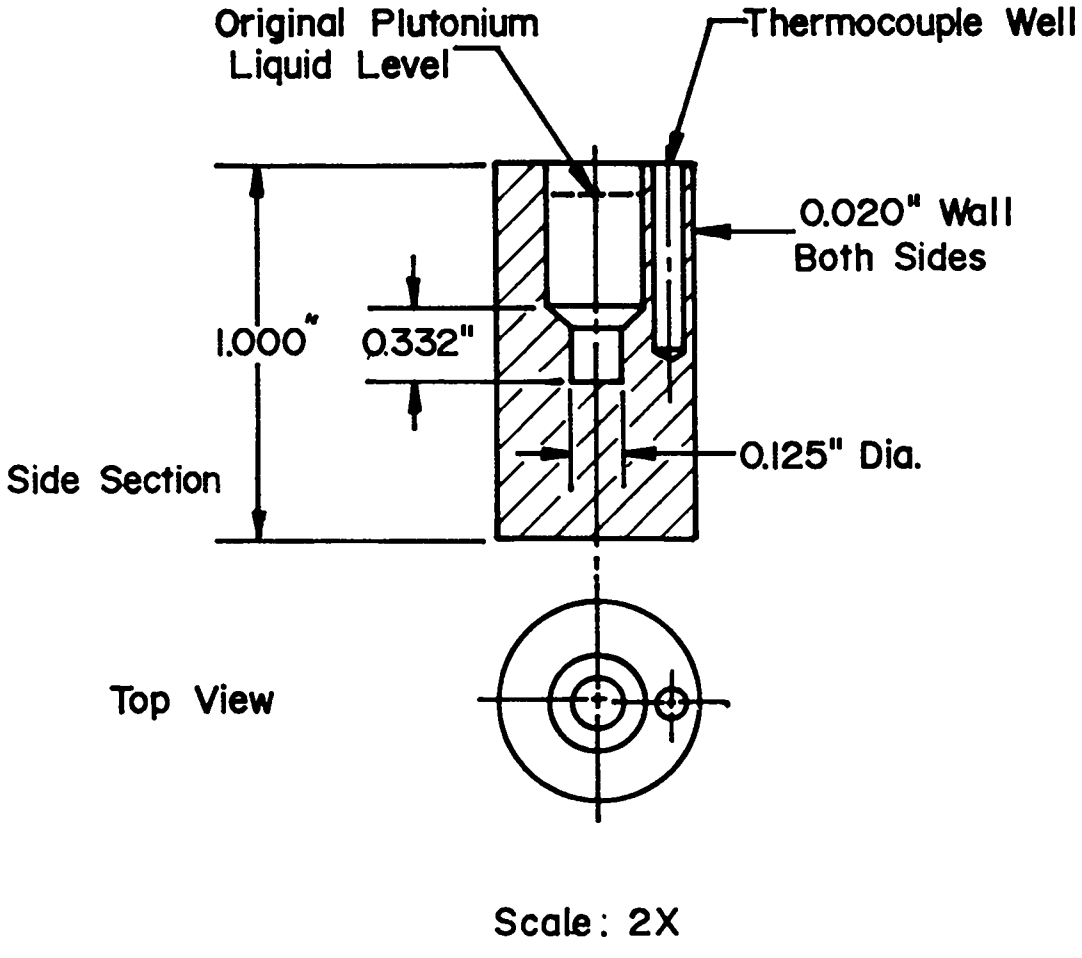

Fig. 1. Titanium Cup.

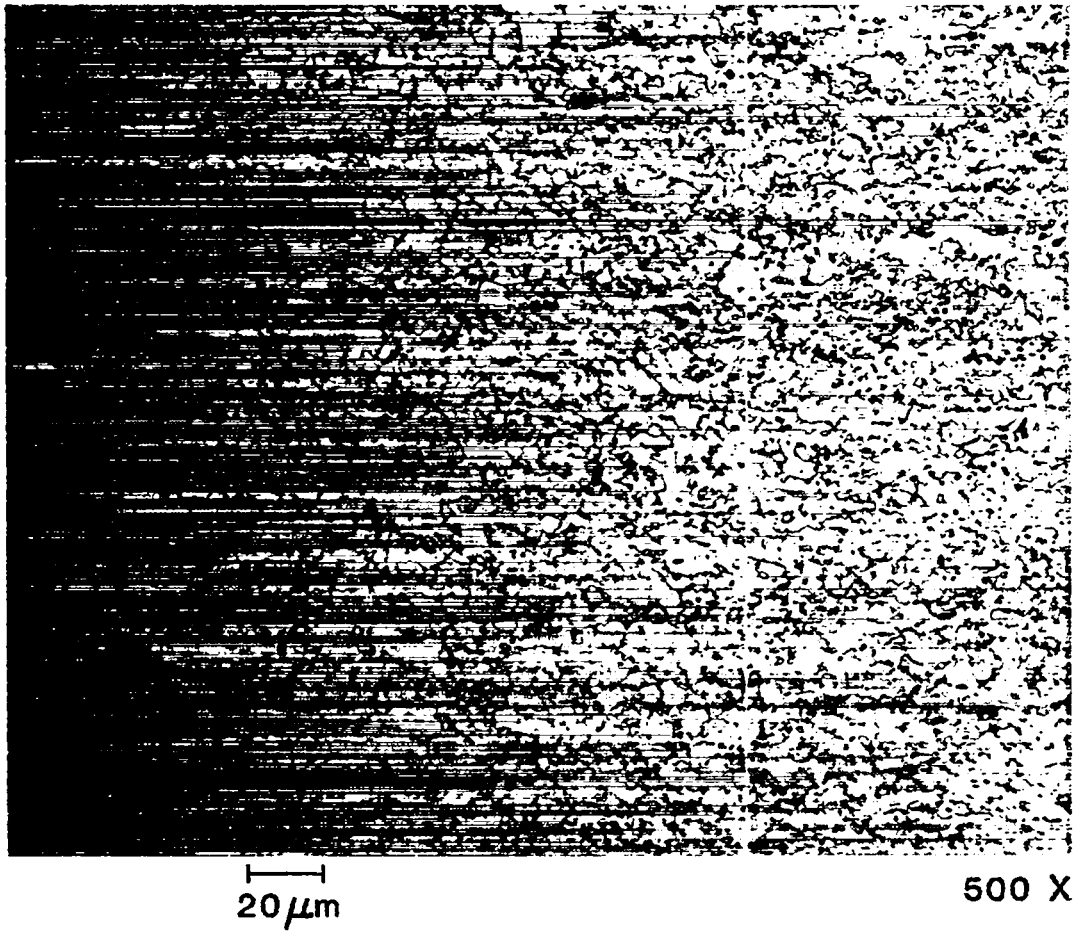

Fig. 2. Commercially Pure Titanium Rod, Longitudinal Section.

Fig. 3. Titanium Cup After Reaction with Liquid Plutonium.

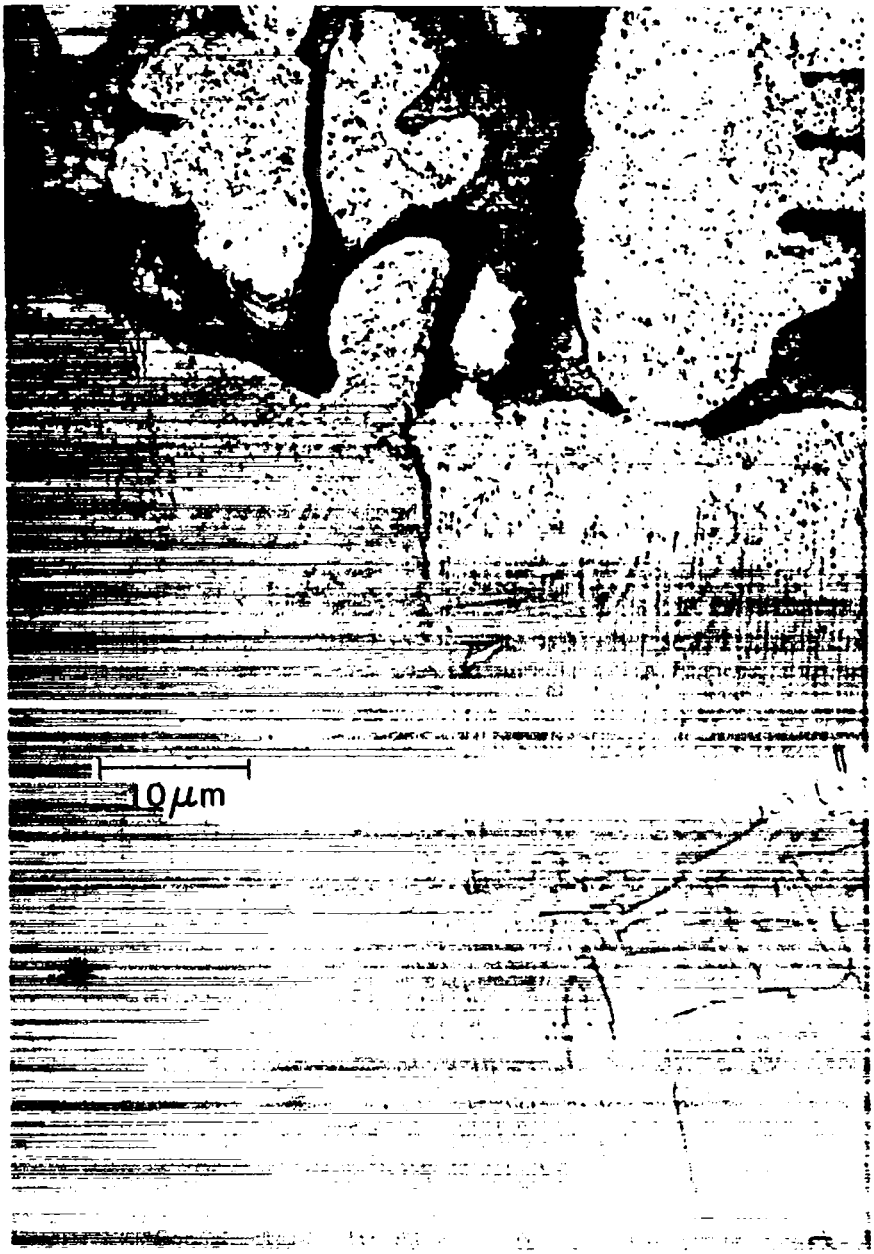

Fig. 4. Liquid Plutonium/Titanium Interface After Testing.

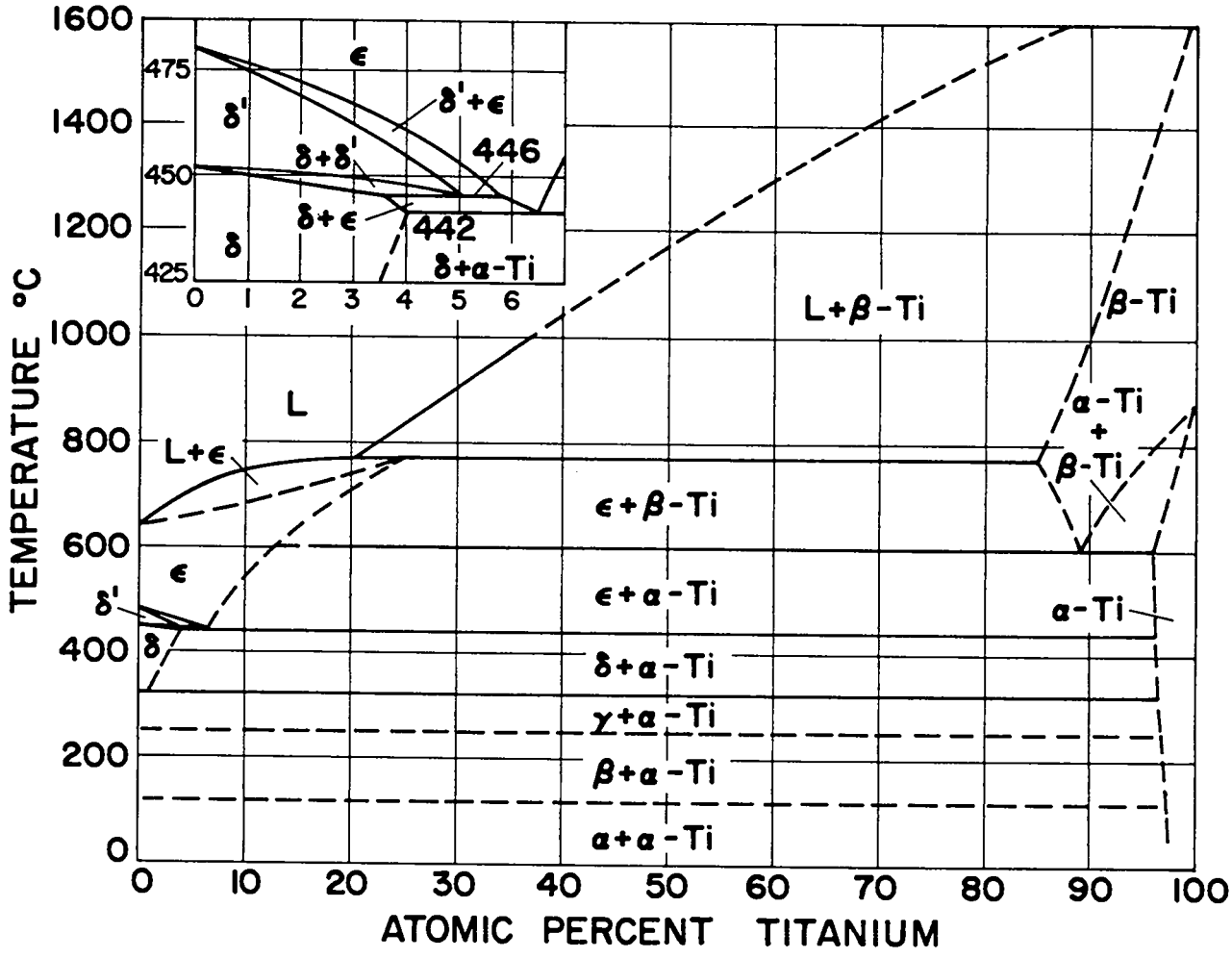

Fig. 5. Equilibrium Phase Diagram of Plutonium-Titanium.

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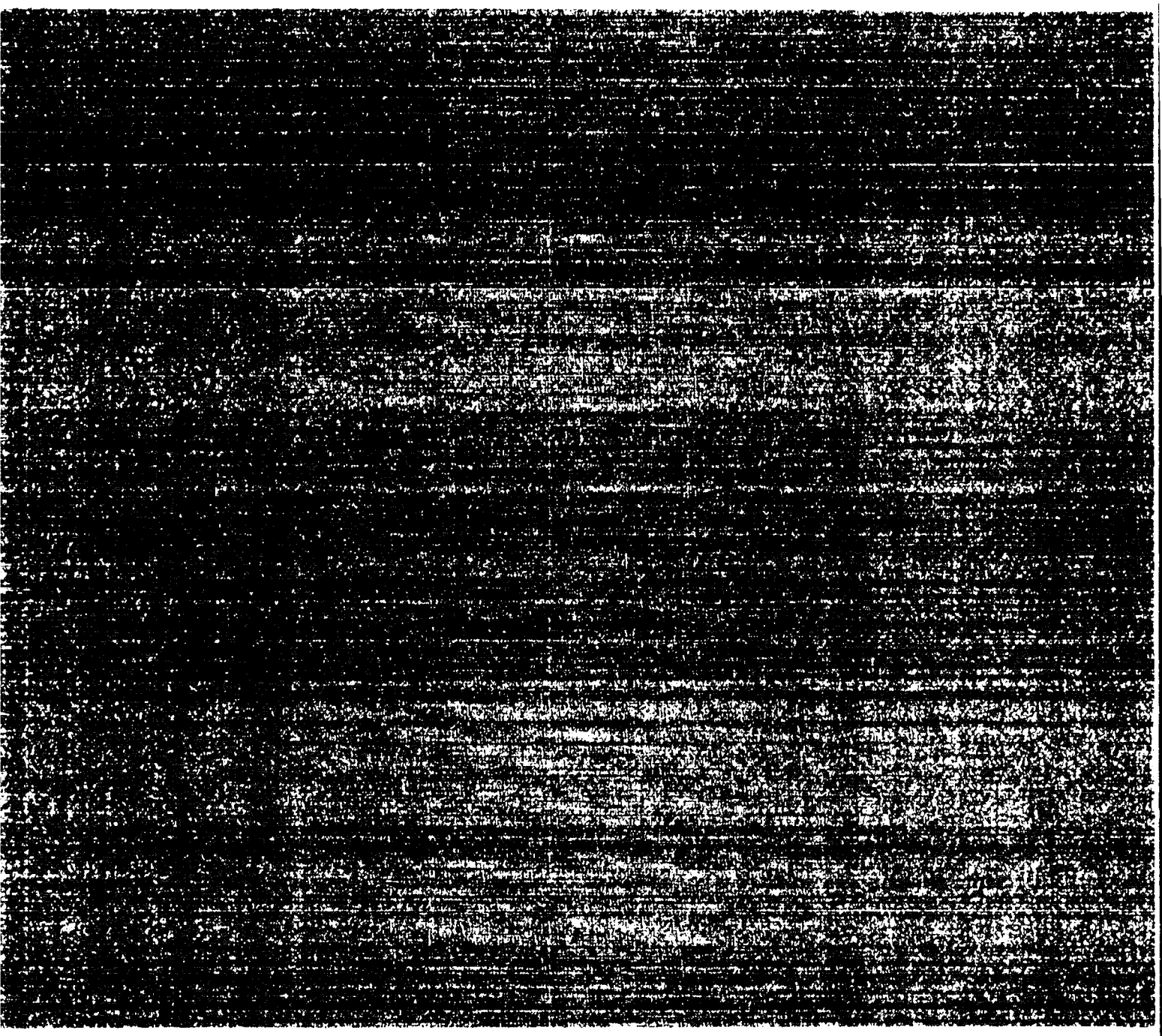

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