*This document is
PROPERTY OF THE
MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
12/3/08*

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
155 Massachusetts Avenue
Cambridge, Massachusetts

AEC D-3851

MEMORANDUM

To: Dr. A. R. Kaufmann
From: R. B. Russell, Physical Metallurgy
Date: May 11, 1953
Subject: Uranium - Zirconium Explosions in Nitric Acid

Photostat Price \$ 1.80
Microfilm Price \$ 1.80

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

In 1952, Roth⁽¹⁾ reported several incidents of explosions while etching uranium-rich zirconium-uranium alloys. Explosions between uranium powder or turnings and nitric acid have been noted in the literature.⁽²⁾ Recently such hazards to workers have been considered serious enough to summarize additional experiences with these alloys since the earlier report. These notes are designed to describe conditions sufficient to cause an explosion with an 80% wt. uranium alloy.

A copper-jacketed uranium alloy, No. 980, was extruded to a final size of 7/16" dia. rod (1/2" O.D. including jacket) at about 600°C. The analysis was:

	Wt. %	At. %
U	78.9	57.4
Zr	20.8	39.5
Fe	0.07	0.2
C	0.20	2.9

1. Roth, H. P., "Explosions Occurring During Chemical Etching or Pickling of Uranium-Zirconium Alloys," MIT-1105 (Dec. 19, 1952).
- (2). Rodden, C. J., et al., Analytical Chemistry of the Manhattan Project, National Nuclear Energy Series, Div. VIII, v. 1, (McGraw-Hill Book Co., Inc., New York, N. Y., 1952).

LEGAL NOTICE
This report was prepared as an account of Government sponsored work. Neither the United States nor the Commission nor any person acting on behalf of the Commission makes any warranty or representation, expressed or implied, with respect to the use of any information, apparatus, method, or process disclosed in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe on any existing or future patent rights or other intellectual property rights. No part of this report may be reproduced or transmitted in any form or by any means electronic or mechanical, including photocopying and recording, or by any information storage or retrieval system, except as may be permitted in writing by the Commission or the sponsor of the work. This report is the property of the Commission and is loaned to your organization; it and its contents are not to be distributed outside your organization.

*Classified from (original) and to uncl.
by H. F. A. Z. Carrol
date 12-5-55*

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

2

The coatings are not particularly pyrophoric when scratched with a sharp file, although they ~~exhibited~~ ~~initiated~~ ~~compared~~ to the original as-ground

round
77-2

Photograph showing two successive blast patterns on a 80% U-20% Zr alloy exploded on contact with white concentrated nitric acid. 3X

Attention is called to the following U.S.A.E.C. safety notices issued by the New York Office:

Serious Accidents, No. 39 (19 March, 1953), No. 44 (1 April, 1953).

Accident and Fire Prevention Information (26 February, 1953).

To: A. R. Kaufmann

4

surface. A Norelco x-ray diffractometer scan of the two active surfaces (sample area $3/4"$ x $7/16"$) coated with the products of from two to ten explosions (but still reactive) showed the following d-spacings in A with $\text{CuK}\alpha$ radiation:

<u>Int.*</u>	<u>d, Å</u>	
strong	3.056	$\text{UO}_2?$
v. weak	2.811	
medium	2.649	"
medium	2.486	"
weak	2.330	
medium	1.867	"
broad medium	1.595	"

* intensities are of little importance
since the sample is not random

It is believed that these lines are partly explained by a somewhat distorted UO_2 (and possibly ZrO_2) coat. No UH_3 lines⁽³⁾ were found. If the black coat be a mixture of $\text{UO}_2\text{-ZrO}_2$, it is difficult to see why the urania does not dissolve in the concentrated acid. The normal uranium oxides dissolve readily in nitric acid without any explosions.

That the degree of shock or impact is a factor in starting the detonation can easily be demonstrated by the fact that very small or light (a gram or less) pieces are exploded less easily than larger (four grams or more) in the dropping test. A clear example of the effect of shock was observed when 3 ml of acid was poured over one of the larger pieces (which had previously exploded by dropping) without exploding, but when the piece was probed with the stainless steel tongs, it exploded.

It would seem to be very difficult to make out a case for the rapid burning of hydrogen itself in these explosions, since there is hardly time

(3). Warf, J. C., "Chemical Properties of Uranium Hydride," AECD-2997, (Sept. 29, 1949), p. 34.

77-4

for enough gas to accumulate. Indeed, one can point out the danger from this source in dissolving uranium-silicon (e.g. 4% wt. Si) alloys in warm concentrated hydrochloric acid. The escaping hydrogen bubbles explode at the surface of the sample and also of the liquid with enough violence to spatter. If the acid is diluted 1:1 with water, the reaction rate is low enough to be safe⁽⁴⁾, although actually concentrated nitric acid is recommended⁽⁵⁾ for dissolving the sample for chemical analysis.

In summary we should state that we have never observed the explosion of uranium, uranium alloys (including zirconium alloys), nor zirconium in the massive dry condition. Detonations at M.I.T. with uranium-zirconium have only been associated with contact with nitric acid, and at that only a reactive surface sensitive to mechanical shock seems to be involved. Whether this surface is a catalyst for the violent decomposition of nitric acid, or whether some metastable compound (such as metallo-nitrogen compound or hydrazine⁽²⁾) accumulated and developed by immersion in nitric acid itself explodes, cannot be stated without further work. The possibility of the generation of UH_3 was considered, in view of its well-known instability,⁽⁶⁾⁽⁷⁾ but it could not be detected by preliminary x-ray tests on active surfaces.

Finally, it should be emphasized that NO SURFACE PREPARATION CAN BE CONSIDERED SAFE AGAINST EXPLOSIONS EVEN WITH MOMENTARY CONTACT WITH CONCENTRATED NITRIC ACID. In conducting tests, the experimenter should be warned to wear a transparent helmet, since the ordinary face mask will not protect the victim against falling acid spray.

(4). Personal communication from Mr. Charles Albright.

(5). Ref. 2, p.219.

(6). Hartman, I., Nagy, J., Jacobson, M., "Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium and their Hydrides," BM-RI-4835 (Dec. 1951).

(7). Ref. 3, p. 52.

77-