(EURAEC-472)

ARF 2198-34
(Quarterly Report)

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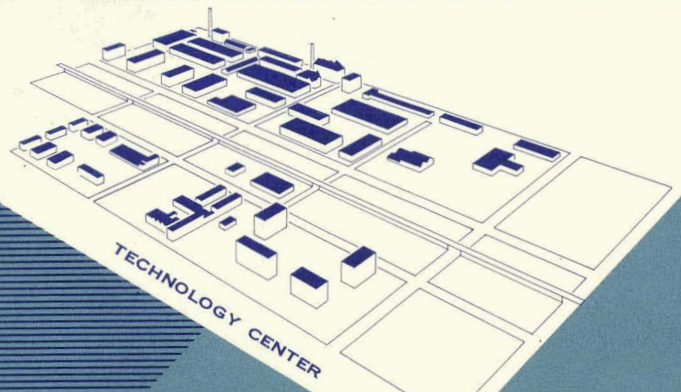

Contract No. AT(11-1)-578
Project Agreement No. 1

IMPROVED ZIRCONIUM ALLOYS

U. S./EURATOM Program
Joint Research and Development Board
Brussels, Belgium

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IMPROVED ZIRCONIUM ALLOYS

D. Weinstein
F. C. Holtz

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IMPROVED ZIRCONIUM ALLOYS

I. INTRODUCTION

The United States and the European Atomic Energy Community (EURATOM), on May 29 and June 18, 1958, signed an agreement which provides a basis for cooperation in programs for the advancement of the peaceful applications of atomic energy. This agreement, in part, provides for the establishment of a Joint U.S.-Euratom research and development program which is aimed at reactors to be constructed in Europe under the Joint Program.

The work described in this report represents the Joint U.S.-Euratom effort which is in keeping with the spirit of cooperation in contributing to the common good by sharing of scientific and technical information and minimizing the duplication of effort by the limited pool of technical talent available in Western Europe and the United States.

II. SUMMARY OF PROGRESS TO DATE

For ternary alloys investigated during the second year of work, corrosion and hydrogen pickup data in 680°F water are available for an exposure time of 4800 hours. Materials have also been evaluated for strength at 680°F, and data have indicated that several compositions satisfy at least one of the program objectives. Moreover, these data suggest that further improvement of properties might be realized by minor modifications of alloying concentrations. A further group of about 40 alloys, therefore, has been prepared for optimization of corrosion properties in 680°F water and strength at this temperature. Thus far, corrosion data have been obtained up to a 2000-hour exposure, which is not sufficient to allow for evaluation of materials. Mechanical properties and hydrogen pickup will be determined on alloys exhibiting acceptable corrosion resistance.

Ternary zirconium alloys have been exposed to 750°F steam for a period of 3000 hours during the second year of work. Weight gain

and hydrogen pickup values, along with tensile properties, have indicated that a few compositions meet the objectives of this program. On the basis of these results, approximately 50 ternary alloys were planned with the intention of optimizing corrosion and strength properties. These compositions are presently being fabricated.

Ternary alloys have been exposed to 900°F steam for a relatively short time. While Zircaloy-2 is entirely unsatisfactory in this atmosphere, no experimental alloys were found to be resistant as well. However, some marked improvement in corrosion resistance was obtained. Additional alloys have been planned for further study; they have not yet been prepared or fabricated.

III. PRINCIPAL INVESTIGATORS

D. Weinstein	-	Project Engineer
F. C. Holtz	-	Group Leader

IV. STATEMENT OF PROBLEM

The program objectives are the development of zirconium-base alloys having corrosion resistance and/or strength (with equivalent corrosion resistance) markedly superior to Zircaloy-2 in 680°F water and/or 750° to 900°F steam. The pickup of hydrogen during corrosion is an important aspect of this program; however, this factor is employed for evaluation of experimental alloys rather than as a criterion for screening and development of material.

V. DESCRIPTION OF WORK-- RESULTS

The corrosion properties of ternary alloys in 680°F water and the strength of promising compositions were presented in the last quarterly report (ARF 2198-31). A more detailed summary of hydrogen pickup properties of selected alloys is shown in Table I. Zircaloy-2 showed very high hydrogen pickup, whereas all the promising experimental alloys exhibited markedly improved hydrogen uptake properties. It is seen that tellurium and germanium additions do not result in high pickup fractions; because of this property, along with a beneficial effect on corrosion resistance and a strong strengthening effect, these elements are ideal additions to zirconium.

TABLE I

HYDROGEN PICKUP OF TERNARY ALLOYS
EXPOSED TO 680°F WATER FOR 200 DAYS

Composition w/o	Weight Gain, mg/dm^2	Total Hydrogen, ppm	Pickup Fraction, %
Zircaloy-2	68.47	183	46
Zircaloy-2	66.26	191	49
Zr-1Cr-0.25Te	35.79	54	15
Zr-1Sb-0.5Nb	68.59	63	12
Zr-1Sb-0.25Te	49.66	62	17
Zr-1Sb-0.25Ge	52.85	38	8
Zr-0.5Nb-0.25Te	46.88	65	22
Zr-0.5Sn-0.25Te	42.84	55	18
Zr-0.5Sn-0.25Ge	36.98	51	18

For ternary alloys in 750°F steam, the corrosion curves and strength of promising alloys have been presented; Table II presents the hydrogen pickup characteristics of selected alloys after 125 days' exposure. Zircaloy-2 shows very high hydrogen pickup; however, in this case, many of the experimental alloys show an equivalent pickup fraction; iron appears to be very deleterious to hydrogen uptake properties. The alloys of 0.5Nb with 0.25w/o Cr or Te are the only ones with markedly improved hydrogen properties. It is seen that this higher temperature not only increases the corrosion rate but apparently increases the percentage of corrosion hydrogen absorbed by the alloy.

VI. FUTURE WORK

Exposure of ternary alloys in 680°F water, which were chosen on the basis of results on ternary materials exposed during the second year, will continue. The ternary alloys for 750°F steam which are in the process of being fabricated will not be studied further until the contract renewal has been received. Similarly, work will not proceed on ternary alloys for 900°F steam application.

VII. CONCLUSIONS

This program is concerned with development of zirconium-base alloys having corrosion resistance and strength superior to Zircaloy-2 and/or development of materials of equivalent corrosion resistance but exhibiting enhanced strength. The current investigations on ternary alloys resulted from an extensive binary alloy corrosion screening study carried out during the first year. At present, a number of ternary compositions have been developed for service in 680°F water which meet the objectives of this program on the basis of corrosion resistance, strength, and hydrogen pickup. The ternary alloys based on Zr-1Sb, Zr-1Cr, Zr-0.5Nb, and Zr-0.5Sn with small additions of Te, Ge, Cr, or Fe, are initially successful for 680°F water applications. In 750°F steam, Zr-3Cr-1Fe, Zr-3Cr-0.25Te, and Zr-1V-1Fe are the salient materials; on the basis of corrosion resistance and strength, these compositions are superior to Zircaloy-2 and meet the program objectives. However, the hydrogen pickup properties are about the same as Zircaloy-2 and the acceptability of this magnitude of corrosion-hydrogen uptake remains questionable. For optimum properties, a large

TABLE II

HYDROGEN PICKUP OF TERNARY ALLOYS
EXPOSED TO 750°F STEAM FOR 125 DAYS

Composition w/o	Weight Gain mg/dm^2	Total Hydrogen ppm	Pickup Fraction, %
Zircaloy-2	87.96	256	50
Zircaloy-2	74.31	212	48
Zr-0.5Nb-0.25Cr	97.47	79	13
Zr-0.5Nb-0.25Te	66.95	94	30
Zr-3Cr-1Fe	65.43	158	50
Zr-3Cr-0.25Te	67.03	141	43
Zr-1V-1Fe	72.00	163	50
Zr-1Fe-1Sb	107.18	246	48
Zr-1Fe-0.5Nb	88.60	212	58
Zr-1Fe-0.25Cr	51.81	126	55
Zr-1Fe-0.25Te	68.84	204	71

number of alloys have been prepared and are presently being evaluated; however, renewal of this development effort has been delayed, and no new work can be initiated. A proposal has been submitted outlining future work which is designed to yield selected materials which are not only considerably superior to Zircaloy-2 but are also stronger and more corrosion-resistant than the alloys developed to date; a comprehensive evaluation of mechanical properties would be performed on larger ingots of the most promising experimental alloys, thus permitting rapid incore reactor evaluation.

VIII. REPORTS ISSUED

None.

Respectfully submitted,

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