

FAST REACTOR SAFETY X: POST ACCIDENT HEAT REMOVAL.

1. Investigations of Thermite-Type Chemical Reactions to Generate Molten Core Materials for Reactor Safety Experiments, L. Baker, Jr. (ANL), G. A. Mansour (U of Ill-Chi), J. D. Gabor, J. D. Ringle (ANL)

To perform reactor safety experiments, one way to obtain mixtures that have the approximate temperatures and compositions of material produced during hypothetical core-disruptive accidents of LMFBR cores, in which mixed-oxide fuel (U,PuO₂) is in close contact with stainless steel (Fe, Cr, Ni, Mo), is by thermite-type reactions.

Thermite reactions involve a reactive metal and an oxide of a less reactive metal. A reaction between uranium metal powder and molybdenum trioxide to produce molten UO₃,



was used successfully in recent studies of molten UO₃ interactions with sodium.^{1,2} However, the UO₃ generated by Eq. (1) contains about 19 wt% molybdenum metal (not normally present in a reactor core).

Studies of other thermite reactions, which might better simulate core debris, were begun for a wide range of reactor safety experiments by producing molten stainless steel and molten steel-UO₃ mixtures. Three reactive metals were studied: Al, Zr, and U. Both pure Fe₂O₃ and a mixture of stainless-steel oxides (see Table I) were used. Approximately 75 g of oxide powders (reactant grade) were mixed with the metal powders in the desired proportions and packed into a reaction chamber made of a 5-in. length of 1-in. stainless-steel pipe (closed at the bottom with a cap that had a 1/2-in. central hole covered with a 3-mil stainless-steel sheet). The powder mixture was ignited using Mg ribbon and the thermite reaction propagated from top to bottom. On reaching the bottom, the steel sheet melted and the mixture, if molten, dumped into a graphite crucible located about 6 in. below the reaction chamber.

The propagation rate was measured by timing the initial rapid rise of two thermocouples located vertically 4 in. apart in the chamber. Driftless temperatures were

measured by taking high-speed motion pictures of the falling molten mixtures, using several calibrated tungsten ribbon-filament lamps.

Results of the experiments are given in Table I. Propagation rates tend, to a lesser extent, temperatures may depend on many factors, including particle size, packing density, etc., which were not varied in these tests. The data should be viewed, therefore, as only typical of what might be expected in an application.

The tests with aluminum gave the slowest propagation rates; however, because of the large density difference between the molten metal and alumina, the metal was effectively separated in a lower layer with the oxide on top. The tests with zirconium gave faster propagation rates and higher temperatures; however, the product was a coarse mixture owing to a decreased difference in densities. The tests with uranium gave intermediate propagation rates; however, the temperature was not high enough to melt UO₃ (MP 2840°C).

In agreement with the experimental results, thermodynamic calculations indicate that all of the reactions in Table I have enough energy to produce boiling steel (BP = 2800°C), although the energy available for the uranium reaction is somewhat marginal.

Reaction (3) is well suited to produce good-quality molten steel and in two tests 1 kg was produced to observe flow and freezing of molten steel in tubes. Reaction (7) was used to simulate a hot but solid fuel rod to observe the meltdown of steel cladding. Mixtures of Reaction (3) and (7) or possibly (1), (3), and (7) may be capable of generating very representative mixtures of molten core debris. Such tests are planned.

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TABLE I
 Summary of Thermite Reaction Experiments

No.	Thermite Mixture ^a	Product Composition	Driftless Temperature, °C	Linear Propagation Rate, in./sec
2	Al-Fe ₂ O ₃	48 wt% Al ₂ O ₃ , 52 wt% Fe	2750	0.2
3	Al-SS oxides	52 wt% Al ₂ O ₃ , 48 wt% SS	2850	0.2
4	Zr-Fe ₂ O ₃	62 wt% ZrO ₂ , 38 wt% Fe	2800	0.9
5	Zr-SS oxides	62 wt% ZrO ₂ , 38 wt% SS	3000	1.3
6	U-Fe ₂ O ₃	38 wt% UO ₃ , 62 wt% Fe	---	0.6
7	U-SS oxides	61 wt% UO ₃ , ^c 39 wt% SS	~2800	0.5

^a SS oxides indicate a mixture of 61.5 wt% Fe₂O₃, 25.5 wt% Cr₂O₃, 10.9 wt% NiO, and 2.1 wt% MnO₂.

^b O₃ was not melted and mixture did not flow.

^c UO₃ was slightly melted and flow was incomplete.

Fast Reactor Safety

Jianjun Gao



Fast Reactor Safety:

Fast Reactor Safety John Graham, 2012-12-02 Fast Reactor Safety deals with safety design criteria and methodology for fast reactors Topics covered include safety evaluation methods system disturbances containment and licensing The characteristics of fast reactors including heat ratings and coolants are also discussed Comprised of six chapters this book opens with an overview of methods used to evaluate nuclear safety along with neutron kinetics thermal and feedback effects and fault tree analysis The reader is then introduced to possible system disturbances in relation to three distinct fast reactor systems liquid metal cooled fast breeder reactors gas cooled fast breeder reactors and steam cooled fast breeder reactors The next chapter looks at safety criteria that are set to define the design of a safe plant together with the safety features that might be included The remaining chapters focus on the particular problems of a sodium cooled design containment building and primary circuit and vessel containment and licensing of the plant This monograph is intended for graduates and undergraduates in nuclear engineering who are attending courses in reactor safety *Proceedings of the 1990 International Fast Reactor Safety Meeting*, 1990

Fast Reactor Fuel Type and Reactor Safety Performance, 2009 Fast Reactor Fuel Type and Reactor Safety Performance R Wigeland Idaho National Laboratory J Cahalan Argonne National Laboratory The sodium cooled fast neutron reactor is currently being evaluated for the efficient transmutation of the highly hazardous long lived transuranic elements that are present in spent nuclear fuel One of the fundamental choices that will be made is the selection of the fuel type for the fast reactor whether oxide metal carbide nitride etc It is likely that a decision on the fuel type will need to be made before many of the related technologies and facilities can be selected from fuel fabrication to spent fuel reprocessing A decision on fuel type should consider all impacts on the fast reactor system including safety Past work has demonstrated that the choice of fuel type may have a significant impact on the severity of consequences arising from accidents especially for severe accidents of low probability In this paper the response of sodium cooled fast reactors is discussed for both oxide and metal fuel types highlighting the similarities and differences in reactor response and accident consequences Any fast reactor facility must be designed to be able to successfully prevent mitigate or accommodate all consequences of potential events including accidents This is typically accomplished by using multiple barriers to the release of radiation including the cladding on the fuel the intact primary cooling system and most visibly the reactor containment building More recently this has also included the use of inherent safety concepts to reduce or eliminate the potential for serious damage in some cases Past experience with oxide and metal fuel has demonstrated that both fuel types are suitable for use as fuel in a sodium cooled fast reactor However safety analyses for these two fuel types have also shown that there can be substantial differences in accident consequences due to the neutronic and thermophysical properties of the fuel and their compatibility with the reactor coolant with corresponding differences in the challenges presented to the reactor developers Accident phenomena are discussed for the sodium cooled fast reactor based on the mechanistic progression of

conditions from accident initiation to accident termination whether a benign state is achieved or more severe consequences are expected General principles connecting accident phenomena and fuel properties are developed from the oxide and metal fuel safety analyses providing guidelines that can be used as part of the evaluation for selection of fuel type for the sodium cooled fast reactor

Proceedings of the International Topical Meeting on Fast Reactor Safety, 1985 Fast Reactor Safety American Nuclear Society. Nuclear Reactor Safety Division, 1985 Nuclear Reactor Safety F Farmer, 2012-12-02 Nuclear Reactor Safety aims to put the nuclear hazard in perspective by providing an objective overall technical review of the field It focuses on reactor accidents and their consequences The technical arguments will be concerned broadly with reactor accident conditions and will deal with both the arrangements necessary to prevent any dangerous diversion from normal operation and to ameliorate the consequences if such a diversion should occur The book is organized into three parts Part I describes the nature of fission products and the hazards to man and his environment resulting from the uncontrolled release of fission products in accident conditions Part II discusses a quantitative approach to reactor safety assessment and the quantification of vessel integrity Part III deals with the basic principles of analysis and assessment of reactor safety and then considers the specific safety problems of thermal and fast reactors in detail This book is intended for two types of readers First are technicians those engaged in nuclear engineering designers constructors and operators of nuclear stations as well as those who would make a career in nuclear safety Second are those not necessarily scientists who are tasked with making decisions in the field of energy use and allocation or are concerned with environmental matters

An Appreciation of Fast Reactor Safety United Kingdom Atomic Energy Authority, 1970 *Safety of Sodium-Cooled Fast Reactors* Songbai Cheng, Ruicong Xu, 2021-09-28 This book highlights the advances and trends in the safety analysis of sodium cooled fast reactors especially from the perspective of particle bed related phenomena during core disruptive accidents A sodium cooled fast reactor SFR is an optimized candidate of the next generation nuclear reactor systems Its safety is a critical issue during its R D process The book elaborates on research progresses in particle bed related phenomena in terms of the molten pool mobility the molten pool sloshing motion the debris bed formation behavior and the debris bed self leveling behavior The book serves as a good reference for researchers professionals and postgraduate students interested in sodium cooled fast reactors Knowledge provided is also useful for those who are engaging in severe accident analysis for lead cooled fast reactors and light water reactors

Nuclear Safety Research Index: Fast reactors OECD Nuclear Energy Agency. Committee on the Safety of Nuclear Installations, 1979 **Severe Accidents in Sodium Fast Reactors** Frédéric Bertrand, Andrea Bachrata, Nathalie Seiler, Christophe Journeau, 2024-11-26 Severe accidents in Sodium Fast Reactors Safety Study Approach Prevention and Mitigation by Design is a unique presentation of research work from the Sodium Fast Reactor Severe Accident team at CEA Focusing on in core and out core severe accident phenomena this book analyzes severe accident scenarios and mitigation related calculations and tools and key outcomes from important

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