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ANOMALOUS NUCLEAR EFFECTS IN DEUTERIUM/SOLID SYSTEMS

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PREFACE

An international gathering of over 150 scientists scrutinized observations of low-level nuclear effects associated with deuterium loaded into various solids. The emphasis was on nuclear physics and geophysical experimental data with theoretical issues also explored. The subjects of calorimetry and electrochemistry were discussed only as adjuncts to investigations of nuclear reaction products. The workshop was sponsored by the Electric Power Research Institute, the U.S. Dept. of Energy Advanced Energy Projects Division, and Brigham Young University.

Nearly seventy papers were presented, with discussions divided into five broad categories with chairs indicated:

1. Neutron Emission Studies: W. Meyerhof (Stanford), K. Nagamine (U. Tokyo), A. Vitale (U. Bologna), K. Wolf (Texas A&M), F. Scaramuzzi (Frascati), H. Menlove (LANL), V. Tsarev (Lebedev Physical Inst.)
2. Charged Particle Detection: J. Ziegler (IBM), E. Cecil (Colorado School of Mines)
3. Tritium/Helium Studies: G. Miley (U. Illinois), N. Hoffman (Rockwell Int'l.), M. Srinivasan (BARC, India)
4. Fusion in the Planets: F. Goff (LANL), E.P. Palmer (BYU), G. McMurtry (U. Hawaii)
5. Theory: J. Rafelski (U. Arizona), V. Belyaev (Dubna), Y. Kim (Purdue), E. Tabet (INFN, Italy)

Sixty-seven papers are included in these proceedings, arranged in alphabetical order under each category. We thank reviewers of the papers for their efforts and note that the screening allows for some rather unusual ideas to be presented in the proceedings.

Neutrons. Significant improvements in neutron detectors and signal/noise ratios were reported. Techniques now include plastic and liquid scintillators often in conjunction with neutron-capture detection using lithium-doped glass or helium-3-filled proportional counters. Time-of-flight and pulse-digitization techniques are also employed. Groups in the United States (S. Jones [BYU], H. Menlove & T. Claytor [LANL], K. Wolf [Texas A&M]), Italy (A. Bertin [Bologna], F. Scaramuzzi [ENEA, Frascati] and F. Celani [INFN, Frascati]), Argentina (J. Granada [Centro Atómico Bariloche] and China (R. Zhu [Inst. of Atomic Energy, Beijing]) reported on neutron studies in deep-underground locations. Observations of neutron emissions from D_2-gas-loaded metals, D_2O electrolysis cells, and d-ion-implanted metal foils, in low background environments (very low cosmic-ray fluxes particularly) and with redundant detectors confirmed earlier observations, with rates broadly consistent with the early Jones (BYU) *et al.* report. Neutron bursts of the order of a few hundred neutrons produced in about 100 μsec, consistent with early observations of Menlove (Los Alamos) *et al.*, were also reported in detectors of various types, including segmented neutron counters in underground locations. R. Anderson discussed the need for redundant detectors and exclusion of cosmic-ray effects based on negative experiments carried out at Los Alamos one year ago. In fact, redundant detectors, exclusion of cosmic-rays, adequate hydrogen controls and improved reproducibility based largely on controlled sample preparation techniques were of paramount importance in recent experiments.

Charged Particles. Several experimenters reported searches for energetic charged particles from deuterium-loaded metal foils. E. Cecil (Colorado S.M.), G. Chambers (NRL), and R. Taniguchi (ARL, Japan) observed charged particles having a few MeV energy using silicon surface-barrier detectors, while K. Wolf (Texas A&M) has not found any evidence as yet. X.Z. Li (Tsinghua U., China) reported numerous ion tracks in etched plastic detectors exposed to deuterided Pd, and showed a dramatic slide of etched tracks that had the appearance of arising from a localized "burst" of ions.

Tritium/Helium-4. Reports of tritium production from deuterided metals and of tritium contamination in metal samples generated considerable discussion at the workshop. The possibility of tritium contamination leading to false readings emerged as a drawback of this technique, and K. Wolf, in particular, reported the presence of tritium contamination in as-received palladium samples. Noting that he had not seen evidence for tritium production for many months, E. Storms (LANL) showed experimental evidence that tritium loaded into palladium diffuses out almost exclusively to the gas phase under cathodic potential in an electrolytic cell, whereas several experiments finding tritium show significant amounts of tritium in the electrolyte. Preliminary results from experiments carried out at the National Cold Fusion Institute of the U. of Utah were originally interpreted as evidence for low-level tritium production in electrolytic cells, but this turned out to be due to a calibration problem for colored solutions. However, M. Srinivasan (BARC), T. Claytor (LANL), and O. Matsumoto (Aoyama Gakuin U.) continue to find evidence for tritium production. In addition, helium-4 production in a molten-salt electrolytic cell was reported by B. Liebert (U. Hawaii), with two caveats: a control with light hydrogen had not yet been done, and the amount of helium-4 above that in the as-received metal was too small to account for observed "excess heat" by a factor of about 10^8.

Geophysical Investigations. P. Britton (Reiss Foundation) reported evidence for increasing helium-3 and tritium with depth in bore holes in the Hamilton shear zone. P. Palmer (BYU) reviewed the geophysical 'cold fusion' hypothesis, which was responsible for the inception of cold fusion experiments at BYU in 1986. F. Goff (LANL) presented evidence for several tritium units in "magmatic" water from Mt. St. Helens. He and G. McMurtry (U. Hawaii) collected samples from the Pu'u O'o vent of the Hawaiian volcano Kileau which will be analyzed for tritium content. Their adventure was the subject of a most interesting after-banquet slide and video talk by Prof. McMurtry at Robert Redford's Sundance Resort on the second night of the conference.

Theory. Lines of thought relevant to the very puzzling observations of low-level nuclear reactions in deuterided metals include: micro-hot fusion, or fractofusion, electron screening, low-energy nuclear resonances, neutron-transfer (Oppenheimer- Phillips) reactions, coherent fusion mechanisms, nucleation centers in metal lattices, reactions associated with phase changes, formation of metallic deuterium, fusion catalyzed by di-quarks or new particles. A few participants, notably P. Hagelstein (MIT) and A. Takahashi (Osaka U.), explored the novel concept that nuclear reactions other than two-body deuteron–deuteron fusion might account for observations of neutrons and charged-particles having energies greater than 3 MeV reported at the workshop. Such models also allow for a large tritium-to-neutron ratio (roughly 10^8 is reported by some researchers) without invoking an anomalous branching ratio for d-d fusion favoring the tritium channel.

Conclusions. Several features emerge from the ensemble of studies presented at the BYU workshop. Observed nuclear particle emissions are episodic, with episodes typically lasting minutes or hours. Rates of particle emission vary greatly from episode to episode, with some observed rates now several orders of magnitude above the instrumental sensitivity. Detectors dedicated to the study of these effects are improving as are signal/noise ratios. However, an immediate "trigger" mechanism remains elusive, as does a coherent model for the observations. Observed effects seem to be related to **changing** temperatures and d/metal ion ratios (highly nonequilibrium conditions); very little evidence has emerged for a correlation between nuclear effects and high d/palladium loading ratios.

Negative experiments were discussed at the meeting, many of which pursued the notion that high d/Pd loading was essential. Still, it was recognized that observations must be checked in sensitive detectors by skeptical observers. In this spirit, an offer was extended by Y. Totsuka (U. Tokyo) for use of the deep-underground Kamiokande detector, a 4500-ton water-Cerenkov system now used for neutrino studies. S. Jones and colleagues accepted the offer on condition that several weeks (rather than days) be allotted to the tests. The tests should be completed by Summer 1991.

It is clear that a robust community intends to pursue the study of anomalous nuclear effects in deuterium/solid systems. We expect that the sensitivity of detectors will continue to be improved, accelerating progress in experiments. Hopefully the interaction between theorists and experimenters will lead to increased understanding and corresponding control of what appears to be a new and intriguing regime for nuclear reactions.

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