of radial advection, hydrological dispersion, kinetic sorption and diffusion, as well as a probabilistic fracture system representation. Testing, especially fracture and mineralization mapping, and hydraulic conductivity measurement results for four deep holes at Stripa are described, as well as calculated head distributions around the mine. A paper on the application of the sinusoidal pressure test includes several theoretical developments of line sources within rock masses and presents very encouraging results from an initial field test.

The section on geochemical and migration studies includes papers on isotope hydrology, groundwater chemistry, and migration experiments in a single fracture in the Stripa granite, as well as a paper on groundwater geochemistry and isotope hydrology at the French Auriat site. Isotope hydrology studies have identified several distinct groundwater systems at the Stripa site and suggest strongly that deeper groundwater systems are much older than shallower waters, even though considerable uncertainty remains about the detailed history of the systems. The geochemical elemental analysis of the deep groundwaters has been used to develop an argument for the case that the high salinity may be due to mixing of infiltrating water with brine or salt inclusions within the granite. Preliminary results of migration experiments in a single fracture in the Stripa granite indicate that flow along a natural fracture, even over relatively short distances of metres and less, occurs along quite complex paths and similarly that fissure width determinations are difficult. Geochemical and isotopic analyses of water sampled from the deep (1000-m) French hole at the Auriat site suggest that the water is a mix of drilling water and shallow groundwater.

Preliminary results from the buffer mass test of phase I, Stripa project, include comparisons between numerical predictions and measured results for temperature, water content, water pressure, and swelling pressure distributions within bentonite buffers surrounding heaters in holes and in the bentonite tunnel backfill above the holes.

The last section of the book presents programs for further *in situ* experimental work to be performed at Stripa, Sweden, at the Canadian underground research laboratory and at the proposed Grimsel laboratory in Switzerland.

The investigations proposed for phase II (1983–86) of the international Stripa project include detection and characterization of fracture zones by cross-hole geophysical and hydraulic methods, tracer experiments in fractured granite, diffusion experiments in highly compacted bentonite and mixtures of bentonite and sand, and sealing of boreholes and shafts with highly compacted bentonite. The Canadian facility in an undisturbed batholith representative of the Canadian Precambrian Shield is intended to assess and improve the ability to interpret geology, geochemistry, and hydrogeology of large volumes of plutonic rock. Additional objectives include study of the effects of excavation on the rock, development and assessment of shaft and drift seals and accuracy evaluation of mathematical models of the near-field response to heat. The Grimsel laboratory in the Swiss Alps is intended to allow testing the applicability of results obtained elsewhere, to study specific aspects of Swiss repository concepts, and to develop the expertise and experience for later experiments at an actual repository site. The paper describes the facility, as well as the geological, hydrological, and geomechanical test plans.

Clearly, the book covers a large number of repository projects. It is ideal, therefore, for anyone wishing to have a rapid overview of ongoing repository site characterization programs in granite. Although all papers of necessity are highly condensed program summaries, virtually all of them include extensive lists of references, primarily to reports prepared by the various organizations operating the sites or testing at the sites, thus greatly facilitating the task of obtaining more detailed information.

Although the book discusses *in situ* experiments in granite, its interest should not be limited only to people involved in granite repositories. The book provides more broadly applicable insight into general testing strategy and methods of approach, test design and implementation, data analysis and interpretation, problems encountered, etc.; hence, it should be of considerable value to anyone wishing a rapid overview of most of the ongoing major projects for repository development and research.

The book has been produced inexpensively from camera-ready copy, but even so, the number of errors is minimal and the presentation of the articles quite consistent in format. The text and virtually all figures are clear and easily readable.

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Quantum Electrodynamics of Strong Fields

Editor	W. Greiner
Publisher	Plenum Publishing Corporation, New York (1983)
Pages	902
Price	$110.00
Reviewer	Howard R. Reiss

In general terms, an electromagnetic field is regarded as "strong" if the magnitude of the interaction energy between the field and a system with which it interacts is as large as a characteristic energy of the system. For instance, if the electromagnetic field term in the equation of motion is as large as the rest energy of the electron, then a quantum electrodynamical description of this problem has to be in terms of strong-field electrodynamics. The usually reliable perturbation theory is not to be trusted in these circumstances and can give answers that are totally misleading both qualitatively and quantitatively.

Quantum Electrodynamics of Strong Fields is a collection of papers presented at the NATO Advanced Study Institute held at Lahnstein-on-the-Rhine, Federal Republic of Germany, June 15–26, 1981. The main thrust of the contributions in this volume is much more specific than is suggested by the general definition of strong fields given above. The principal focus of this book is the physics that arises in the presence of a coulomb field strong enough to cause polarization of the vacuum. Although the roots of this physical problem go back to the earliest days of relativistic quantum mechanics, it has only been in the last 15 years or so that it has been recognized as containing fascinating experimental ramifications as well as posing fundamental philosophical questions.

It has been shown in relativistic atomic theory that when an atom possesses a nuclear charge greater than 173 proton charges, the binding energy of the innermost electrons exceeds $2mc^2$. This is so great that the bound energy levels overlap the positron states proceeding downward from $-mc^2$. If the innermost electron shell (the K shell) is initially unoccupied, the end result is that two sets of electron-positron pairs are created from the vacuum, with the two electrons occupying the two degenerate ground states in the K shell and the two positrons being ejected. At first glance, this process seems unphysical. After all, the heaviest naturally occurring element has $Z = 92$, the heaviest man-made nucleus has $Z = 105$, and the theoretical predictions of "islands of stability" for superheavy nuclei have yet to be demonstrated in practice. However, there now exist particle accelerators capable of accelerating very heavy atomic ions. If, for example, two uranium atoms are collided at very high energies, a quasi molecule is formed that behaves briefly as a single center of coulomb attraction with an effective nuclear charge of $2 \times 92 = 184$. Furthermore, the process of creation of the quasi molecule has the effect of ionizing the innermost electrons from the colliding ions. These emitted inner-shell electrons are called delta rays. They are often quite energetic. The end result is that the quasi molecule is formed with K-shell vacancies available to be filled by electrons from the electron-positron pairs created out of the vacuum.

The physics just described has been very fruitful for both theoreticians and experimentalists and promises to be much more so in the future. For instance, with respect to theory, the volume under review contains a general survey by Müller, a treatment of positron creation in supercritical quasi molecules by Reinhardt et al., a study of ground-state electron ionization probabilities in heavy-ion collisions by Soff et al., and a discussion of continuum x-ray emission in heavy-ion collisions by Vincent. Experimental papers presented include results by Backe et al. on positrons from heavy-ion collisions, a report by Armbruster on characteristic x-ray production, a review of inner-electron excitation by Bosch, a report by Bokemeyer et al. on spontaneous positron production in heavy-ion collisions, and a discussion by Kozhuharov on delta-ray spectroscopy of quasi molecules.

There is much more in this book, however. The subject has been interpreted fairly broadly, although there is only one paper on intense-plane-wave electrodynamics, given by Mitter. For example, there is a paper on precise measurements and calculations in quantum electrodynamics, a report on radiative corrections in strong fields, papers on general methods for treating the Dirac equation, several papers each on Yang-Mills theory and on quantum chromodynamics, papers on particle condensates in strongly coupled fields, and so on.

Strong field electrodynamics is a relatively new area of endeavor in physics. It is rich in new insights and new understanding as well as in new difficulties. *Quantum Electrodynamics of Strong Fields* presents a fascinating sampling of the activity in this area.

Howard R. Reiss has been visiting research professor of physics in the University of Arizona since 1975, and professor of physics at the American University in Washington, D.C., since 1968. Prior to that, he headed the Nuclear Physics Division at the Naval Ordnance Laboratory. A substantial fraction of his published papers over the years have been related to intense fields and nonperturbative methods in electrodynamics, starting with his PhD dissertation at the University of Maryland.

Low Reynolds Number Flow Heat Exchangers

Editors	S. Kakac, R. K. Shah, and A. E. Bergles
Publisher	Hemisphere Publishing Corp., Washington, D.C. (1983)
Pages	1016
Price	$125.00
Reviewer	Thomas R. Rehm

This reference work is a collection of papers presented by the invited lecturers at the fourth NATO Advanced Study Institute on heat transfer held in Ankara, Turkey, July 13-24, 1981. As such the topics covered in these lectures represent the latest theoretical and empirical thinking associated with the evaluation, design, and operation of heat exchangers where at least one of the fluids is in the laminar, <2300 Reynolds number flow region.

The arrangement of topics in the book begins with a general description of the field based on classification and design methodology. Next, the situations in which forced convection is predominant are presented. Included are papers on fully developed channel flow, axial conduction Graetz problems, developing and transient flows, flow across or along tube bundles, and experimental techniques.

Subsequent sections focus on non-Newtonian flows, numerical analysis, heat transfer augmentation, compact heat exchangers, plate heat exchangers, fouling, and finally problems and prospects for the future in the field of low Reynolds number flow heat exchangers.

From this list of topics, it can be seen that the material would be of primary interest to those nuclear scientists and engineers involved with heat transfer in reactor cores.

Although the book is made from photo-offsets of the original typed papers, it reads well and, in my estimation, contains a thorough and comprehensive presentation of the state of the art in its field. A rigorous attention to and understanding of the book's contents would put a reader well on the road to being an expert in the field.

Thomas R. Rehm, professor of chemical engineering at the University of Arizona, Tucson, Arizona, taught chemical engineering from 1960 to 1966 at the University of Denver and at the University of Arizona since 1966. His teaching areas are in the plant and equipment design, mass transfer, and material and energy balance fields. He has also spent 20 years in the supervision of research and teaching laboratory operations along with equipment specification, purchase, and