**AdvANCES IN
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AND TECHNOLOGY**

VOLUME 17

Simulators for Nuclear Power

ADVANCES IN NUCLEAR SCIENCE AND TECHNOLOGY

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Cambridge University, Cambridge, England

Martin Becker

Rensselaer Polytechnic Institute, Troy, New York

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VOLUME 17

Simulators for Nuclear Power

Edited by

Jeffery Lewins

*Fellow of Magdalene College
Cambridge University
Cambridge, England*

and

Martin Becker

*Rensselaer Polytechnic Institute
Troy, New York*

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PREFACE

This volume represents the second of our occasional departures from the format of an annual review series, being devoted to one coherent topic. We have the pleasure therefore in presenting a concerted sequence of articles on the use of Simulators for Nuclear Power.

An essential attribute of a quantified engineer in any discipline is to be able to model and predict, i.e. to analyze, the behaviour of the subject under scrutiny. Simulation goes, one would argue, a step further. The engineer providing a simulator takes a broader view of the system studied and makes the analysis available to a wider audience. Hence simulation may have a part to play in design but also in operation, in accident studies and also in training. It leads to synthesis as well as analysis.

There is no doubt that the massive scale and the economic investment implied in nuclear power programmes demands an increased infra-structure in licensing and training as well as in design and operation. The simulator is a cheap alternative - admittedly cheap only in relative terms - but also perhaps an essential method of providing realistic experience with negligible or at least small risk.

Nuclear power therefore has led to a wide range of simulators. At the same time we would not overlook the substantial role played by simulators in say the aero-industry; indeed the ergonomic and psychological studies associated with that industry hold many lessons.

In this volume we have sought to provide a coherent account of the approach necessary to commission simulators on the scale required in civil nuclear power applications. To do this we have drawn on a number of authors who have been associated with the UK nuclear power program, in the Central Electricity Generating Board responsible for the reactors

themselves, with their associates in the South of Scotland Electricity Generating Board and with the associated contractors and university research staff. We are particularly grateful to the CEGB that we can publish an account of the philosophy and methodology of the development of simulators in one of the world's largest interconnected utilities. They have enabled all our authors to elucidate the systems thinking necessary to implement simulation on a scale that encompasses tens of nuclear plants and a fifty years planning horizon.

Many established nuclear utilities are now coming to grips with the transition to a 'steady state' in which the operation, refuelling and ultimate decommissioning of nuclear plant looms as large in corporate planning as design and construction. It is easy to forget that over a forty-year life, a nuclear reactor will have as much in money terms flowing through it as fuel as it did initially as construction capital. Correspondingly, the training of operators - to be renewed and replaced over a forty year life - is as significant as initial design. Aids for prediction in normal and emergency circumstances, which must run faster than real time, are as important as design simulations.

The large scope and far planning horizon of a nuclear power plant calls for suitable management methods to ensure satisfactory performance from simulators which themselves represent an investment of millions of dollars. In general terms, the UK, like many other developed countries using 'high tech', is better at the initial entrepreneurial development and not so good in the management aspect of seeing that new engineers come forward to complete and maintain the high tech systems. Thus a methodology for high tech simulation, a Quality Assurance programme and a management approach are essential ingredients to success.

It seemed to your editors that an account of such a philosophy would be valuable and our first two articles, by CEGB authors, are directed to that understanding of how a large organization might tackle the management of simulation problem.

The third article turns to the psychological problems of simulation in terms of the viewer and user rather than the organization. Before committing large resources, it is as well for the proprietor to establish what it is he wants and why a simulator might provide it.

Our fourth article is again authored from within the CEGB but addresses in more explicit terms how the computation for simulation of nuclear plant can be carried out in relation to the rapidly changing availability of computing facilities. A particular feature of CEGB experience is the driving of training simulators from mainframes more than 200 km away

New developments will come in simulation as well as in computing power. But the need for real time or even better computation with the detail required in such complex plants, for training and emergency situations, puts a premium on new thinking. One current and promising development is in the use of parallel processing; our second contribution from the universities addresses this area with specific reference to two-phase flow calculations. The preliminary results reported are indeed encouraging.

Parallel processing is in part here with us in the use of multiple microprocessors. The final article of the volume puts both present and future practice together with an account of the construction of the SSEBs simulators with their parallel processing architecture and the possibilities of future development.

To obtain the coherent picture of nuclear simulators provided here we have drawn our authors from the UK with its experience of gas-cooled reactors. But the more important features are the scale of the operations involved rather than the particular reactor design and it is this scale of enterprise with its concomitant demands on technical management that we have sought to put before our readers.

Jeffery Lewins and
Martin Becker
August, 1985

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SI UNITS

It is twenty five years from the adoption of the internationally agreed system of units, the SI Units or Le Système International d'Unités. Our series uses SI units to facilitate the international exchange of information and learning we exist to promote. A few words on the system may be of interest to some of our readers and, of course, to our potential authors.

The system was adopted by the 1960 meeting of the General Conference of Weights and Measures. The international Standards Organisation (ISO) publishes the fundamental documents detailing the system in a series of reports under the number R 31. Part 0 deals with general principles, Part I with the fundamental units and so on. Of particular interest might be: Part IV, heat; Part IX, atomic and nuclear physics, Part X, nuclear reactions. Of course changes of detail authorised at subsequent meetings have occurred. It is usually best to obtain up to date information from the relevant national standards organisation.

Some particular changes to note include the following. The symbol for the litre may now be taken as either L or l. We prefer the capital L since the lower case l may well be confused, especially in typescript, with 1 although we note the breach of the convention that only eponymous symbols should be capitalised. *En passant*, we note that the correct abbreviation for second is s and not sec.

The SI units for health physics with special names have been agreed more recently. The significant units are:

Activity: becquerel (Bq) 1 disintegration per second. This has replaced the obsolescent unit of the curie (Ci) where $1 \text{ Ci} = 37 \text{ GBq}$.

Absorbed Dose: gray (Gy) 1 joule per kilogram. This has replaced the obsolescent unit of the rad ($100 \text{ rad} = 1 \text{ Gy}$).

Equivalent Absorbed Dose: sievert (Sv) also 1 joule per kilogram. This has replaced the obsolescent unit of the rem (100 rem = 1 Sv).

In some applications, large quantities of becquerels etc. are involved. Recently the following size modifiers have been authorised in the SI canon and would be useful in this context:

E (exa) 10^{18} : P (peta) 10^{15} .

Nuclear technology is bound to the wheel of its own history. It will take some time for the older units to be phased out and for new dogs to come with new tricks. The universities have a particular responsibility here to be didactic. It will not of course be until the old units have been replaced in national legislation that they can be said to be obsolete rather than obsolescent. The charm of the barn, 10^{-28} m^2 , is likely to stay with us for a long time despite its deviation from SI norms.

There are other individual areas where we must suppose practice has not made for perfection. It is of course time for British Units to be dropped. One can see that if a reactor has been designed with a six-inch diameter pitch or coolant pipe etc., then it is quixotic to solemnly translate this design into meters but for international understanding perhaps the original design value should be followed by its SI equivalent in what we hope will be limited cases. There is really no case for the retention of British Thermal Units or the Fahrenheit/Rankine temperature scale. Rather we prefer the kelvin unit and speak of a temperature of (say) 300 K.

It is of course customary to use an offset or celsius scale analogous to a reference to gauge pressure or (absolute) pressure. The symbol for the celsius temperature is $^{\circ}\text{C}$ as in say 100 $^{\circ}\text{C}$. The unit of interval on the celsius scale however is of course the kelvin (K). The 'degree' sign is only necessary in conjunction with the abbreviated symbol of which it is part to distinguish $^{\circ}\text{C}$ from C or coulomb; there is no place for the word 'degree'.

The SI system calls for the nature of what is quantified to be written *before* the quantity, followed by the SI units

in suitable multiples. It would be good practice then to write a neutron flux as

neutron flux $10^{17} \text{ m}^{-2} \text{ s}^{-1}$

and *not* as neutron/m²s. One notes that symbols are not pluralised. It would follow (but is not yet recognised practice) that a gauge pressure might be written

gauge pressure 10 Pa

and *not* 10 Pa gauge while a celsius temperature might by analogy be written as

celsius temperature -10 K

and *not* -10 °C.

This principle of placing only the SI units to the right of the quantity raises a difficulty in referring to the power output of a nuclear plant. Here one desires to distinguish between the thermal and the mechanical/electrical power delivered. Because we lack the established words to distinguish these concepts we are driven to the neologisms of MW(t) and MW(e) in the units against good SI practice. If it is energy to be distinguished in this way we can suggest the European usage of exergy to refer to the equivalent as mechanical and hence electrical work. We could then write in terms of an energy of so many joules for the (total) or an exergy of so many joules for the mechanical element. We tentatively suggest the term *rexergy* (rate of exergy) for the corresponding rate of transmission of energy in its equivalent mechanical form so that we might refer to (say)

reactor power 3000 MW and reactor rexergy 1000 MW.

This 'kite' is flown with the intention of stimulating discussion and perhaps better suggestions.

National practice has differed in the writing of large numbers with some using a '.' and some a ',' for the decimal point. Thus it may avoid confusion with a decimal point to use blank spaces only to separate trios of figures as in 11 000.001 01. Tables should be prepared accordingly.

Economy in the writing of numbers is sometimes available.

For example, it seems pointless to write typical values of fuel burn-up as 30 000 MWd/tonne when the same quantity might be written 30 MWd/kg. Here we accept that Wd is a more meaningful but less basic unit to be employed rather than (24×3600) J. Strictly there should be space between units and we should write W d *not* Wd.

Some aspects of the technical writers craft are not yet covered in SI but various national handbooks amplify good practice. We think particularly of the Royal Society of London's useful booklet "Quantities, Units and Symbols" (1975). We adopt their advice over the labelling of the axes of graphs. If an axis is shown as say pressure divided by its unit, P/Pa, then the numbers used along the axis are properly non-dimensional.

Much can be done at the editorial stage to provide for a consistent usage of SI units but it is even more economical if our authors would cooperate in making their work as widely available as they deserve.