THE IMPACT OF HIGH TEMPERATURE SUPERCONDUCTIVITY ON THE ELECTRIC POWER SECTOR

A.M. Wolsky
Argonne National Laboratory
USA
on behalf of the Executive Committee of the IEA
Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector.

The progress and prospects for the application of high temperature superconductivity to the Electric Power Sector has been the topic of an IEA Implementing Agreement, begun in 1990. The present Task Members are Canada, Denmark, Finland, Germany, Israel, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, Turkey, United Kingdom and the United States. As a result of the Implementing Agreement, work has been done by the Operating Agent with the full participation of all the member countries. This work has facilitated the exchange of information among experts in all countries and has documented relevant assessments. Further, this work has examined the status of high amperage conductor, fault-current limiters, superconducting magnetic energy storage, cables, rotating machines, refrigeration, and studies of the power system. The Task Members find more progress toward applications than many expected five years ago and the grounds for further international collaboration to hasten the use of superconductors in the power sector, early in the 21st century.

I. INTRODUCTION

Great progress toward the future practical application of ceramic superconductors has been made since the discovery in 1987 of $YBa_2Cu_3O_{7-x}$ a ceramic composed of yttrium, barium, copper and oxygen.

As was widely reported then, this ceramic was observed to became superconducting at 92K, a far higher temperature than had been obtained with any other material. A material in the superconducting state can transport a direct electrical current without resistance (i.e., energy loss). The discovery of high temperature superconductors, as they are called, raised the hope that further research, development and demonstration would yield materials that would offer economic advantages over those now employed by the electric power sector. The basis for this hope rested on: (a) the belief by scientists that the hardest part of the problem had been solved (and so subsequent challenges would be overcome) and (b) the fact that today's refrigeration technology is able to maintain even lower temperatures (e.g., 77 K) without great expense or inconvenience when compared with the very low temperatures (i.e., 1.8 - 4.2 K) that had previously been required for superconductivity. Technically experienced persons understood that great difficulties remained and that the commercial fruit of the scientific discovery was uncertain, at best. This uncertainty stimulated many to want to better understand the situation as it would continue to develop. An international collaboration was formed to meet that need.

This paper reviews the work of that international collaboration, now constituted as International Energy Agency *Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector.* This IEA Implementing Agreement concerns itself with future applications of ceramic superconductors in the electric power sector. The Implementing Agreement is described, its efforts are sketched and its observations are summarized.

THIS WORK WAS NOT FUNDED THROUGH ARGONNE NATIONAL LABORATORY

II. IEA IMPLEMENTING AGREEMENT

The discovery of $YBa_2Cu_3O_{7-x}$ was hardly an isolated event. It was stimulated by the 1986 discovery in Switzerland of $La_{1.85}Sr_{0.15}CuO_4$, a ceramic material that becomes superconducting at 38K. That discovery was completely unexpected by the scientific community. Indeed, a Nobel Prize was soon awarded. Nor did investigation of related materials stop with $YBa_2Cu_3O_{7-x}$. Investigators in Japan and the US soon identified $Bi_2Sr_2CaCu_2O_x$ and $Bi_2Sr_2Ca_2Cu_3O_x$ as ceramics that become superconducting at higher temperatures and soon thereafter, $TlBa_2Ca_2Cu_3O_x$ was found to have an higher transition temperature. Important and startling scientific progress was made almost simultaneously in Europe, North America and Asia.

All observers understood that no one had a monopoly on progress and that there were many groups of investigators, geographically dispersed, from whom to learn. Energy policy makers and funding agencies were aware of the enthusiasm of scientists and began to consider the potential importance of technical success. In 1988, the International Energy Agency (IEA) organized a meeting of experts that the Ministry of International Trade and Industry of Japan hosted in Tokyo in September. The twenty five participants, drawn from ten countries, represented electric utilities, industry, public and government supported R&D organizations, and government agencies. The participants found that they had much the same goal--to assess the likelihood and potential impacts of scientific and/or technical progress, while bearing in mind that the electric power sector requires long term planning based on the best available information.

It appeared that substantial cost savings might be realized by proceeding cooperatively. Further, the reliability of results from cooperative work could be checked by international peer review. Italy's Ente Nazionale per l'Energia Elettrica (ENEL) offered to host a follow up meeting of experts for the IEA in May 1989. The consensus of that meeting was that, although it would be many years before superconducting technology found routine commercial application in the power sector, progress was such that attention must be paid to both liquid nitrogen and liquid helium superconductors. The participants agreed to continue their hitherto informal cooperation within the framework of an IEA Implementing Agreement.

By the summer of 1990, the IEA *Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector.* was signed by the interested parties from Canada, Denmark, Finland, Germany, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, Turkey, United Kingdom and the United States. Subsequently, Israel joined the Implementing Agreement. (Also, Belgium paid dues for years two and three, entitling Belgium to receive the reports from the first three years.) During the past year, Austria has requested permission to join the Implementing Agreement, with its Executive Committee's full agreement; formal approval is expected from IEA.

The Implementing Agreement (IA) calls for Argonne National Laboratory (ANL) to act for the USDOE as the Agreement's Operating Agent and for work to commence on 1 October 1990. According to the IA, ANL performs three subtasks with the participation of the member countries. SubTask I was to create and subsequently keep current a directory of all the relevant activity in each member's country. This Directory enables members to know the technical topics (with level of activity) being investigated and it facilitates international communication. SubTask II was to summarize and synthesize assessments already performed within members countries. The resulting report enables each member to access the work of others and judge its relevance to the member's particular situation. SubTask III calls for brief reports, each describing a topic of common interest. These topics have included: (IIIa) High Amperage Conductors, IIIb) HTS Use in Generators and Motors, IIIc) Refrigeration for HTS, IIId) Progress toward Superconducting Magnetic Energy Storage, IIIe) Modeling Behavior of Power System Using Superconducting Devices, IIIf) Cables and IIIg) Fault Current Limiters. The purpose of these reports is to catalyze further consideration of these issues. In all cases, input from the participating countries has been important to the success of the task. Further contributions to this Task have been made by several members. Japan's Central Research Institute for the Electric Power Industry (CRIEPI) performed a first computer simulation of the result of a fault on a hypothetical superconducting transmission line with current limiter. Because of the difficulty and importance of system studies, Canada's Ontario Hydro has convened an electronic-mail/fax discussion group to further international consideration of system studies. Last fall, Germany's Kernforschungszentrum Karlsruhe (KfK) hosted an international meeting on Superconducting Energy Storage. The Task also stays in contact with CIGRE Working Group 11.05 by formal and informal liaison. The work of the Implementing Agreement is documented in a series of reports to the participants and related reports with wider distribution. They are listed in the last section, titled References, of this paper.

III. PROGRESS TOWARD APPLICATIONS

When considering the future applications of ceramic superconductors in the electric power sector, three levels of description are helpful: the component, the device, and the system. Each requires attention. Here our emphasis is on the component (i.e., bulk superconductor and tape) and on the devices in which ceramic superconductors may be incorporated. (As noted earlier, this Implementing Agreement is also encouraging discussion to lay the basis for relevant future system studies.) This section compares where we were five years ago with where we are now. The discussion is meant to be accessible to the interested, but not technically expert reader. The basis for this necessarily brief sketch can be found in the reports listed under References at the end of this paper. They are available to persons in participating countries through their representative on IA's Executive Committee.

III.a Conductor

Five years ago, high temperature superconductivity was a phenomenon observed in laboratory samples whose dimensions were measured in centimeters. Today we are approaching the manufacture of conductor with useful sizes. Five years ago, one did not know how to make a "wire" from a ceramic. Since then a particular approach, "powder-in-tube", has been vigorously pursued around the world with very promising results. Below, we summarize progress in wire/tape and in bulk material.

bulk material

There are four applications for which conductor need not have the ductility of wire. They are: (a) current leads, (b) bus bars, (c) magnetic bearings (d) fault current limiters. "Bulk" superconductor might serve in these applications. Five years ago, disks of bulk superconductor were used to demonstrate the possibility of levitating an object in a magnetic field for a sustained period. The sustained period was the crucial point; the currents within the otherwise isolated disks persisted rather than dissipated as they would in normal materials (e.g., copper). However, while the currents did persist they were not large. Nor was there an ability to reliably fabricate anything other than a small disk. Today, technology has been developed to melt and then cast kilogram quantities of Bismuth 2212, one of the ceramic superconductors, into "any shape". Cylindrical components can be cast with diameters of approximately one meter. The resulting material has zero field critical current density, J_c, of 3,000-4,000 A/cm^2. In practice, such material would be subjected to its own field, so for design purposes the current density might be taken as 1,000 A/cm^2. This technology can enable construction of prototype fault current limiters that use the superconductor as a magnetic shield. It might also enable the straight forward production of current leads. (Such leads can reduce the heat leak to a low temperature superconductor, making its use more economic.) Magnetic bearings made from bulk superconductor might reduce the losses from a flywheel to the point where utilities would find it economic to store energy in groups of flywheels. The use of a bus bar made from bulk superconductor appears technically feasible and might be considered for application at a chlor-alkali facility or an aluminum plant. (The economic attractiveness is likely to be site specific.)

wire and tape

Electrical wire and magnetic iron are the two central components of power sector devices. Five years ago, there was no plausible approach toward making practical wire. The difficulty was simple to state. The superconducting material is a ceramic--weak, brittle and prepared in kilns by the batch. Present technology is built around metals--ductile, flexible and made in long lengths of wire by a continuous process. The way to overcome these tremendous differences was not apparent, although now there is a promising approach which is being developed in Asia, Europe and North America.

That approach is to (1) prepare a powder of the ceramic superconductor; (2) fill a hollow metal tube with the powder; (3) draw the tube into a filament with conventional wire making machinery and repeatedly bundle separate filaments and again draw them into multi-filament composites and (4) subject the composite to heat treatments and an oxygen atmosphere so that the powder forms a continuous electrical superconductor. This approach has been explored and refined by many groups in Asia, Europe and North America. To date the approach has worked best when the superconductor is BSCCO and the metal tube is silver. (The application to TlBCCO has been less explored because thallium requires expensive precautions to handle.) Silver is permeable to oxygen, enabling the final reactions that enable the superconductor to be made from the powder. Unlike YBaCuO, the required temperatures for BSSCO are below the melting point of silver, a decisive simplification. Moreover, simple and quick mechanical rolling substantially improves the current density in BSCCO, while the thermal process for improving YBaCuO is impractically slow. Thus today's efforts are principally directed toward BSCCO in silver tubes.

To date this approach has yielded prototype tape (i.e., the cross-section of individual filaments has a high aspect ratio). Indeed, leaders in the field, report the ability to make a continuous multi-filament tape with current density 1.6 x 10^4 A/cm^2 at 77K in self field in 600-700 meter lengths. These specifications are comparable to what is needed for transmission cable. Further, short segments of 6kA and 11kA prototype technical conductor have been assembled. Five years ago, laboratories reported current densities of 10^3 A/cm^2 in samples whose length were several centimeters.

III.b Transmission and Distribution Cable

A practical cable is more than the conductor it incorporates. From the mid 1960s to the mid 1970s, cable design received substantial attention. Experiments on prototypes incorporating low temperature superconductors were ended by the mid 1980s. Not surprisingly, reduction of heat generation was an important design goal. This was to be achieved by coaxial cable which avoids eddy currents in nearby conventional materials. Since superconductor is used in both the axis and the sheath of the coaxial cable the dielectric between them was maintained at liquid helium temperatures. Even after eliminating eddy current losses, there are still AC losses in a superconductor even though there are no DC losses.

After the discovery of ceramic superconductors, many assumed that they should be incorporated in "liquid helium designs". Reduced operating costs were projected. The significance of these reductions varies by region. In Europe and Japan, coaxial cable projects are underway. Completion of a thirty meter segment of single phase cable is scheduled for 1997 in Germany. A different approach is being taken in the US. Underground Systems Inc., a small consulting firm under contract to EPRI, suggested that one could afford much greater energy losses at 77K than at 4.2 K (or 1.8 K) if the capital cost of the superconducting line could be brought near that of a conventional line. More specifically, it was suggested that a conventional design for three phase cable could be modified to include a superconductor wrapped around an axial cooling channel. No special attempt would be made to refrigerate the dielectric or avoid eddy current losses. By proceeding in this manner, the participants (Pirelli of North America, American SuperConductor, EPRI, & USDOE) hope to have a commercial underground cable, ready for use in existing tunnels, in much less time than would otherwise be expected. This approach sought a device design suitable for the superconductor, instead of trying to make the superconductor fit into a device designed for low temperatures.

Another aspect of interest in superconducting transmission deserves attention. Although, high temperature superconductors promise reduced operating costs (because of reduced energy losses), some consider another benefit to be as important. Superconducting transmission appears to offer the possibility of using existing underground tunnels to carry more power; it is the avoided capital cost of construction (and the avoided need for permits and public acceptance of same) rather than reduced operating costs that prompts the interest of some utilities.

III.c Fault Current Limiters

Soon after the discovery of ceramic superconductors, the possibility of their use in fault current limiters was discussed. "Fault currents" are occasioned by lightning strikes and other accidents that cause short circuits (intermittent or sustained) between different phases or between one phase and the ground. These currents can grow so quickly and to such large values that they can cause substantial damage. The engineering challenge is twofold: (a) to limit the fault current and (b) to return quickly to normal operation after the fault subsides. Initial interest focused on the use of current limiters in high power transmission lines which appeared to be stressing the limits of conventional circuit breaker technology (i.e., the current might not be curtailed until the breaker melted).

While there is an important difficulty (i.e., dissipating the energy of the fault current without harming the limiter) to be overcome, work continues on limiters for high power transmission. However, subsequent consideration emphasized a different need. The different need is to limit currents in distribution systems. As mentioned above, utilities desire more capacity from existing infrastructure. As more power is distributed, there is less margin for error. Hence a greater need to limit faults when they do occur.

Ceramic superconductors can contribute to making practical current limiters for distribution systems in two ways. The operating cost of liquid helium current limiters would be reduced if electrical current could enter and leave without permitting heat to leak into the low temperature region. Current leads made from ceramic superconductor might enable this. TEPCO and Toshiba, as well as, Alsthom and Alcatel are interested in this possibility. Also ceramic superconductors have (or might have) the potential to permit lighter more compact designs by virtue of their reduced cooling requirements and their expected electromagnetic characteristics. Thus small limiters with low operating cost may offer a new capability to distribution systems.

III.d Energy Storage

In the mid 1960's, it was suggested that energy might be usefully stored in the magnetic field concomitant with a persistent current circulating in a superconducting coil. Energy would be discharged during the day when there was not enough generating capacity to meet the load and energy would be added during the night when otherwise idle generating capacity would be available. This idea was explored in the US and elsewhere for many years. It is now believed that such storage is too expensive or the break-even size is too large for any group to risk construction. The substitution of ceramic superconductor for NbTi or Nb_3Sn does not change the conclusion because refrigeration is only a small part of the cost of diurnal storage.

Ceramic superconductors can contribute to making economic storage for enhanced power quality. Superconductivity Inc. is commercializing a NbTi, liquid helium cooled superconducting storage device (1MW, 1-3 MWsec) appropriate to individual businesses. Approximately, 25-40% of the operating cost is accounted for by refrigeration (the rest goes to the power conditioning system). As with a liquid helium fault current limiter, current leads that do not permit a significant heat leak would reduce the operating cost. Ceramic superconductors might enable a completely different approach to energy storage by making magnetic bearings with negligible losses. These bearings would support a fly-wheel of modest size. However, many flywheels could be co-located to provide significant storage. Argonne National Laboratory (USA) is studying this approach with the support of its local utility, Commonwealth Edison. Flywheels are also being investigated in Japan by TEPCO, Koyo Seko, and others. The future Japanese program is now under consideration.

While large scale SMES appears impractical and small scale storage appears to benefit from ceramic superconductors, consideration of intermediate scale storage (0.1-10.0 MWH) raises unresolved, but interesting possibilities. Such storage could serve important uses, for example it could provide spinning reserve, complement renewable sources of electricity or buffer loads like those from electric steel furnaces. The capital cost of intermediate scale SMES depends on the price of the superconducting tape and the quantity needed. The quantity needed depends on the operating current density at the design magnetic field. At this time, prototype ceramic superconductor can carry 10^4 A/cm^2 at 20K in a 1-2 Tesla magnetic field, substantially less than short sample performance and less than the requirements of some rough SMES designs. If and when long lengths can achieve short sample properties is not known. Beside improved electromagnetic properties, it will also be desirable to reduce the price of the conductor which is now approximately 75% silver by volume. Efforts are being made to reduce the silver or find a less expensive substitute. These same concerns, performance and cost, also bear upon the field coil of a rotating machine.

III.e Rotating Machines

Soon after the discovery of ceramic superconductors, several toy electric motors were made. Serious design work continued in the US on one project whose goal is a 7.5 MW motor that would operate at 77K. This work has been redirected toward a nearer term goal: the design, construction and demonstration of a 75 kW motor whose superconducting field coil operates between 20-40K. A smaller motor, 1.5 kW, is under construction by a collaboration of the Nordic countries. That project's goal calls for demonstration by June, 1995. General Electric is working to build a field coil from ceramic superconductor that would be suitable for a 100 MWe generator. Japan, which has worked on ceramic superconductors from the start, has announced that its generator project will continue to consider ceramic superconductors. As noted above, the capital cost of the tape must be reduced and its electrical performance in high magnetic fields must be improved before commercial application.

III.f Transformers

Five years ago, Alsthom actively, but unsuccessfully sought customers for a transformer that would embody ultrathin filaments of NbTi. (As a general rule, the thinner the filament and the higher the critical current density, then the lower the AC losses in the superconductor.) Recently, Alsthom and Siemens began a project to make a transformer for railroad locomotives; the goal is reduced weight. Although some measurements of AC loss in ceramic superconductors have been made, effort to reduce these losses has been set aside in favor of other goals deemed more pressing (e.g., longer lengths with higher critical current density). Nor have extensive design studies of transformers using ceramic superconductors been publicized, as has been the case for rotating machines. However, some groups have continued to consider transformers considered them. The Krzhizhanovsky Power Engineering Institute, in Moscow, designed and built a laboratory prototype of a special purpose transformer (e.g., arc welding) which incorporates a magnetic shield made from bulk ceramic superconductor. Recently, ABB and American Superconductor announced that their team will design, manufacture, and test a 630kVA transformer that incorporates wire/tape made from ceramic superconductor. The transformer will use liquid nitrogen as both a coolant and a dielectric fluid. The project will be supported by EdF and SIG, the electric utility of Geneva. The team expects to show that smaller transformers and reduced energy losses can be achieved.

IV. LIKELY FUTURE DIRECTIONS

As is well known, it is difficult to make accurate predictions, particularly about the future. Thus this paper will call attention to some trends that appear plausible. Fruitful research, development and demonstration will continue in Japan, North America and Europe. Increasingly, this RD & D will be pursued by teams including members from both government laboratories and the private sector. Unlike lab science, such team work cannot be easily checked by others because of the resources required to duplicate it. Thus it will continue to be important to actively and carefully assess progress. Concern about RD&D budgets will continue and make international collaborations (e.g., BRITE-EURAM) more valuable as all sides try to economize while the work progresses from "inexpensive science" to more "expensive demonstration". Participants in such collaborations will have a market advantage, if they have technical success. Of course, these collaborations will have to show a mutual benefit to overcome the competitive urge to go it alone.

Assuming continued RD&D as above, fault current limiters for distribution systems will either be available in ten years or a technical difficulty will be clearly disclosed. The same is expected for underground cable.

Power quality will remain an interest of utility customers and superconducting storage devices will find a niche here.

The prospect of smaller and more efficient transformers will direct great interest to the recently announced collaboration ABB, ASC, EdF, and SIG. If progress is made, other groups, certainly capable of such projects, will undertake them.

The ultimate usefulness of ceramic superconductors in rotating machines will take longest to resolve. This is a difficult technical challenge. However, one of the things we have learned during the past five years is that 77K is not an economic cut-off point and that substantial gains might be had if lower temperatures make possible operation in higher magnetic fields.

Finally a speculation, two uses for ceramic superconductors will receive more attention in the future than they have in the past five years. The anisotropy of ceramic conductors will be used to make a switch. Ceramic superconductors will be used to make very high magnetic fields, at temperatures below 10K

REFERENCES

"Assessing the Impact of High-Temperature Superconductivity on Electric Power," Proceedings of an Experts' Meeting, Tokyo, September 1st-2nd, 1988 (International Energy Agency, OECD, Paris 1988) 283 pages

"Assessing the Impact of High-Temperature Superconductivity on Electric Power," Proceedings of the Second Experts' Meeting, Sorrento, Italy 11th-12th May, 1989 (International Energy Agency, OECD, Paris 1989) 283 pages

Sheahen, T.P., and A.M. Wolsky, *"Directory of Ceramic Superconductor Research and Related Research Bearing upon the Electric Power Sector"*, for signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (October, 1991). 235 pages.

Giese, R.F., and M. Runde, *"Fault Current Limiters"* for signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (November, 1991). 63 pages.

Wolsky, A.M., and T.P. Sheahen, "The *Status of Progress Toward HTS High-Amperage Conductor*", for signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (January, 1992). 90 pages.

Giese, R.F., and A.M. Wolsky, *"Published Assessments Bearing on the Future Use of Ceramic Superconductors By the Electric Power Sector"* for signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (August, 1992). 90 pages.

Giese, R.F., *"Superconducting Transmission Cables"* for signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (February, 1993). 72 pages.

Wolsky, A.M., "The *Status of Progress Toward HTS High-Amperage Conductor*", for signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (October, 1993). 100 pages.

Giese, R.F., *""Directory of Ceramic Superconductor Research and Related Research Bearing upon the Electric Power Sector" for* signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (December, 1993). 252 pages.

Giese, R.F., *"Superconducting Energy Systems"* for signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (January 1994). 64 pages.

Ueda, K., H. Taniguti, M. Takasaki and S. Akita, *"Basic Characteristics of Superconducting Current Limiter"* IEA Report to ANL-DOE on behalf the signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (February, 1994)

Giese, R.F., *"Refrigeration Options for High-Temperature-Superconducting Devices Operating between 20 and 80 K for Use in the Electric Power Sector"* for signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (October, 1994). 51 pages.

Giese, R.F., *"Projects Involving High-Temperature Superconductors in Rotating Machinery"* for signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (October, 1994). 19 pages.

Giese, R.F., *"Fault-Current Limiters - A Second Look"* for signatories of the IEA Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector, (March, 1995). 48 pages.

Jüngst, K.-P., P. Komarek, W. Maurer (editors), *"Uses of Superconductivity in Energy Storage, Proceedings of IEA Symposium Karlsruhe, Germany, 25-27 October 1994"*, World Scientific Publishing Company, Singapore, 1995.

DISCLAIMER