

ELECTRICAL CONTACTS—1984



Proceedings of the
TWELFTH INTERNATIONAL CONFERENCE
ON ELECTRIC CONTACT PHENOMENA
and the
THIRTIETH ANNUAL
HOLM CONFERENCE ON ELECTRICAL CONTACTS

Sponsored by
Illinois Institute of Technology
Chicago, Illinois



ELECTRICAL CONTACTS - 1984

Proceedings

of the

TWELFTH INTERNATIONAL CONFERENCE ON ELECTRIC CONTACT PHENOMENA

meeting jointly with the

THIRTIETH ANNUAL HOLM CONFERENCE ON ELECTRICAL CONTACTS

The purpose of the conference is to provide a forum for the presentation and discussion of the latest findings and developments in the field of electrical contacts, including connectors and relay applications. Areas to be covered include permanent, separable, arcing and sliding contacts, spanning the range from microcircuit to heavy current applications.

Price: \$75.00

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Illinois Institute of Technology
Department of Electrical Engineering

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ELECTRIC CONTACT PHENOMENA**

1st	1961	Orono, Maine, USA
2nd	1964	Graz, Steiermark,, Austria
3rd	1966	Orono, Maine, USA
4th	1968	Swansea, Wales, UK
5th	1970	Munich, Bavaria BRD
6th	1972	Chicago, Illinois, USA
7th	1974	Paris, France
8th	1976	Tokyo, Japan
9th	1978	Chicago, Illinois, USA
10th	1980	Budapest, Hungary
11th	1982	Berlin (West), BRD
12th	1984	Chicago, Illinois, USA

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THE 1985 HOLM CONFERENCE

Monday through Wednesday, September 30 through October 2 are the dates for the 31st annual meeting of the Holm Conference at the Palmer House in Chicago. Sponsorship of the Holm Conference and of the Intensive Course on Contacts will be transferred in 1985 from the Illinois Institute of Technology to the Institute of Electrical and Electronics Engineers. The IEEE Coordinator for the Holm Conference and the Course is Sam Vaughn, Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, New York 10017. Phone 212 705-7405.

ORIGIN OF THE HOLM CONFERENCE

Erle I. Shobert II, Consultant
The Stackpole Corporation
St. Marys, Pennsylvania 15857

I met Ragnar Holm in the Siemens Laboratories in Berlin in March of 1936. I was an Exchange Fellow of the Institute of International Education at Goettingen from Susquehanna University. Through the research agreements between Stackpole and Westinghouse, and Westinghouse and Siemens, I was invited to spend the spring vacation in the Siemens Laboratories.

Ragnar was polite and gracious to a young engineer. He gave me a proof copy of a book on Carbon Brushes by J. Neukirchen, which I later received permission to translate.

From that time on, I followed Ragnar's work although communication was interrupted by the war. He left Berlin for his native Sweden just ahead of the Russian occupation, leaving his home and possessions behind. He had written a book on Electric Contacts in German; and, while in Sweden, he and his wife Else prepared a new edition in English.

When I learned that Ragnar was coming to the United States in June of 1947, I arranged to meet him in Philadelphia. As a result, he and his wife came to work at Stackpole in August of 1947.

Through his connections with friends at M.I.T. and Phillip Alger of General Electric, arrangements were made for him to give a seminar on contacts at M.I.T. in the fall of 1948.

As a result of the success of this meeting at M.I.T., Ragnar and I discussed the possibility of a larger audience. With his concurrence, I met with Eric Walker, then Dean of Engineering at Penn State University. He referred me to Arthur Waynick, Head of the Electrical Engineering Department at Penn State, who brought Ralph Armington into the picture.

Arrangements were made for the first seminar on an invitational

basis, and this was held at Penn State in November of 1953. The first seminars consisted of lectures by Ragnar on an instructional basis, with participation by others only as they took part in the discussions.

It became apparent that there could be more interest developed if others were brought into the picture, and under Ralph Armington's guidance and direction, the contact seminars became an annual event at Penn State.

With experience and concern, the organization of the seminars has developed until they are models for successful meetings. Every detail which can affect the success of the technical presentations, and the housekeeping, has been considered as the system developed. Ralph Armington alone is responsible for this climate and environment. He has set a standard which will be difficult to maintain.

In more recent history, the seminars, which were eventually to be called the Holm Seminars, followed Ralph Armington to the University of Maine (1961), and finally to the Institute of Technology (1967). Along the way, several thousand scientists and engineers have been influenced by Ragnar's fundamental work and a solid core of individuals is carrying on.

THE START OF THE INTERNATIONAL CONFERENCE

J. B. P. Williamson
Williamson Interface Limited
Malvern, Worcestershire, England

With the ongoing success of the Contact Seminar at the Pennsylvania State University in the middle 1950's and the evident value to U.S. scientists of the Seminar's meeting annually, Dr. Holm proposed that there would be value in calling together an International Research Symposium on Electric Contact Phenomena.

From his world-wide acquaintance with scientists working at the frontiers of the several facets of electric contact technology, Dr. Holm listed those scientists who should be asked to write papers for the Symposium.

Since several of these scientists were University faculty, it was agreed that the National Science Foundation should be approached with a request for travel assistance for any persons whose Symposium participation would not be industry-supported. The NSF was agreeable; 1960 dates were set; and invitations were sent to the several proposed authors.

From a British author came almost immediate reply to the effect that a contact meeting in England had already been announced, overlapping two days of the proposed Symposium. The Symposium dates were then moved to November of 1961, and arrangements proceeded for the Symposium to meet at the University of Maine in Orono, Maine.

The Symposium Program included 25 papers for Austria, England, Japan, The Netherlands, Switzerland, Wales, West Germany and the U. S.

New England weather that November was anything but hospitable, the nearest open airport being Boston, 250 miles from the Symposium; and many attendees had harrowing experiences ranging from all-night taxi rides on fog-bound expressways to the witnessing of robberies in rail stations. But, in spite of all, at 9:00 AM sharp on the opening day of the Symposium every preregistered attendee was seated in the auditorium - save one from whom a message had been received that he had just had his appendix removed and could not attend.

Whereas this Symposium was planned as a one-time event, several participants immediately recognized its value, and an invitation was tendered by Professor Peter Klaudy an author from the Technische Hochschule in Graz, Austria, to a second meeting in 1964 in Graz.

The invitation was accepted, an International Advisory Group on Electrical Contact Conferences was formed; and the bi-ennial series of International Conferences was started whose twelfth gathering we are now enjoying in Chicago.

THE HOLM CONTACT COURSE

Harold N. Wagar
Consultant - Contacts and Relays
Holmes Beach, FL

INTRODUCTION

This is a brief history of the Holm "Intensive One-Week Course in the PRINCIPLES OF ELECTRIC CONTACT THEORY AND APPLICATION" that has now been offered since 1971. Other than Dr. Armington himself, the best person to tell this story would be Dr. Wilfred E. Campbell, who was Course Organizer, But as his health prevents this, I will do the best I can in his place, based on my experience as Collaborating Organizer. Naturally, I've picked his brains while preparing this review. It will tell how the course originated, its objectives, how it became a reality, and how it evolved over the fourteen years since it started.

ORIGIN

After the Contact Seminar had moved from the University of Maine and become well established at the Illinois Institute of Technology in Chicago in 1967, Dr. Ralph Armington and others sensed a growing demand for a course on contact fundamentals somewhat along the lines of the earlier courses given by Drs. Ragnar and Else Holm. In 1970, Ralph talked seriously about this with Bill Campbell and asked him to plan how such a course might be presented (1).

Bill had done extensive original contact development work before he left the Bell Laboratories in 1954, and then again as a Consultant and also as Professor of Materials Engineering at Rensselaer Polytechnic Institute. He had also been a member of the Holm Seminar Steering Committee.

In 1970, I had just retired from the Bell Laboratories, where in addition to various contact-oriented development activities, I had also written and taught courses on contact design for several years. And I too had become a Consultant and was available for lecturing. As Bill and I had known each other from his early Bell Laboratories years, it was only natural for us to join forces.

OBJECTIVE

We visualized a group of students new to the field of contacts, who might be specializing in any of the numerous branches of contact technology. We felt it necessary to present all relevant topics in the physics, metallurgy, and chemistry of metallic surfaces such as friction, adhesive wear, physics of conduction through constrictions or films, thermal effects, switching action including arcing and other discharges, and corrosion including environmental effects, their control and evaluation. Instrumentation and test procedures also needed coverage, as well as various practical

procedures. The final plan was to compress this into one solid week of lectures--Monday through Friday.

IMPLEMENTATION

To do this required lecturers, prepared lecture notes, and some complicated logistics. Bill Campbell found William Abbott, of Battelle, well-known for his metallurgical and environmental work, for three lectures on these subjects, and Walter Krellner, of Stackpole, to give one lecture on sliding carbon contacts. Bill and I split the remaining fourteen lectures. Dr. Armington and his able assistant, Mrs. Leal Smith, collected and collated our notes, circulated announcements, and made the lecture, living, and financial arrangements. The first class assembled on June 14, 1971, with 22 students, using dormitory and lecture rooms on the IIT campus. From this attendance, and general student response, it was clear that we had a viable program for later years. Today, the course has spanned fourteen years, missing one poor business year (1973), but with registration size generally corresponding to business conditions.

<u>Year</u>	<u>Class Size</u>	<u>Year</u>	<u>Class Size</u>
1971	22	1978	19
1972	31	1979	35
1973	--	1980	19
1974	25	1981	25
1975	12	1982	20
1976	28	1983	26
1977	14	1984	40

Total to Date - 316

Figure 1
Yearly Registration

EVOLUTION

During this period the course has evolved along three lines: technical content, teaching personnel, and accommodations.

Technical Content

The curriculum was aimed to match the wide variety of interests of students from the many branches of contact work, never quite the same from year to year. We monitored student specialties and tried to match them with a proportional amount of lecture coverage. For example, we learned early-on that more detailed coverage of higher-voltage areas was needed. George Farrall, a G. E. expert on high voltage and vacuum contacts joined us for two successive courses, to be followed by Albert Snowdon, a skilled designer of industrial control devices, who still lectures on this subject despite his increasing involvement in managerial aspects of the Eaton Corporation business.

Lecture notes were modified a little each year to keep pace with new information and new developments. Also we incorporated into the class notes two contact chapters that I had written as part of a Bell Laboratories textbook series (2). And, as the new lecturers joined the course, notes were modified as appropriate to match their expertise.

Personnel

Eventually the time came for Dr. Campbell and me to taper out, and two outstanding replacements were made: Dr. Brian Williamson as Course Director and Lecturer on surface, electrical and thermal aspects of contacts, and Dr. Morton Antler as Lecturer on tribological and chemical aspects. A roster of the Course "Faculty" over this period is seen in Figure 2. During the entire period, of course, the program was being "managed" by Dr. Armington and Mrs. Smith.

Student Accommodations

After the first two years, the course was moved from the somewhat Spartan lodgings on the IIT campus to the more time-efficient (and more expensive) quarters of various Chicago hotels: in 1974 at the La Salle Hotel, in 1975-78 at the Pick Congress Hotel, and since then at the Palmer House. The tuition in 1971 was \$190, rising almost linearly to this year's fee of \$550. Likewise, nightly accommodations have risen steadily--from \$5 per night for the first dormitory year to \$60 last June at the Palmer House.

SOME CLASS SIDELIGHTS

The course deserved its description as "Intensive." There were two morning and two afternoon lectures approaching an hour and a half each, with mid-point coffee breaks. Often lectures began at 8:30 A. M. with an hour and a half for lunch. Some problems were given, as illustrations, but no homework was required. It was customary to have a get-acquainted social hour and dinner on one evening and at the end of the course we gave certificates of completion to all participants.

The mix of students has been interesting. Women have been well represented. Geographically, students have come from nearly every state, though Chicago area students have been the most numerous. Students have also come from other countries: there have been 20 from Canada, 4 from England, 3 from Switzerland, 2 each from France, West Germany and India, and 1 each from Belgium and Holland.

The yearly announcement states that the course "is intended for research and development engineers with little or no experience in electrical contact principles or practice." Yet, from the titles given in the registration sheets, many class members have come from truly responsible and experienced assignments in their

<u>Name</u>	<u>Teaching Years</u>
W. E. Campbell - Organizer and Lecturer	1971-1981
H. N. Wagar - Collaborating Organizer & Lecturer	1971-1982
W. H. Abbott - Lecturer on Contact Materials	1971-Present
W. G. Krellner - Lecturer on Carbon Brushes	1971 Only
G. A. Farrall - Lecturer on High Voltage Contacts	1972-1974
A. C. Snowdon - Lecturer on Industrial Contacts	1975-Present
J. B. P. Williamson - Course Director Since 1982	1980-Present
M. Antler - Lecturer on Tribology and Chemistry of Contacts	1982-Present

Figure 2

Course Faculty 1971 to Present

own companies. In illustration, there have been 4 Presidents or Vice Presidents, 43 Managers, 39 Senior Engineers, and numerous other titles suggesting a depth of prior experience. Certain companies have almost always sent one or more students each year; this year, for example, one company broke the record by sending nine.

CONCLUSION

Speaking for myself, and I'm sure for Drs. Armington, Campbell, and Williamson, and all the other Lecturers, I want to say how pleased and proud we are to observe the success of large numbers of our graduates. Many have grown to high responsibility within their companies, have given good papers at the Holm and other conferences, and now fulfill important functions in these Contact Conferences.

REFERENCES

- (1) R. E. Armington, "THE HOLM CONFERENCE, HIGHLIGHTS OF THE FIRST TWENTY-FIVE YEARS," Proc. 25th Holm Conf., IIT, Sept. 1979, pp. 1-9.
- (2) Bell Laboratories, Physical Design of Electronic Systems, Vol. III, Prentice-Hall, 1971, Chapters 8 and 9.

CONTINUATION OF THE INTERNATIONAL CONFERENCE

W. Rieder

Chair of Switching Devices

Technical University Vienna, Austria

Since the start of the International Conference on Electrical Contact Phenomena was promising, those who wanted to repeat it formed an International Advisory Group to find hosts and organizers for future Conferences and to provide them with certain guidelines.

For the time being the International Advisory Group consists of delegates from twelve countries plus three past chairmen. It was agreed that one Conference organized in America should be followed by two in Europe. Once, however, we had the pleasure to meet in Japan.

Essentially the International Conference has been kept alive by the chain of ad hoc constituted Organizing Committees in each of the host countries (Austria, France, Germany, Hungaria, Japan, UK, and USA) and we are going to continue in that way in Switzerland (1986).

It appeared that the Conference developed well during its early years demonstrating a true demand was met by its foundation and continuation. It seems important that the Conference was well attended even in years of commercial stagnation. Obviously the respective companies around the world realized the efficiency of information exchange on this platform.

The main task of both the International Advisory Group and the National Organizing Committees has been to keep the standard of the papers and of the discussions on that level needed to attract the attendance.

Their number must be high enough to meet most of those people active in the field you want to see and to be well informed about the essential progress in R and D, but also high enough to run the Conference economically with an acceptable attendant's fee. On the other hand a monster Conference shall be avoided dominated by social events but suppressing live and informal discussions.

I believe the number of attendants of our Conference has been scattering well within this critical range. E.g., at the 1982 ICECP in Berlin 362 participants were counted coming from 27 countries and presenting 90 papers.

Continuation of an institution requires more than organisation and effort: it requires continuity and personalities. Even the most perfect organisation would starve if not kept alive by the spirit and by the activity of certain outstanding people.

There is no doubt that the nucleus of cristallisation and the mental father of the Conference was Ragnar Holm who determined both the field of activity and the atmosphere of the Conference without formal membership to any organizing body.

On the other hand it was Ralph Armington who created the necessary preconditions and the required ambience for Ragnar's public activities, including the International Conference. He did not only create the necessary preconditions, he also continued to be the stable pole needed by such a vagant organization. Independent whether or not he happened to be the US representative or the Chairman of the International Advisory Group, continuity of the Conference was maintained essentially by Ralph Armington.

I deeply regret that he is going to retire now. Although the Conference is no longer a baby but is 23 years old and has been coming of age, I do hope Ralph will not abandon its child abruptly and will be with us even at Lausanne in 1986.

THE TRANSITION OF THE HOLM CONFERENCE FROM IIT TO IEEE

Morton Antler
IEEE CHMT Society
AT&T Bell Laboratories

With the steady growth of the electrical contacts industry and the continuing success of the Holm Conferences and the intensive Course on Electrical Contacts, it was inevitable that the Holm Organization would eventually look forward to becoming associated with the professional and technical society in whose work the technology and science of electrical contacts is rooted. Accordingly, in 1982 the Holm Steering Committee agreed to accept the invitation of the Electrical Contacts Committee of the Institute of Electrical and Electronics Engineers Components, Hybrids, and Manufacturing Technology (IEEE CHMT) Society to join it, and this will occur at the close of the 1984 Conference. The Conference will henceforth be named the IEEE Holm Conference on Electrical Contacts.

The affiliation of the Holm Conference with the IEEE CHMT Society continues and broadens an association which began many years ago. The IEEE CHMT Society has been its technical co-sponsor for a long time, and indeed supports the present 12th ICECP, together with other technical organizations. Papers submitted to the Holm Conference are reviewed for possible publication in IEEE Transactions on Components, Hybrids, and Manufacturing Technology (Figure 1.) In its new role the IEEE CHMT Society will provide financial, operational, and promotional support through the resources of IEEE.

The IEEE is the largest professional engineering society in the world, with 250,000 members in the United States and in other countries. This year it celebrates its Centennial. The purposes of the Institute, as defined in its Constitution, are scientific, educational, and professional. Historically, the IEEE has been concerned with the advancement of the theory and practice of electrical engineering, electronics, radio and its allied branches of engineering and the related arts and sciences. The CHMT Society is an organization of 3,000 within the framework of the IEEE of people whose professional interests are in the field of component parts, hybrid microelectronics, materials, packaging techniques, and manufacturing technology. Through its Technical Committees, listed below, it sponsors conferences, symposia and workshops, many jointly with other organizations.

Technical Committees

- TC-1: Electrical Contacts
- TC-2: Discrete Component Parts & Subassemblies
- TC-3: Hybrid Microelectronics
- TC-4: Manufacturing Technology
- TC-5: Materials
- TC-6: Electronic Packaging
- TC-7: Semiconductor Processing Technology

Some of these meetings are:

IEEE Holm Conference on Electrical Contacts
Electronic Components Conference (ECC)
Electronics Manufacturing Technology and Systems Conference (EMTAS)
VLSI Chip Packaging Workshop
University-Government-Industry Microelectronics Symposium (UGIM)
Workshop on Micrometer and Submicrometer Lithography
Capacitor and Resistor Technology Symposium (CARTS)
Integrated Optics Workshop
VLSI Multilevel Interconnection Conference
International Solid State Circuits Conference (ISSCC)
Power Electronics Speciality Conference
International Conference on Robotics
Hybrid Technology Forecasting Workshop

In addition, the CHMT Society is active in education through its support of courses, tutorials, and seminars. It coordinates standardization activities with the Electronic Industries Association, the American Society of Testing and Materials, and other organizations. It has chapters in several countries where members discuss their local specialized technical needs.

The IEEE Holm Conference Steering Committee joins with the IEEE CHMT Society Technical Committee on Electrical Contacts in welcoming contributed technical papers to future Conferences. They should be forwarded to:

Mr. Sam Vaughn
IEEE
345 E. 47 Street
New York, New York 10017

Anyone interested in becoming active in the IEEE CHMT Technical Committee on Electrical Contacts or the work of the Holm Organization should discuss his interests with members of these groups.

FOREWORD

The Twelfth International Conference on Electric Contact Phenomena meets jointly this year with the Thirtieth Annual Holm Conference on Electrical Contacts.

The Conference is sponsored by Illinois Institute of Technology, in cooperation with: Institute of Electrical and Electronics Engineers (Electrical Contacts Committee of the Components, Hybrids and Manufacturing Technology Society), American Society for Testing and Materials, Electronic Connector Study Group, Incorporated, National Association of Relay Manufacturers, The Electrochemical Society (Electrodeposition Division and Corrosion Division), American Electroplaters' Society, American Institute of Metallurgical Engineers and Electronics Industries Association.

This five-day conference comprises seventy-six technical presentations scheduled into seventeen sessions, concentrating in the following areas: electrical connections, electronic connections, interconnection technology, high current contacts, arcing phenomena, fundamentals, materials, sliding contacts and commutators, silver-metal oxide contacts, reliability testing, environmental effects, surface analysis, manufacturing processes (e.g. electrodeposition, welding, cladding & physical vapor deposition) and other areas related to electric contacts & allied technologies.

Opportunity is provided in each session for questions and discussion of individual papers, and for general discussion.

Included in this volume are the reviewed and edited papers of those speakers who made their materials available in written form. The papers are arranged in the order in which they are presented. One must recognize that questions, answers and discussions constitute in substantial measure the value of the Conference and that these Proceedings, assembled before the Conference, cannot include them.

Prior years' Holm Conference Proceedings for the convenience of users of this volume, are listed starting on page 619 with contents and ordering information and covering the eight most recent years of the conference.

Illinois Institute of Technology is grateful to the Conference Program Committee, the Authors and Speakers and the Session Chairmen and Cochairmen for their valuable contributions to the Conference and the authors' permission to include their writing in this volume.

Illinois Institute of Technology
Chicago, Illinois 60616
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Ralph E. Armington
General Chairman