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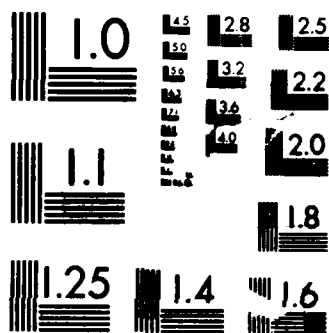
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OFFICE OF NAVAL RESEARCH LONDON (ENGLAND) C J FOX
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European Science Notes Information Bulletin
Reports on Current
European/Middle Eastern Science

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A NOTE ON THE NEW
ESNIB

Distribution of this document, ONRL's initial *European Science Notes Information Bulletin (ESNIB)*, marks an important and natural stage of evolution in the manner that ONRL informs the US R&D community of the current European scientific activity.

It is essential to the ONRL mission to report as much of that activity as possible. Over the past year, we have added new sections in *ESN* on trip reports by US scientists travelling to Europe, abstracts of reports by other commands, and items of interest reported by US embassies. Thus, our primary document, *ESN*, was gradually taking on a new shape, a new dimension, a new scope--even a new sort of function.

The next logical step in the process of supporting the mission--and our readers--is to issue the information we gather when, by topical importance, technical significance, breadth of coverage, or general interest it should be put in your hands. Thus, the new *ESNIB* will be issued according to the dictates of the information which becomes available to us. We do not know how often the information we are gathering will dictate its distribution. In any case, our aim is to fulfill our mission in the best possible manner, and that translates into serving your needs more fully and more efficiently....Incidentally, you, gentle reader, remain on the distribution list.

Welcome to *ESNIB*!

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ESN INFORMATION BULLETIN

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87-01

Behavioral Sciences

- Research on Social Comparison, Range Seeking, and Their Relationship ;..... William D. Crano 1

Recent research by the Netherland's John Rijsman on the ways people validate their beliefs or abilities in the absence of objective benchmarks is reviewed. Of primary interest in Rijsman's work on "range seeking," the tendency of people to seek information about the most extreme members of the class or group to which they belong as a strategy to evaluate their own position.

Biological Sciences

- Water and Ions in Biological Systems--The Fourth International Conference ;..... Claire E. Zomzely-Neurath 6

The presentations given at this conference, held in Bucharest, Rumania, in May 1987, are summarized. The topics of interest are water and ions at membrane surfaces, relations between membrane structure and transport, action of drugs and hormones on water and ion movements through membranes, and the role of divalent actions in biological systems.

Chemistry

- XIII Sandbjerg Meeting on Organic Electrochemistry ;..... M. Irene Montenegro 11

The purpose of this meeting, held in Denmark in June 1987, was to gather groups consisting of young and some experienced scientists to discuss various topics in organic electrochemistry, and to stimulate international cooperation. In the author's opinion, the meeting succeeded. She reviews all five plenary lectures and offers comments on the shorter papers.

Computer Sciences

- Control Research at Northern Universities in Italy Daniel J. Collins 13

The author discusses the results of his visits to control research groups at three universities--Politecnico di Milano, the University of Firenze, and the University of Pisa. He concludes that the work at the Politecnico is particularly strong, the mathematical aspects of nonlinear control dominate at Firenze, and the work at Pisa has a strong American slant. He reaffirms that control research in Italy is very strong.

- A Review of Nonlinear and Robotic Control
Theory in Southern Italy ;..... Daniel J. Collins 16

Control research at three universities in Italy is reviewed: the University of Rome "La Sapienza," the University of Rome "Tor Vergata," and the University of Naples. The author concludes that control research in Italy is of a very high order.

Electronics

- Optoelectronics at University College,
London J.F. Blackburn 19

The work reviewed here concerns the development of a technology that will allow the designer of optical computers to switch from the optical to electronic domain, and conversely, in order to use the best of both electronics and optics in the same systems. Topics include the work in passive pathway switches, wavelength routing, active pathway switches, and fast synchronous switches.

Material Sciences

- Some Observations on Hybrid
Microelectronics in Yugoslavia ;..... Robert W. Vest 22

Visits to the Mihailo Pupin Institute and the Research and Development Institute of Elektronska Industrija along with attendance at this year's Yugoslav Conference on Microelectronics form the basis of this profile of the current state of hybrid microelectronics research in Yugoslavia. The author concludes that the quantity of work is quite large in relation to the population while the quality covers the full spectrum.

- Engineering Ceramics: A One-Day
Meeting in the UK Louis Cartz 26

Presentations at this meeting held in July 1987 concerned the advantages and disadvantages of replacing metal components with ceramic ones. Papers are reviewed under the topics of engineering applications and property requirements, and engineering ceramic properties.

- Materials Meeting in London, UK
May 1987 Louis Cartz 29

Presentations on the surface treatment and tribology of ceramic materials are discussed--with special reference to plasma-spray coatings and adequate preparation of the substrate. Papers on toughening mechanisms of zirconia-based ceramics, ion implantation, microstructure, and tribology of ceramic surfaces are also reviewed, and a detailed discussion of WC-Co cemented carbides is given.

- Stress Relieving After Welding:
Eastern European Approaches Kenneth D. Challenger 33

Presentations given at the annual Assembly for the International Institute of Welding, held in Bulgaria in July 1987, are assessed. Topics under which the papers are discussed are: a new heat source for materials processing, metallurgy of stress relieving, residual stress generation, and mechanical stress relieving.

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- NATO Workshop on Mathematical
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This meeting, held in April 1987 in Lyons, France, brought together experts in the field of combustion to discuss the state of the art in the modeling of combustion phenomena. Selected presentations are reviewed.

- Shock/Boundary-Layer Interaction, Vortex
Flow, and Process Automation Research
At RWTH Aachen Daniel J. Collins 40

Research activities and facilities of West Germany's technical university (RWTH) in Aachen are reviewed. The institutes concerned are the Jet propulsion and Turboengines Institute, the Aeronautics and Astronautics Institute, and the Control Technology Institute.

Ocean Sciences

- Marine Science at the Netherland's
Hydraulic Laboratory Jerome Williams 43

This report concentrates on the estuarine and coastal aspects of the work of the Hydraulics Laboratory. The author concludes that the work being done here and the support evidenced by the facilities give ample evidence of continued Dutch eminence in this field.

- Oceanography on the French Riviera--
Laboratoire de Physique et Chimie Marines ; Jerome Williams 45

Activities and facilities of this major French oceanographic laboratory are reviewed. The laboratory comprises physical chemistry, geophysical, and biological groups, and has a well-equipped electronic and instrumentation laboratory and workshop. The author concludes that the quality of work being done here is of very high quality.

- Tracers in the Ocean--A Small
International Meeting ; Jerome Williams 47

This meeting, held in May 1987 in London, UK, attracted about 40 participants who discussed the use of both natural and anthropogenic tracers in a wide variety of studies. The presentations are reviewed under the following topics: tracer characteristics, biochemical processes, air-sea interactions, and physical processes.

Physics

- 1st European Workshop on High T_c
Superconductors and Potential Applications Ray Kaplan 50

Selected presentations at this workshop, held in Genoa, Italy, in July 1987, are discussed. Topics of this review include ideal structure, structure defects, T_c 92 K, theory and conductivity mechanisms, applications, and wires.

Quantum Optics Research at Naples University	Paul Roman	54
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This article describes research in several areas of quantum optics, molecular physics, liquid crystal optics, the galvano optical effect, theoretical studies on free electron lasers and optical wave propagation--all pursued vigorously at the newly reorganized and fast growing Physics Department of Naples University.

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Behavioral Sciences

RESEARCH ON SOCIAL COMPARISON, RANGE SEEKING, AND THEIR RELATIONSHIP

by William Crano. Dr. Crano is the Liaison Scientist for Psychology in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until June 1988 from Texas A&M University, where he is a Professor of Psychology.

How do people validate their beliefs, or evaluate their abilities, in the absence of objective benchmarks? Nearly 35 years ago, Leon Festinger attempted to come to grips with this issue, which is, in fact, one of the central questions of social psychology. In his theory of social comparison, Festinger proposed a coherent model of the processes that people engage in the social validation of ideas and abilities. Put most simply, Festinger assumed that people have a need to know whether their ideas are correct, a need to gauge the quality of their skills and abilities. In many situations, such information is objectively available. In such circumstances, there is no difficulty--the objective evidence is used by the individual to assess his or her status on the relevant issue.

However, there are contexts in which objective information either does not exist or is not available. In such situations, Festinger hypothesized that we would compare ourselves with others (hence the term, social comparison theory) to make the appropriate determination. Identification of the processes that motivate social comparison, the preferred targets of comparison, etc., remain crucial issues in the development of this still-controversial theory. The theory is important because it can be used to explain a host of apparently unrelated social phenomena, ranging from the tendency for people under stress to affiliate with one another, to stereotyping and racism, to the homogenizing influence of groups on members' attitudes and opinions. As such, Festinger's ideas have stimulated considerable research, and this expenditure of research energy appears fully justified.

The research history of social comparison theory is remarkable. Scientific interest in the theory has proved extraordinarily variable. Intensive research on the model was undertaken in the middle

1960's, the late 1970's, and is evident again today; at other times, there has been almost total neglect of the model. I know of no other theory in psychology whose research history is characterized by such extremes. It is almost as if when a hot new theory comes along (e.g., Festinger's own dissonance theory in the late 1950's, early 1960's, and attribution theory in the 1970's), social comparison is laid aside. But like one's first love, social comparison theory, often out of sight, is never fully out of mind. Goethals (1986) has proposed a number of possibilities for this variability in interest, but for present purposes, it is more important to realize that researchers always seem to come back to the theory, and this suggests that it is important, or stimulating, or both.

In this report I will discuss recent critical social comparison research undertaken in Europe. The research calls into question some of the major assumptions of Festinger's theory, and suggests that much of the data on which it is based are more parsimoniously interpreted in a "cold" (i.e., amotivational) information-processing framework that is orthogonal to the motivation-based model proposed by Festinger. However, I am jumping the gun. Let me first present more concretely the general outlines of social comparison theory for those unfamiliar with this particular explanation of one area of complex human social behavior.

SOCIAL COMPARISON THEORY: A BRIEF INTRODUCTION

The model, like all of Festinger's theories, begins with a set of apparently innocuous assumptions whose logical extension leads to some rather unexpected predictions. Let us itemize some of the theory's major features:

- We begin with what is one of the theory's most controversial assumptions, namely that people are motivated to be right--that is, we have a need for self-evaluation. The word "need" in this context signifies an organismically inherent drive-state, similar to other drives (e.g., for food, water, sex).
- The model holds, further, that in the absence of objective criteria, we will compare ourselves with other people to determine the correctness of our beliefs, or our level of skill or ability in a particular area of endeavor.
- But not any person is equally satisfactory for comparison purposes. For such, we seek to compare ourselves with people who are similar to us on

the attitude or skill under consideration. Why? Because, according to Festinger, "A person does not tend to evaluate his opinions or his abilities by comparison with others who are too divergent from himself. If some other person's ability is too far from his own, either above or below, it is not possible to evaluate his own ability *accurately* by comparison with this other person. There is then a tendency not to make the comparison....One does not evaluate the correctness or incorrectness of an opinion by comparison with others whose opinions are extremely divergent from one's own." (See Festinger, 1954, p. 120.)

In other words, when driven to evaluate our ideas, or to gauge our skills, abilities, or developmental progress, we seek to compare ourselves with people who are like us. In some circumstances, this proposition makes intuitive sense. For example, how could a neophyte chess player best determine how well he was progressing in learning the game? There is no objective way of doing so. Instead, he would look to compare himself with another player. Who would be the preferred comparison partner? Clearly, if one were motivated to learn about one's progress, it would make little sense to engage Boris Spassky in a game--the outcome is a quick and foregone conclusion, and the information conveyed would be minimal. Much more informative would be the result of an engagement with a person with similar chess experience. In this way, the outcome would allow for a more certain estimate of one's rate of progress in the game, and from that, facilitate inferences about relative ability levels.

The theory leads to some unexpected hypotheses, some of which have been borne out by subsequent research. In their work on the identification of emotion, for example, Schachter and Singer (1962) reasoned that there must be a strong social component to the experience of emotion, since the physiological cues that are experienced in many different kinds of arousal (anger, happiness, fear) are so similar. To test this idea, they administered an arousal-inducing drug (epinephrine) to subjects, and either identified or misidentified the source of the resulting physiological reactions (which included increased heart rate, tremor, sweating, etc). When subjects in the "misidentified symptoms" group were paired with a euphoric experimental accomplice, they reported being happy, elated, etc. However, when placed in a situation with a person feigning anger, injected subjects (who had been misin-

formed about the drug's effect) also reported being upset, angry, etc. Those who had been appraised correctly of the source of their physiological reactions, however, were not influenced by the accomplice's behaviors. These findings prompted Schachter and Singer to hypothesize that we employ external cues, perhaps most importantly the actions of others, to help us define important emotional states which are only vaguely signalled by our internal states. Social comparison theory could not have hoped for a more positive result.

However, it has not all been smooth sailing for social comparison theory. One of the characteristics of this theory, as with all of Festinger's theories, is that it is sufficiently extensive to be apparently applicable in almost any circumstance. This is, at once, both a blessing and a curse. It is a blessing because it guarantees that the theory will receive attention from many different areas of the field. It is a curse because it is likely to lead to an overextension of the model, to its attempted application in situations that were never intended by its originator. This is, perhaps, as Festinger would have it, given his reputation of preferring to be controversial over being correct (cf. Deutsch and Krauss, 1965). Let us now consider some current European research on Festinger's theory.

RANGE SEEKING

One interesting research series that has been focused on the range of applicability of social comparison theory has been undertaken by John Rijsman, of the University of Tilburg (the Netherlands). For more than 10 years, Rijsman has devoted at least a portion of his impressive research energies to the study of social comparison processes (e.g., see Rijsman, 1983). Since the results of some of his investigations have not been published, or have been published only in Dutch, this report will provide information that US researchers (at least those who cannot read Dutch) probably could not have known about previously. We begin with a description of his work on an interesting phenomenon called "range seeking."

Range seeking refers to people's tendency to search for information about the most extreme (i.e., the highest and lowest ranked) members of a class, or of a group to which they belong. Researchers have assumed that this behavior is undertaken to facilitate the range-seeker's self-evaluation through comparison. However, range seeking appears to fly in the face of one of Festinger's central assumptions, that we will seek comparison

partners who are similar to ourselves; obviously, by seeking the extremes, we guarantee that at least one of the comparison partners will be maximally different from us. The research of Rijsman and his colleagues (J. Syroit, and J. von Grumbkow, University of Tilburg) was undertaken first to establish the generality of the phenomenon, and then to determine whether range seeking was a behavior that really fell within the predictive confines of social comparison theory. As Rijsman has told me, and as is obvious from his major investment of research energy on social comparison processes, his work on this phenomenon was undertaken initially to specify the conditions under which Festinger's theory applied or did not apply. Only with later research did the question arise of whether the theory applied in any circumstance.

Two Generality Studies. In studying the robustness of the range seeking phenomenon, Rijsman and colleagues engaged 70 high school students (from Turnhout, Belgium) in a reaction time task, and then presented them individually with information purportedly based on their performance, and that of six other subjects (their peers) who also had taken part in the study. The information was arranged such that only the rank order of performance was presented. Information was manipulated to indicate that the subject's score fell at the midpoint of the distribution of reaction times. As shown in Figure 1, which presents an example of the information format employed in the study, the subject knew only his own reaction time, and the fact that his performance placed him somewhere in the middle of the pack. Two simple questions then were asked of each subject: (1) Indicate the person whose reaction time you would most like to know, and (2) Indicate another person whose results you also want to know. The results of this study are shown in the "Turnhout" columns of Table 1. As shown, the first choice of

Rank Order of Reaction Time Scores

Student:
 A (the fastest)
 F
 D
 P (yourself; your time
 was .15 seconds)
 B
 E
 C (the slowest)

Figure 1. Example of information presented in Rijsman's range seeking studies.

Table 1
 Choice Distributions of the Turnhout and Tilburg Experiments

Ranks	Turnhout		Tilburg	
	1st	2nd	1st	2nd
1	44.2%	15.7%	66.3%	24.5%
2	17.1	5.7	2.0	8.2
3	18.6	17.1	10.2	5.1
4 (subject)	----	----	----	----
5	10.0	20.0	4.1	9.2
6	4.3	5.7	2.0	0.0
7	5.7	35.7	15.3	53.1

almost 45 percent of the sample was the fastest member's score. The second choice of 36 percent of the sample was the slowest member's score. The choice distributions for both first and second choices differed significantly from chance (at $p < .001$, in both comparisons).

This experiment was replicated on a sample of 98 undergraduates of Tilburg University, and the results are presented in the "Tilburg" columns of Table 1. As shown here, the data strongly resemble those obtained in the Turnhout sample. As before, there was a strong preference for the most extreme scores, and the obtained frequency distributions for both first and second choices were significantly different (at $p < .001$) from the random distribution.

The data of both studies support the generality of the range seeking phenomenon. At the same time, they provide little support for Festinger's theory. The results appear to show that people prefer to know the extreme values of a distribution of scorers, rather than the scores of those most similar to themselves. However, in light of results of earlier psychophysical experiments, we might question whether social comparison theory is relevant to subjects' behavior in the range seeking studies. The results of these earlier studies show that the information value of an item increases with the extremity of its position in a distribution (Slovic & Lichtenstein, 1971). As such, solely on the basis of information value, we can predict that the extreme items in an information seeking task will be more sought after, relative to other less extreme items. Perhaps it was differential information value, rather than the need to compare, that motivated the particular information choice patterns observed in the studies discussed to this point.

To test this possibility, Rijsman placed subjects in a situation in which social comparison with the stimulus objects was not likely, since the objects of comparison were nonsocial entities, unlike the social beings of the Turnhout and Tilburg studies of Table 1. If range seeking is found in this nonsocial context, this would cast doubt on the relevance of the ranked data experiments for social comparison theory. In addition to the range seeking phenomenon, Rijsman wished to study the conditions under which subjects would seek information about adjacent stimuli, be they persons or inanimate objects. According to social comparison theory, of course, such comparisons should be common.

To test these alternative propositions, Rijsman assembled 128 school children in a study that took the general form of a classic psychophysical weight-judgment experiment. Subjects were told, rightly, that the context in which an object appears affects the perception of the object. A lamp that is lit in a dark room appears brighter than the same lamp lit in an already bright room. A similar phenomenon occurs with the judgment of weight. A man who weighs 180 pounds appears much lighter when surrounded by 3 men of 260 pounds than when he appears in the context of 3 100-pounders.

Subjects were told their job in the study would be to evaluate the perceived weight of a wooden block. In fact, they were told, the block weighed exactly 215 grams. Further, the block occupied the middle position of a row of seven blocks, arranged from lightest to heaviest (i.e., the distribution was ordered). In one condition of the study (the "Range" condition), the subjects were told that the lightest block of the distribution weighed between .5 and 2.5 grams, and the heaviest between 2310 and 2820 grams. In the "No Range" condition, the weights of the extreme stimuli were not provided.

Subjects then were asked to identify the block whose exact weight they wished to know; then, to name another. At this point, the experiment was effectively over. The parallel nature of this study with those discussed previously is striking--as are the results, as will be seen.

If, on the basis of their requests, we define subjects as being *range seekers* (i.e., those wishing information about the extreme stimuli), *similarity seekers* (those wishing information about blocks adjacent to the one whose weight they knew), or *others* (everyone else), the distribution of choices is quite informative. By chance, we can assume approximately 13 percent of the choices to be

of the range seeking type, and 13 percent of the similarity seeking variety. However, nearly 50 percent of the subjects who were not provided with weights of the endpoints of the distribution were range seekers--i.e., sought to learn the weights of the extreme members of the ordered distribution. And, nearly 40 percent of those who had been provided this information (subjects in the range condition of the experiment) were similarity seekers. These obtained frequencies differ significantly from chance expectations in both cases.

These results indicate that range seeking occurs even in situations in which the comparison objects are inanimate. Further, they suggest that once the endpoints of an ordered distribution are known, information about stimuli adjacent to one's own are sought. The inanimate nature of the stimuli would appear to disqualify these results from the realm of social comparison theory, which is based on the assumption that we will seek similar *persons* with whom to compare. As such, the data on one level suggest that range seeking is not a phenomenon to which social comparison theory is relevant.

The interesting additional finding of this study, that people seek information from adjacent objects *when the range of the distribution of comparison objects has been specified*--even when the distribution consists of nonsocial objects--appears to cast a shadow over the very validity of social comparison theory. Syroit, et al. (1987, p. 16) put it succinctly:

The choice of information about comparison persons is very similar to the choice of information about, for example, wooden blocks. This remarkable similarity between "social" and "non-social" choice behavior forces us to reformulate our initial question about range seeking. The most important question is not...[whether] only range seeking, but the choice of similar others as well, has something or nothing to do with social comparison dynamics. We are inclined to answer this question in a negative way....It is impossible to explain all the results with the aid of Festinger's social comparison theory. The choice of similar blocks cannot be explained by assuming a tendency to compare with these objects. The search for information about the range cannot be interpreted in terms of self-evaluation...needs.

What, then, accounts for range seeking and for similarity seeking once the extremes of the comparison distribution

have been determined? Rijsman argues that a simple information-processing orientation is sufficient to understand such behavior. We engage in range seeking because the "cognitive usefulness" (in Rijsman's terms) of such information is maximal--i.e., we seek to know the range in order to obtain the most valid information available. Knowing about the endpoints of an ordered distribution conveys important knowledge about all the other members of the distribution. By obtaining endpoint information, the category is determined. No other stimuli in the range provide as much information. As such, range seeking is a reasonable strategy when attempting to categorize a distribution.

With such information in hand, the task becomes one of subcategorization, and in this context (i.e., the general category having been established), similarity information becomes very instructive. According to Rijsman, we need not appeal to social motives (e.g., self-evaluation) to explain this sequence of choice events. Parsimony argues for a nonsocial, information-processing interpretation. Generalizing these observations to situations involving human comparison objects calls into question a central assumption of social comparison theory: that we seek similar others with whom to compare in order to validate a belief or evaluate an ability or skill.

A proponent of social comparison theory would not be inclined to accept Rijsman's logic. One could argue that the Syroit et al. investigation was not an appropriate test of Festinger's theory. It is not logically sufficient to conclude that we do not compare with others simply because subjects in a nonsocial comparison setting chose similarity information only if end-point information had been made previously available. A better test would have included both social and nonsocial choice contexts, crossed with the range manipulation described earlier. In addition, motives for specific choices would have been determined. If results similar to those encountered were found, and the motivation data were nonsupportive too, then the theory would be on much thinner ice--but even then, the social comparison model could take refuge in the many past studies that did show preferences for comparison with similar others. To negate these earlier findings through the information processing explanation would necessitate postulating an ordered distribution of comparison stimuli in the earlier supportive studies, with established endpoints. In light of some of the research conducted over the past 35 years,

such a postulation process would require some exceptional assumptions.

The research cited here has left us with a series of questions at least as significant as those we faced before its initiation. However, the questions are different from those that gave rise to the research originally; they are more informed and more central, in my opinion, and the sequence in which a question stimulates research which gives rise to another, different, question, is the path of scientific progress. It seems evident on the basis of the research discussed here that people do seek to establish a range of possible options when faced with a choice, or when seeking to determine the quality of their own performance. It is also clear that once having established the range, they seek information about objects similar to that which they possess, or about the performance of others who are at levels similar to their own. Whether they seek this information for social, self-enhancing, or self-evaluating purposes, or merely to learn more about the choice distribution, and the consequent range of reasonable behaviors or decisions available, remains an open question. What is obvious, however, is that pure information seeking and social comparison as motives for information search are neither mutually exclusive nor mutually contradictory. Both processes could operate, conceivably in the same choice setting. It remains for the future to determine when, and if, and perhaps most importantly, why, such processes occur.

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7/22/87

Biological Sciences

WATER AND IONS IN BIOLOGICAL SYSTEMS--THE FOURTH INTERNATIONAL CONFERENCE

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Introduction

The Fourth International Conference on
Water and Ions in Biological Systems was
held in Bucharest, Rumania, from 22
through 28 May 1987. The conference was
jointly sponsored by the United Nations
Education, Scientific and Cultural Organ-
ization (UNESCO), the Academy of Medical
Sciences of Rumania, the Union of the
Societies for Medical Sciences in the
Socialist Republic of Rumania, and the
Rumanian Biophysical Society--all in co-
operation with the International Union
for Pure and Applied Biophysics. There
were 448 participants at the meeting re-
presenting seven West European countries
as well as the UK, US, Japan, Israel,
and India. In addition, the attendance of
scientists from the USSR, and East Euro-
pean countries was very high (80 percent
of the total attendance). This skewed
distribution was surprising since I have
attended conferences in other East Euro-
pean countries (e.g., Czechoslovakia and
Hungary) where the maximum participation
of East European scientists was 35 per-
cent of the total attendance.

The conference format consisted of
plenary lectures, eight symposia ses-
sions, and 107 poster presentations. The

symposia and related posters covered the
following topics:

- Water, ions, and macromolecules
- Relations between membrane structure
and transport
- Action of drugs, hormones on water,
and ion movements through membranes
- Physical techniques applied to the
study of water, and ions in biosystems
- Molecular aspects of water stress con-
ditions
- State and dynamics of water and ions
in biological systems
- Role of divalent cations in biological
systems
- Water and ions at membrane surfaces
- Water and ions in pathology.

Because of the large number of pres-
entations at this conference, it is not
possible to present a detailed review of
the entire conference in this relatively
short report. Therefore, summaries of
only selected topics emphasizing research
by European scientists are given.

A plenary lecture dealing with pro-
tein molecules in aqueous solution viewed
by nuclear magnetic resonance (NMR) was
presented by K. Wüthrich (Institute for
Molecular Biology and Biophysics, Eid-
genössische Technische Hochschule [ETH],
Zürich, Switzerland). During the period
1979 to 1983, methods were developed for
the efficient, sequence-specific assign-
ment of the ^1H NMR spectra of proteins.
This procedure provides, for the first
time, a basis for the determination of
three-dimensional protein structures in
solution; i.e., it does not require crys-
tallization of the protein. Wüthrich and
his group have been leaders in this area
of research. One of the great advantages
of the NMR methods is that measurements
can easily be performed over a wide range
of solution conditions attained by varia-
tion of the temperature, the pH value,
and the ionic strength. Applications of
the methods so far include several small
globular proteins with a wide range of
different biological functions, as well
as polypeptide hormones studied in dif-
ferent noncrystalline environments. Wüth-
rich and his group analyzed Tendamistat,
made by Hoechst Co., West Germany. This
compound is used as an anti-inflammatory
agent. The NMR method gave the same re-
sults as obtained by x-ray crystallo-
graphy, indicating that the three-dimen-
sional structure was preserved in solu-
tion. These investigators have also used
the NMR method to study nonglobular pro-
teins such as glucagon.

Water and Ions at Membrane Surfaces

Water-mediated effects of polyethy-
lene glycol (PEG) on membrane structure

and fusion were discussed by K. Arnold (Karl-Marx University, Leipzig, and Humboldt University, Berlin, East Germany). PEG is a widely used agent for the artificial fusion of cells and it is used as a fractional precipitating agent for protein purification, isolation, and crystallization. Arnold and coworkers found that electrophoretic measurements on liposomes and erythrocytes in the presence of PEG demonstrated that PEG is excluded from the membrane surface. Therefore, they concluded that PEG exerts the fusogenic activity due to an indirect action on the membrane via the alteration of the physicochemical properties of water. PEG decreases the polarity of an aqueous phase and leads to a relatively high osmotic pressure. Arnold also discussed the following properties of membrane systems in the presence of PEG:

- Phospholipid hydration and hydration force in the lamellar phase studied by NMR
- Swelling properties of lamellar systems
- Chemical potentials of membrane components and alteration of the membrane stability due to the changed polarity of the aqueous phase
- Lateral arrangement of membrane components and lateral diffusion
- Ion-phospholipid interaction (NMR).

It was found that all of the PEG-induced effects could occur without any direct interaction between the polymer and the membrane.

Evidence for the propagation of an action potential by the endoplasmic reticulum was presented by J.M. Bassot (Laboratory of Bioluminescence, Gif-sur-Yvette, France). Bassot made use of bioluminescence for his studies, taking advantage of the fact that it is a natural intracellular probe of activity occurring in the system he used--i.e., that of elytra of scale-worms. Isolated elytra emit a flash when stimulated by an electric shock. With repeated stimulation, hundreds of flashes can be elicited which in a typical series exhibit large and progressive variations. The activity of individual microsources or photosomes was observed through a microscope and image intensifier. Sequential observation showed a progressive and basically intracellular recruitment that correlated with facilitation, so that the amount of light emitted during a flash was a function of the number of reactive photosomes.

Photosomes can be described, according to Bassot, as paracrystalline arrays of tubular endoplasmic reticulum (ER). Their membrane tubules, folded in a regular serpentine fashion, develop a

considerable membrane surface which separates an intracisternal compartment from the cytosol. They are known to contain a membrane photoprotein, polynoidin, which is specifically triggered by the superoxide ion. To characterize morphologically the coupled state of photosomes, which decouple within seconds at rest, Bassot and his group used a fast freeze fixation technique to compare stimulated and non-stimulated elytra. Upon stimulation, the elytral epithelium conducts an action potential which is $\text{Na}^+ - \text{Ca}^{2+}$ in the photogenic area, and Ca^{2+} is considered to trigger the reaction. However, according to Bassot, the observed morphological findings suggest that the excitation-bioluminescence coupling process involves an intracellular pathway precisely represented by the ER junctional complexes.

In order to obtain further evidence of this internal conduction, Bassot and his group recorded the electrical activity of flashing elytra with suction electrodes. In response to stimulation, two types of action potentials occurred simultaneously, a monophasic and a biphasic response. The results showed that monophasic potentials can be considered as the epithelial potential spreading over the plasma membrane, and biphasic potentials as the internal potential following the pathway of ER and increasing with the increasing network of coupled photosomes. It thus appears that a signal can be transmitted from the plasma membrane to the ER membranes at the level of the dyad junctions and propagated via the intermediate ER to the photosomes where it triggers the luminous reaction. According to Bassot, these findings imply the existence of specific ER channels and ion exchanges between the intracisternal compartment and the cytosol. The fast differentiation and the short lifetime of the conducting ER constituting the junctional complexes act as a short-term memory in preparing an improved response to a possible further stimulation.

Studies on the effect of microviscosity on proton transfer at the phospholipid-water interface was presented by M. Gutman (Department of Biochemistry, Tel-Aviv University, Israel). The hydrated proton is the smallest probe which can dynamically gauge the biomembrane-water interface, according to Gutman. Proton transfer reactions are diffusion-controlled and sensitive to the medium properties. Gutman stated that fast measurements of these reactions reveal the properties of the microenvironment with spatial resolution related to the temporal one.

Gutman and his group used the laser-induced proton pulse for probing the membrane surface. Apparently, this technique

can resolve the proton diffusion and determine the second-order rate constants of the reaction. By this method, these investigators analyzed the concerted mechanism of proton transfer between bulk and surface groups. This process is dominated by proton exchange among surface groups and between mobile proton carriers and the surface. In the present study, Gutman and coworkers used the above system to evaluate the role of viscosity on diffusion at the interface. Both sucrose and dextrans were used to adjust the viscosity of the solution. Sucrose slows down proton transfer reactions, while dextran 70 was found to hardly affect these rates. Thus, the macroscopic viscosity appears not to be directly related to the rate constants of diffusion-controlled reactions. Furthermore, the effect of sucrose on the limiting conductivity of HCl is smaller than its effect on the diffusion-controlled rate constants of protonation of anions. In a similar way, Gutman and his group monitored the effect of various viscosity-increasing agents on proton diffusion limited to the interface of phospholipid membranes or proteins.

Studies on the effect of the state of hydration and hydrogen bonding on phospholipid bilayers was reported by A. Watts (Department of Biochemistry, University of Oxford, UK). According to Watts, the state of the phospholipid bilayer hydration depends upon the ionization state of the lipid head group. He and his group have investigated two such phospholipids in detail. For one, phosphatidyl glycerol (PG), of the phosphate group, has been titrated, and, for the other, phosphatidyl ethanolamine (PE), the amino group, has been titrated. For PG gel phase layers, x-ray diffraction studies have shown that the limiting hydration level changes from 22 to 63 when the phosphate is titrated from the protonated to the deprotonated form. In addition, the bilayer thickness increases from 5.5 nm to 3.9 nm and the acyl chains change from an essentially untilted to a markedly tilted orientation at about 47 degrees with respect to the normal bilayer. Electron microscopic investigation showed that these bilayers have very different surface structure depending upon the temperature and the ionization state of the PG bilayers, with ripples and undulations at high pH and smooth surfaces at low pH. For PE bilayers, ^2H -NMR measurements of the quadrupole splittings of the labeled polarhead group revealed, in a nonperturbing and direct way, that the pK_a of the amino group is about 9.6 when mixed in an equimolar ratio with PC. However, PC does not perturb the structure of the ethanolamine lipid--most probably

due, according to Watts, to the rather strong hydrogen bonds between adjacent lipids. On the other hand, hydrogen bond formation with other lipid types, such as PC, is mediated through water, as suggested by x-ray crystal studies. This implies, as stated by Watts, that PE molecules prefer to be adjacent to other PE rather than other lipid types. It is clear from these studies that lipid-lipid and lipid-protein interactions can significantly alter membrane surface structure through electrostatic and hydration-level changes.

Relations Between Membrane Structure and Transport

Because of its availability and simple structure, lacking internal membranes, the red blood cell (RBC) is ideally suited for studying water permeability. In principle, water can cross the RBC membrane by two pathways: by diffusion through the lipid layer and by permeation through aqueous channels in membrane proteins. Studies to evaluate each pathway were carried out by G. Benga (Department of Cell Biology, Medical and Pharmaceutical Institute, Cluj-Napoca, Rumania). Benga and his group performed a variety of investigations using nuclear magnetic resonance (NMR) spectroscopy, biochemical manipulations of membrane structure, radioisotope labeling, and electron microscopy.

An NMR method was used to measure the water diffusion through the human RBC membrane. In addition, Benga and coworkers carried out systematic studies of a variety of reagents and chemical manipulations of the RBC membrane on water diffusion. Mercury-containing sulphydryl group (SH) reagents were the only reagents which significantly inhibited the water diffusion. The fact that mercurials appeared to specifically inhibit water diffusion was used in experiments aimed at associating water channels with specific membrane proteins using ^{203}Hg -p-chloromercuribenzenesulfonate (PCMBS). It was found that under conditions of maximal inhibition of water diffusion, together with minimal PCMBS binding to the membrane, and taking precautions to block the nonspecific sulphydryl groups by N-ethylmaleimide, the mercurial binds to band 3 and band 4.5. This strongly points, according to Benga, to proteins in these bands to be associated with water channels in erythrocytes. Freeze-fracture and scanning electron microscopic studies indicated that major morphological changes do not take place in RBC membranes after treatment with SH reagents, including PCMBS. Benga stated that the significance of his studies for human pathology and the usefulness of the NMR

method for measuring water permeability in clinical laboratories is documented by recent findings of a decreased water permeability of RBC's in Duchenne muscular dystrophy subjects.

A study on the action of diamines on the bacterial rhodopsin pump was given by L. Keszthelyi (Institute of Biophysics, Szeged, Hungary). It is well established that bacteriorhodopsin (bR) molecules in *Halobacterium halobium* pump protons under light irradiation from the inside to the outside of the cells. The proton translocation activity is preserved in purple membranes (pm-s) isolated from the bacteria. The flash-induced electric signals recorded in oriented pm-s correspond to the motion of charges inside the bR molecules. The first very fast components and the second microsecond component of the electric signal are negative (related to the direction of proton pumping), according to Keszthelyi, and are followed by three positive components of different lifetimes. The sum of the areas under the electric signal is not zero but a positive value. Keszthelyi said that this fact is considered as a direct demonstration of a net charge translocation, though the positive area of the electric signal corresponds to a forward moving-positive charge (a proton which is generally accepted as that pumped on by bR).

Keszthelyi and his group found that diamines added to a solution containing bR can transform the positive integrated area of the electric signals into a negative value which they interpret as a reversal of the direction of the proton pump. A more detailed investigation of the effect of N.N.N'.N.'-tetramethylethylenediamine (TEMED) revealed several important features--the reversal:

- Can essentially be complete under certain conditions
- Is concentration dependent
- Can be abolished by adding calcium chloride or sodium chloride to the solution.

Keszthelyi said that the data showed that the charge states of some groups near to the surface of pm-s (probably carboxyl groups) can also be modified by the simple, reversible adherence of diamines.

Action of Drugs and Hormones on Water and Ion Movements Through Membranes

The action of local anesthetics on model lipid membranes was studied by G.E. Fedorov (M.V. Lomonosov State University, Faculty of Biology, Moscow, USSR). Fedorov and his group investigated the effects of local anesthetic substances

on the electric properties of bilayer lipid membranes (BLM). They measured, simultaneously, conductivity of BLM at constant current, the electrical capacity of the substances and the transversal Young module (E_t) and the difference of surface voltage. The electrochemical stabilities of the BLM were also estimated. Fedorov and coworkers found that trimecaine, tetracacaine, and nupercaine increased the conductivity of bilayers from egg yolk phosphatidyl choline--gradually at first and then by causing the appearance of current fluctuations. Benzocaine and procaine caused a slight increase of BLM conductivity and did not cause a current response up to a level of 30 mM. They established the correlation of the effects of local anesthetics on the electric responses of BLM with the pH of the medium in the range of 5 to 10 pH. It was shown that the efficacy of the anesthetics' effects is determined by their neutral forms. According to the data obtained, it appears that local anesthetics display protonophoric activity and do not induce the K-selectivity in the BLM.

The action of channel modulating drugs on lymphocyte membranes was studied by J.M. Witkowski (Department of Histology, Medical Academy, Gdansk, Poland) in collaboration with H.S. Micklem (Department of Zoology, University of Edinburgh, UK). The importance of ion fluxes across the membrane for adequate activation of mammalian lymphocytes has been established for some time. The membrane (Na^+ , K^+)-ATPase and different kinds of ion channels clearly participate in early stages of activation of these cells during the immune response. Molecules responsible for cation transfer across the membrane (especially ion channels for Na^+ , K^+ and Ca^{2+} ions) appear on the surface of individual lymphocytes in minute quantities which render them prone to the deteriorating effects of aging, illness, and negative environmental factors, according to Witkowski.

The aim of Witkowski's study was to correlate decreased function of immune cells in aged individuals with the activities of ion-transporting membrane systems and their susceptibility to modulators. Transmembrane potential (TMP) of resting and mitogen-stimulated lymphocytes were examined by means of flow cytometry and microfluorimetry using cyanine and oxonol dyes as potential-sensitive probes. The rate of K^+ ion efflux from concanavalin (Con A)-stimulated cells was estimated with an ion-selective electrode. Different modulators of ion channels (saxitoxin, verapamil, tetraethy' ammonium (TEA) and veratridine) were assayed for their influence on immune

functions and lymphocyte membrane electric properties. Profound differences between young and old cells were found: the TMP of resting lymphocytes as well as the rate of K^+ efflux and the TMP changes in mitogen-activated cells decreased rapidly with advanced age. In the activated lymphocytes of young individuals there was a tendency to depolarize initially in response to a stimulant while old cells responded initially by hyperpolarization. Witkowski and his group found some differences in susceptibility to the action of TEA and veratridine between young and old cells suggesting, he said, the existence of differences in the numbers or activities of channels modulated by these drugs on the surface of lymphocytes. He suggested that the lack of early depolarization of lymphocytes of old animals in response to Con A stimulation might be due to an impairment (either qualitative or quantitative in nature) of the membrane mitogen-regulated Na^+ channels in these cells. These investigators are now carrying out a detailed examination of the properties of the membrane channels of lymphocytes as a function of age using the voltage patch clamp technique.

Role of Divalent Cations in Biological Systems

Studies of calcium-dependent inorganic ion and water changes in human platelets were presented by A. Ludany (Department of Clinical Chemistry, University Medical School, Pecs, Hungary) in collaboration with C.F. Hazelwood (Department of Physiology and Molecular Biophysics, Baylor College of Medicine, Houston, Texas). Although it is well known that calcium ions as ubiquitously important regulators are involved in a wide variety of cellular processes, our knowledge is still far from being complete about calcium regulatory mechanisms. Ludany and Hazelwood decided to use human platelets separated from blood as models for *in vitro* studies of the role of Ca and polymerizable proteins in the regulation of the ionic environment and water structures in living systems. The basis for this model was the following: platelets are enucleated cytoplasmic fragments in the circulation enriched with proteins capable of polymerization. These proteins, which may build up the cytoskeleton of the platelets, dynamically change their state of polymerization and association to other molecules upon activation. The degree of polymerization of the cytoskeletal proteins and their association to other molecules are both directly and indirectly regulated by Ca^{2+} during activation.

Human platelets were used in the studies carried out by these investiga-

tors. The fresh platelet samples were obtained from healthy, normal blood donors. At the beginning of the experiments, the platelets were washed with a Hanks solution containing 13 mM Na citrate. Aliquots of the washed platelets were resuspended and incubated at 37°C in modified Hanks solutions with or without Ca^{2+} or Mg^{2+} or both. After different incubation periods, the K^+ , Na^+ , Ca^{2+} and Mg^{2+} contents of platelets pelleted by centrifugation at 40,000 g were measured. The water contents were also determined, and the relaxation times on the basis of a water proton NMR technique were studied as well. The highest K^+ and Ca^{2+} levels were found in platelets incubated in citrate-containing medium. When free Ca^{2+} ions at mM concentration were present in the media, an increased K^+ and Ca^{2+} release was observed parallel with a significant increase in the water contents. The K^+ and Ca^{2+} mobilizing effect of Ca^{2+} was accelerated when thrombin was added to the incubation medium. The T_1 relaxation times were the shortest in the citrate-treated samples and longest in the thrombin plus Ca^{2+} -activated samples. Without thrombin, the platelets incubated for 2 to 4 hours in the presence of Ca^{2+} had intermediate T_1 values. According to Ludany and Hazelwood, these experimental findings suggest that the reorganization of cytoskeletal structures during the "platelet activation" is connected to, or followed by significant changes in the intracellular ions and water structures as well.

Studies on the control of membrane permeability by extracellular divalent cations and pH were presented by C.A. Pasternak (Department of Biochemistry, St. George's Hospital Medical School, London, UK). Ions and other low molecular weight compounds leak across biological membranes: (1) if specific protein channels such as those for H^+ , Na^+ , K^+ , Ca^{2+} or Cl^-/HCO^- are present and (2) if the membrane is damaged by cytotoxic agents such as certain animal, bacterial, or plant toxins; certain viruses; the membrane attack complex of complement or endogenous cytolysins from eosinophils; or T lymphocytes. Pasternak and his group have shown that leakage induced by agents of category (2) can be prevented by divalent cations such as Ca^{2+} or Zn^{2+} , as well as by reducing the ionic strength of the suspending medium (Pasternak, 1987).

In this study, Pasternak assumed that the action of divalent cations is extracellular and that the effect of reducing ionic strength is to lower pH in the vicinity of the membrane. In his report, Pasternak presented evidence to substantiate both assumptions. There is, therefore, some overlap between the

control of permeability through channels of type (1) and that of lesions of type (2), according to Pasternak. Thus, communicating (gap) junctions which clearly fall into category (1) are nevertheless closed by Ca^{2+} or H^+ . Moreover, there is evidence that Na channels (category 1) can also be closed by Ca^{2+} . Despite such apparent similarities, Pasternak said that, in general, channels of type (1) have a quite different structure and function than do lesions of type (2). It is the latter type of lesion which exists to a greater or lesser extent in cells even in the absence of added agent, and it is its inhibition by divalent cations that lends credence to the long-felt view that Ca^{2+} and Zn^{2+} have a generally "membrane-protective" action on cells. Pasternak stated that by comparing the effects of Ca^{2+} , Zn^{2+} , H^+ and other cations on membrane permeability in simplified systems, it is now possible to delineate their protective role in greater detail than was previously possible.

Conclusion

Many of the presentations at this international conference, which dealt primarily with biophysical studies of the action of water and ions in biological systems, were given by scientists from East European countries. A few selected papers have been summarized in this report and indicate that, at least in this area, the East European scientists are carrying out research that compares favorably with studies reported by scientists from West European countries.

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7/24/87

Chemistry

XIII SANDBJERG MEETING ON ORGANIC ELECTROCHEMISTRY

by M. Inez Montenegro, Ph.D., Montenegro is an associate professor of chemistry at the University of Miami, Coral Gables, Florida.

The 13th Sandbjerg Meeting on Organic Electrochemistry was held at the

Sandbjerg Castle in Denmark from 12 through 15 June 1987 and followed the tradition of previous Sandbjerg Meetings organized by Professor Henning Lund from Aarhus University, Denmark. The purpose of these meetings is to gather a group consisting of a mixture of young and more experienced scientists to discuss various topics of organic electrochemistry and to stimulate international cooperation within the field. About 50 scientists from 12 countries attended this meeting whose program consisted of five main lectures and 26 short contributions.

The Plenary Lectures

The first plenary lecture, delivered by Professor H. Shine from Texas Tech University, Lubbock, Texas, gave an excellent account of reactions induced by electron transfer to cation radicals. While reactions of cation radicals with nucleophiles, although they can be quite complex, are fairly well known, the coupling of radicals with cation radicals is not at all well known, the reason for this being that generating neutral radicals in the presence of cation radicals can be a difficult task. Here, the aim was to generate radicals photolytically in the presence of the thianthrene radical. Several examples of electron-induced cycloaddition reactions brought about by Th^+ , and also Ar_3N^+ were presented. Reactions of Th^+ with Grignard reagents were also discussed, and it does appear that coupling of a cation radical and a radical does occur.

A very stimulating presentation was given by Professor V. Parker (University of Trondheim, Norway) on the application of several electrochemical techniques used in physical organic chemistry to obtain thermodynamic information, equilibrium constants, and kinetic data of fast reactions. Methods such as derivative cyclic voltammetry and double potential step were applied to the study of fast reactions between cation radicals and nucleophiles and the proton transfer reactions between methylene cation radicals and nitrogen bases. Thermodynamic cycles requiring only electrode potential measurements were developed to determine the relative basicity of anion radicals and dianions, as well as the relative electrophilicity of cation radicals and dications of organic compounds. Some interesting examples of the application of electrochemical methods for the study of mechanisms of reactions of organo-transition-metal compounds in unstable oxidation states were also described.

The paper on electrosorption and heterogeneous electrocatalysis in electro-organic reactions was given by Professor H. Wendt from the Institut F.

Chem. Technologie, Darmstadt, West Germany. After an introduction emphasizing the lack of selectivity in most organic electrosyntheses, Wendt demonstrated the most important principles of heterogeneously catalyzed chemical consecutive steps in organic electrosynthesis by exemplifying them with anodic oxidations of vinyl compounds to yield dimeric and monomeric diethers, cathodic reduction of pyridylketones, and scavenging of anodically generated azide radicals by olefins.

The lecture by Professor J. Simonet from the University of Rennes, France, was devoted to recent studies on the electrochemical behavior of sulphones. The cathodic reduction of sulphones corresponds, generally, to a cleavage obeying an ECE-type process where the rate-determining step is the scission of the unstable anion radical resulting from the first charge transfer. However, some other reactions may be observed and a good selection of examples was provided.

The last plenary talk, given by Professor E. Steckhan from the University of Bonn, West Germany, reviewed progress in the exciting field of indirect electrochemical oxidations and their application to selective deblocking of protecting groups. Indirect electrochemical processes offer the following advantages over direct processes:

- Electrode passivation can be avoided
- Overpotentials can be eliminated
- Redox catalysts can be used, and these have considerably lower potentials than those that have to be applied for the direct electrochemical transformation of the substrates
- Selectivities can be enhanced.

Organic redox catalysts can act in three major ways: as hydrogen atom abstracting agents, as hydride atom abstracting agents, and as electron transfer agents. Steckhan's talk was mainly devoted to the application of these methods to deprotection reaction in peptide synthesis and clearly demonstrated the strong potentialities of electrochemical methods in this area of chemistry.

Other Presentations

The short contributions (limited to about 15 minutes) were delivered by a number of internationally known specialists. Following are some highlights from those presentations which reflected the most recent research topics in the field.

The advantages of indirect electrolysis were considered in the oxidation of O-nitrophenylsulfenamides to O-nitrophenylsulfenimines. Direct oxidation fails since it leads to cleavage of the sub-

strate whereas indirect electrolysis was successful. Another contribution described the indirect electrochemical reduction of vinyl and cyclopropyl halides.

A number of presentations were devoted to new electrode materials for organic electrosynthesis. The use of $\text{Ti}/\text{Cr}_2\text{O}_3$, TiO_2 -anode was used to oxidize alcohols, ethers, and ethylbenzene in acid solutions and the Ti/TiO_2 -cathode was developed to reduce nitrobenzene and ketones. The nickel hydroxide electrode was applied to the oxidation of p-lactones, which are converted to oxocarboxylic acids with excellent yields. With this electrode the oxidation proceeds, most probably, via an indirect heterogeneous anodic dehydrogenation accompanied by the reduction of the nickel oxide hydroxide covering the electrode. The reactivity of this electrode seems to be very similar to that of the chemical oxidant nickel peroxide. The problem of reproducible enantioselective conversions at chiral modified electrodes was also presented.

Some contributions were devoted to new electrolysis cells and reactors for organic electrosynthesis.

An interesting contribution addressed the importance of electrochemical cleavages applied to biomass-derived compounds. The cleavage of the C-O bond is the most important feature of reactions used to transform lignocellulosic biomass. This can be achieved by anodic oxidation and cathodic reduction, and thus electrochemical methods have been applied to the useful conversion of compounds readily available from lignin and from cellulose. Details were given on the possibilities for electrochemical replacement of the conventional oxidative degradation of lignins.

A contribution of importance to the electrochemical cleavage of protecting groups dealt with the electro-reduction of organic compounds activated by complexation with chromium tricarbonyl. The $\text{Cr}(\text{CO})_3$ group is electron withdrawing and can activate compounds normally difficult to reduce; mild conditions for cathodic cleavage are especially important if the reaction is to be used for protective group removal.

An important topic dealing with kinetic studies included the use of electrochemical methods for the determination of rate constants of homogeneous electron transfer followed by elimination induced by the substrate anion. The use of the linear sweep voltammetry technique and simulated curves allowed the determination of the rate constants. The synthesis of asymmetrical biaryls was considered, the mechanism discussed, and the rate constants calculated. The cathodic

reduction of anthraquinone to anthrone was also presented.

Some communications discussed mechanistic aspects of reactions involving anion radicals such as those related to their protonation in aprotic solvents and dimerizations.

Another interesting topic related to lanthanide-ion-assisted electrochemical aldol condensations. The electrochemical reduction of alpha-bromo ketons in tetrahydrofuran in the presence of added aldehydes affords aldols in very low yield; however, the presence of lanthanide salts in the reaction medium lead to the formation of aldol condensation products in excellent yields. This was a good model system for studying the effects of metal ions upon the electrochemical behavior of organic substrates.

Some researchers debated other relevant topics including electro-oxidation of oximes and furoxanes, electroreduction of dithiopivalates and thiopivalanilides in the presence of arylating agents, electrochemical studies of β -lactams, intramolecular addition of Kolbe radicals, electrochemical reactions via quinonemethides, and others.

Conclusion

This was a successful meeting with many valuable contributions by both experienced and younger scientists predicting a promising future for organic electrochemistry. The sessions were held during the mornings and evenings, leaving the afternoons free for many informal discussions, which are the heart of these meetings. Each main lecture lasted about an hour, and the authors of the short presentations were allowed about 15 minutes. The discussions following every talk were always lively, friendly, and stimulating. It is regrettable, however, that industry was not well represented. An important target for these meetings would be to bring scientists and industrialists together for productive collaboration in order to direct research in organic electrochemistry to the industry.

The standard of all the contributions was unquestionably high, and it is always rewarding to participate in meetings where, under informal conditions, so much can be stated about progress in the field of organic electrochemistry.

Computer Sciences

CONTROL RESEARCH AT NORTHERN UNIVERSITIES IN ITALY

by Daniel J. Collins. Dr. Collins is the Liaison Scientist for Aeronautics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until June 1988 from the Naval Postgraduate School where he is a Professor of Aeronautical Engineering.

In order to characterize the work being accomplished in the controls area in Italy I recently visited three universities in northern Italy: Politecnico di Milano, the University of Firenze, and the University of Pisa. For some time there was not a doctorate degree in engineering in the Italian university system but 4 years ago an American-style doctorate was introduced. Graduates in the controls area with this degree will start to appear in the next couple of years. It will be interesting to see how these people are integrated into the overall research and development program for the nation. Control research in nonlinear and robotic controls in Italy which involved another three universities--these in southern Italy--is presented in the article following, page 16.

Politecnico di Milano

Professor G. Guardabassi, my host for the visit to Politecnico di Milano, is in the Electronics Department. The department activities include control theory and system theory, computer science, bioengineering, and environmental engineering. The department has 80 to 85 professors and 15 to 20 researchers who are working on the new doctorate degree.

Research funding is perhaps typical of that at a university in the US in that the percentage of outside research support is about 30 to 40 percent of the overall budget. The Italian Center for National Research (CNR) supplies about 25 to 30 percent of the support through a System Theory Research Center, which has been established in the department, while another 25 to 30 percent comes from the Ministry of Public Education. CNR has a strong interaction with the universities in Italy which in my opinion is very productive of high-quality research. Since outside research money cannot be used to expand the staff there is a tendency to increase class size (~150) to reduce the teaching load.

Computer facilities appear quite adequate. Most professors have, as in America, a personal computer or terminal on their desk. The department has about 45 IBM AT's, two Vax 750's, a Vax 780 for students, and two microvax computers. There will be, shortly, a room with 60 personal computers for students. The central computer facility has large Univax and IBM computers. Curiously enough there does not appear to be much software developed for student use in solving problems.

There are three general areas of research in the department:

- Periodic control
- Decentralized control
- Industrial process control.

The first two areas are theoretical in nature, and process control is mostly industrial and applications oriented. There is also some interesting controls research being conducted in bioengineering.

Periodic control. Periodic control has been a central problem of investigation for over 15 years in the department. An excellent review of the department's activities in optimal periodic control (OPC) is contained in a paper by Bittanti and Guardabassi (1986). The basic OPC problem may be formulated in the following manner:

Given a system

$$\dot{x}(t) = f(x(t), u(t))$$

where x is the state, t time, and $u(t)$ the control and an instantaneous performance index $g(x, u)$. Find a period T and a control u over the interval $[0, T]$ such that

$$J = \frac{1}{T} \int_0^T g(x(t), u(t)) dt$$

is maximized subject to the the periodicity constraint that

$$x(T) = x(0)$$

The previous development might be termed the basic OPC problem. There are many extensions and elaborations to this problem. The main issues that Guardabassi and his colleagues have investigated are necessary and sufficient optimality conditions, quasi-stationary and high-frequency periodic control, proper periodicity, structural properties of linear periodic systems, and periodic solutions to the Riccati equation.

Decentralized control. Control methods developed in this area have some application to power systems. A recent paper on a robust decentralized regulator

(Guardabassi et al., 1986) deals with the existence and characterization of the local structures of the regulator. The design of the regulator can be conveniently divided into three steps or subproblems. The first step is to develop the best information flow pattern among the different regulation subsystems. There must be some cost or constraint on each admissible connection in order for the problem to make sense, otherwise one would take as the optimal solution all possible connections. The second problem is that of selecting the local substructure--that is, each regulator subsystem. The subregulators must satisfy the so-called Internal Modeling Principle which involves the concept of a proper structure for the regulator. In an earlier referenced paper Guardabassi and colleagues considered the computer aided design of structurally constrained multivariable regulators and developed the concept of proper structure. A complete class of proper substructures can be obtained from a suitable parameterizing of all possible input-output relations. This class includes all possible solutions of interest in the problem at hand. The final subproblem is to tune the given structure. This tuning or initialization problem is essentially a computational problem, and programs exist for improvement of given asymptotical stable solutions.

Further theoretical work is being done by R. Scattolli in the area of multivariable self-tuning controllers with integral action. This latter work was conceived when the author was working at Oxford University in England.

Industrial Process Control. Industrial process control covers a variety of areas, and there is support at the Politecnico from several Italian companies such as Montedison ENEL (Italian Electric Board), Riva Calizoni, FIAR, and Agusta.

Professor C. Maffezzoni has developed a large modular computer code, called LEGO, which he has used in problems associated with energy conversion. Maffezzoni has several publications on the modeling and control of electric power plants, on the speed control of hydro stations, on the optimal control of a drum boiler power plant, and on the integrated design of high-temperature solar receivers. The LEGO code is quite versatile and is presently being applied to modeling in robotics.

Maffezzoni's present work is thus directed at modeling and simulation of nonlinear systems. He is also interested in reduced order modeling and digital saturation effects. Further work in process control is indicated in a recent

article by Guardabassi on output linearizable models and the nonlinear control of a distillation column. This last work considers the case of a given nonlinear dynamical system which is linearized by means of a suitable feedback.

Controls in Bioengineering. I had an opportunity to talk with some of the people concerned with bioengineering (which has 100 students and eight professors) where I found some innovative applications of control theory to biological systems and complex signal processing. Professor M. L. Maranzana Figini has considered the neuromuscular system as a dynamic stochastic system and the electromyographic signal (EMG) as the output of the system. The EMG samples are described by means of an autoregressive model (AR) both in the case of simulated and pathological signals obtained by concentrated probes. From the AR model the discrete transfer function was obtained and the value of the poles in the z plane were calculated. For simulated signals the location of the poles were indicative of pathological conditions. Complication in clinical EMG resulted in only slight indications of pathology but it was felt that the pole description offered an efficient procedure for data compression of neuromuscular systems. Figini said she follows closely the work of C.J. De Luca (Boston Childrens Hospital and Harvard), who does similar work in the US.

Recent work by Figini has involved multivariate analysis of electromyographic variables, and she is thinking of analyzing the effect of combining sonic probes with electro sensing of muscle signals, particularly with respect to fatigue. Figini's activities in modeling of neuromuscular diseases has been summarized (Figini 1986).

Professor S. Cerutti, a member of the CNR System Theory Research Center, is using Wiener filtering and Kalman filter techniques to analyze electrocardiograph (ECG) and electroencephalograph (EEG) signals. In a typical recent publication (G. Baselli et al., 1986) Cerutti worked with medical teams actively concerned with physiological signals. He developed a parametric method for autoregressive and auto- and cross-spectral analysis for the processing of heart rate and arterial blood-pressure variability signals. The purpose of the study was to develop better diagnostic techniques for hypertension and other heart pathologies.

In other publications Cerutti has reported on an optimal linear filter for the reduction of noise superimposed on an EEG signal, studies of the clinical relevance of the abdominal fetal electrocardiogram, and the use of Kalman filtering

and parametric identification in the classification of EEG during neurosurgery. Cerutti's most recent work has used Wiener filtering, applied to a small number of sweeps, on visual evoked potentials.

University of Firenze

Studies in control and system theory at Firenze are conducted in the Department of Systems and Information. Part of the department, which has 12 professors and 10 researchers, was formed from the previous mathematics institute at the university, and for this reason, there is strong emphasis on the mathematical aspects of control. In fact, the background of my host for the visit, Professor G. Stefani, is in mathematics. Stefani's recent work has been directed at the determination of the necessary conditions for local controllability of a scalar-input nonlinear control system (Stefani 1986). In the December 1986 Conference on Decision Control (CDC) conference in Athens, she extended this analysis to sufficient conditions for local controllability. Stefani is also concerned with geometrical methods and optimal methods in control theory.

Professor P. Nistri is also concerned with controllability, and he has studied topological methods for the global controllability of nonlinear systems. He has also developed sufficient conditions for local and global 1-controllability of nonlinear systems. Professor P. Zezza, who has just completed a year at the University of Alberta in Canada, has been working on fairly basic ideas from the calculus of variations and how these ideas can be extended into optimal control theory. Zezza has considered the conjugate point condition for smooth control sets and the connection with the necessary conditions for optimal control. Finally, in other activity in controls, Dr. S. Monico has reported on a sampled nonlinear controller for large-angle maneuvers of flexible spacecraft.

I also talked to Professor S. Marsili-Libelli, who is involved in process control. Marsili-Libelli also conducts a course in the use of microcomputers and PC's. He has an excellent PC laboratory and is in the process of writing a book on software for process control. His research interests are connected with environmental systems and water pollution, and one of his recent papers was in the 1987 *Advances in Biochemical Engineering*. In this paper Marsili-Libelli discusses the modeling, identification, and control of the activated sludge process. Essentially, he outlines the operational improvements that can be obtained in the wastewater treatment process by

means of dynamic modeling and the application of modern control theory. Another interesting result in other work has been his use of fuzzy sets in the assessment of crop growth and stress.

Since computer science in general is of great interest to me I also took the opportunity to talk to some of the researchers in that area. Dr. R. Pinzani is concerned with the management of large data bases with an emphasis on data base response time. Pinzani is beginning to consider the application of artificial intelligence or expert systems in computer problems. His colleague, Dr. E. Barucci, has developed a software development system based on a macroprocessor, a recognizer for finite languages, and index selection in a distributed data base. Data base systems and distributed microprocessors are the subject of research of others in the department.

University of Pisa

My visit to the University of Pisa was confined to Professor M. Innocenti, who is in the Aerospace Engineering Department and does research in controls. The Informatics and Systems Department as well as the Electrotechnic Institute are also doing research in the controls area at Pisa. Innocenti has spent some 7 years in the US and his research interests have a distinctly American flavor. Innocenti has published an article on analytical pilot modeling techniques to be used in display synthesis. (This is similar to the work of R. Hess at the University of California at Davis.) Innocenti's other main interest is in robustness and the characterization of the limits of reconfiguration algorithms with various damage mechanisms. Thus, given an actuator failure, he would like in his current research to describe the limits of performance with this failure in terms of the system singular values. He is also investigating the relationship of eigenvector assignment and the linear quadratic problem (LQP). In a recent publication (A. Balestrino and M. Innocenti 1986) Innocenti reports on the investigation of an adaptive inverse multimodel following control for a nonlinear plant. Innocenti's objective was to develop a variable-structure control law for a plant which was considered to be a bank-to-turn air-air missile. The control law is based on what is termed a hyperstable variable control structure developed by Professor A. Balestrino and his colleagues while he was at the University of Naples.

Conclusions

The controls research at the Politecnico di Milano is particularly strong.

The internal CNR laboratory complements the university research program. This combination of university and CNR laboratory appears to be particularly fruitful. The University of Firenze is especially strong in the mathematical aspects of nonlinear control. The control research that I reviewed at Pisa has a strong American slant. Control research in Italy is, indeed, very strong.

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7/20/87

A REVIEW OF NONLINEAR AND ROBOTIC CONTROL THEORY IN SOUTHERN ITALY

by Daniel J. Collins.

Control research is found normally in electronics departments, informatics, and system theory departments. In the case of the informatics and system departments there is a heavier emphasis on the mathematical foundations of control theory than on the practical application of control theory. In order to characterize the work being accomplished in the controls area in Italy, I visited three universities in southern Italy--the two universities of Rome and the University

of Naples. There are three other universities capable of good work in the area of controls in Italy which I also visited. These are discussed in the preceding article, page 13.

University of Rome "La Sapienza"

The Engineering School of the University of Rome "La Sapienza" has about 12,000 students, and graduates about 900 a year. My host for the visit was Professor A. Isidori of the Department of Information and Systems. Currently, Isidori is also the director of a national program initiated by Centro Nazionale di Ricerca (CNR) that involves eight universities in nonlinear system theory. Isidori, who is an international authority on nonlinear system theory, has spent some time as a visiting professor at Arizona State University, which has an interdisciplinary center for systems research. The department of Information and Systems has 20 professors and about 150 students who are equally split between computer science and system theory. The department research interests are in nonlinear system theory, industrial control, and control of robots. Other research in the department is in the area of informatics, operation analysis, and bioengineering. Several American professors (from California, Arizona and Harvard) have also recently spent time at the University of Rome.

Nonlinear System Theory. Isidori has written a well-received book on nonlinear control systems. One of the more interesting recent results in nonlinear system theory (Isidori and Moog, 1986) has been Isidori's work on the nonlinear equivalent of the notion of transmission zeros which clarified some aspects in the linearization of square nonlinear systems by appropriate feedback. Isidori has shown that the characterization of "transmission zero" for a nonlinear system can involve three different concepts, namely, a "pole" of the inverse system, zero output constrained dynamics, and unobservable dynamics under certain state-feedback. His other recent work has been the design of a nonlinear feedback control law for the attitude control of a rigid satellite and the matching of nonlinear models via dynamic state-feedback. The solvability of model matching depends on or is related to the so-called "structures at infinity" of the system and of the model. Finally, Isidori has published an interesting survey article which contains some recent results on the control of nonlinear systems by means of dynamic state-feedback.

Control of Robots. The robotics group consists of Professor A. De Luca and Professor F. Nicolò, who is head of

the department. The robotics laboratory consists of several robots which are presently being programmed on an IBM-AT in order to obtain flexibility in changing control algorithms. Development of new robotic systems with multimicroprocessors involving constrained trajectories and associated optimization techniques is planned. Theoretical and hardware aspects of the robotic control are being addressed in a cooperative program with other institutes, among which is the second University of Rome (see below). Emphasis is on robotic arms with elastic or flexible joints, and control by means of nonlinear dynamic feedback (De Luca et al., 1985). A further paper by the same authors is concerned with nonlinear model matching in the dynamic control of a flexible robot. The nonlinear techniques developed by Isidori find a natural application in the field of robotics and are being applied in the control algorithms.

Industrial Control. The industrial control area is concerned with factory automatization and the application of microprocessors to that automatization. Some aspects of flexible manufacturing are also involved. Much of the work in this area is in the development of software--for example, in the manufacturing of parts. Complete equipment is available to design a part on a computer and then have a computer-directed machine manufacture the part. In fact, part of the educational system in the department consists of student laboratories directed at such activity. The automatic manufacturing equipment of the laboratory is impressive, for a university.

University of Rome "Tor Vergata"

The second university of Rome, which was created 3 or 4 years ago, is located on a modern campus somewhat out of the center of the city. The present student population is 5000 but this is expected to increase greatly. The research program in controls in the electronics department is similar to that at "La Sapienza".

Electronic Engineering Department. Professor R. Marino of the Electronic Engineering Department, my host, was recently a visiting professor at the University of Illinois. Examples of his current research interests in nonlinear control and singular perturbation were presented at the recent Conference on Decision and Control (CDC) in Athens in December 1986 (see ESN 41-9:488-492 [1987]). He used nonlinear geometric techniques and singular perturbation methods (Marino, 1986) to design a high-gain stabilizing control for a single-input nonlinear system. In another recent result, Marino applied center manifold

theory to singularly perturbed systems. This geometric approach developed a composite control for a two-time scale system. Under certain conditions the asymptotic properties of the singularly perturbed control system can be related to a reduced-order control system. Marino has done further work on feedback linearization in direct drive robotics with switched reluctance.

Much of the other research activity in the controls area in the department is directed at flexible or elastic robots. I talked with Dr. P. Tomei, who, along with Professor S. Nicosia, is actively involved in the development of a robotics laboratory and a new robotics course. The laboratory has two small robots controlled by an IBM-AT and a 32-bit microprocessor. Research is directed at the application of adaptive control and model reference methods to global strategy and trajectory control of robots. Current research has considered adaptive control for flexible robots, dynamic modeling of flexible manipulators, a discrete time model reference adaptive system for industrial robots, and pseudo-linearization techniques in feedback control of elastic robots.

University of Naples

The University of Naples has perhaps 100,000 students, of whom about 10,000 are in engineering. Dr. B. Siciliano, my host at the Department of Information and Systems, recently finished a year as a visiting scholar at Georgia Institute of Technology. His thesis research, completed in 1986, deals with the kinematic inversion of a robot manipulator. If one is given a final position and orientation of a robot, the problem is to calculate all the possible methods of achieving this final position and orientation. The trajectories may also be constrained in some manner such as by intervening obstacles. Siciliano developed a new algorithm which he feels is quicker and more efficient. Department research activity is divided into two groups: a robotic control group and a group referred to as the systems application group.

Robotics Group. The robotic group was founded in 1980, and Siciliano joined it in 1982 after he obtained his first degree. The head of the group is Professor L. Sciavicco; other members of the group are Professors G. De Maria and P. Marino. Although the work of the group has been primarily theoretical, they have started a robotics laboratory in order to test some of their theories. They are also working closely with groups in Rome and have contacts with the European Space Research and Technology Center (ESA) in the Netherlands. A recent further devel-

opment has been the creation of a new institute called CRIAI, which is funded by the Council for Southern Italy and also has support from industrial companies such as AERITALIA and FINSIEL. CRIAI has about 60 people divided into three groups in the area of robotics and automation. The groups include industrial automation, software engineering, and computer vision. CRIAI is working closely with the university and industry. The institute already has extensive equipment and CAD/CAM work stations. This type of institutional setup, particularly with CNR laboratories, is very common in Italy and in my opinion leads to very productive research.

Work by the robotics group has included an adaptive model following control for robotic manipulators, symbolic modeling and dynamic analysis of flexible manipulators, and robust control of industrial robots. One of the more recent publications (Sciavicco and Siciliano, 1986) with references to earlier work considers the problem of coordinate transformations from the work space coordinates to the corresponding joint coordinates. The inverse kinematic problem is solved for robotic manipulators whose three end effector revolute joint axes intersect two-by-two. The application of an integral manifold approach to control of a one-link flexible arm was recently reported at the CDC meeting in Athens (referenced above).

Systems Application Group. The systems application group consists of Professors F. Garofalo, G. Ambrosino, and G. Celentano. I talked to Professor F. Garofalo, who has done some innovative applications of control theory to nuclear fusion. Garofalo will be visiting the University of California at Berkeley for about an 8-month stay beginning in summer 1987. He plans to study the control of uncertain dynamical systems with parameter variations within a fixed region but with uncertain statistics. While working in Munich with the European project on nuclear fusion, Garofalo was concerned with the application of modern control theory to the stabilization of a vertical plasma column in a tokamak both in the vertical and horizontal direction. With his colleagues in Naples he has published an article on the design of the controller.

For the past 2 years the group has been concerned with another project on the positioning of ships by cable in the ocean. Accurate laying of pipeline from a large barge involves dynamic mooring with complex anchoring positioning. Reports on this activity were given in July 1987 at the International Federation of Automatic Control (IFAC) Conference in

Munich and at the ship control symposium in October in The Hague, Netherlands. Other work by the group includes the study of nonlinear systems with discontinuous control laws by means of a model-following controller with a view of eliminating undesirable chattering of the control signal. Finally, a dynamic control scheme capable of rejecting polynomial disturbances in a single-input single-output unknown plant was developed (Ambrosino et al., 1986) and applied to process control where the plant may be poorly understood.

Conclusion

Control research in Italy is of a very high order. There is special emphasis on nonlinear control systems and on robotic control. There is strong interaction with American scientists both from their visits to Italy and in sabbaticals spent in America by Italian scientists.

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Electronics

OPTOELECTRONICS AT UNIVERSITY COLLEGE, LONDON

by J.F. Blackburn. Dr. Blackburn is the London representative of the Commerce Department for industrial assessment in computer science and telecommunications.

Introduction

Because of the superior transmission characteristics of optical fiber it is rapidly displacing metal cable for transmission in the world's communication systems. Research is underway in many laboratories on photonic switching, and there is serious work directed toward all-optical computers (ESN 40-10:338-341).

Professor John E. Midwinter, University College London, has taken as a prime objective over the past several years the development of a technology that will allow the system designer to switch from the optical to the electronic domain, and conversely, in order to use the best of electronics and the best of optics in the same system.

Midwinter says, "One immediate attraction of all-optical switching is seen in avoidance of the need for two optoelectronic interfaces at each network node. Further, in a local or campus network, the low insertion loss and bandwidth of single-mode fiber offers the possibility of truly 'transparent' networks, in which the format and data rate are set by the communicating terminals and the routing is achieved independently in a way that does not require synchronous or rigidly formatted data streams. Such switches may also support bidirectional operation both within the fiber and the switch. Another attribute of such technology is likely to be the provision of very large communication bandwidths as well as the usual optical advantages of low crosstalk and distortion."

He makes the point that the above concepts apply most readily to networks in which data is carried from one single user to another in which wideband circuit switching without multiplexing is used. If multiplexing is needed the switch has to perform a more complex function. Two approaches are under study based on wave division multiplexing (WDM) and time division multiplexing (TDM). WDM amounts to circuit switching with dispersed wavelengths while TDM requires an accurately timed switch structure and optical memory

and requires great accuracy in timing. There is also a growing interest in packet format transmission, initially in wideband local area networks (LAN's) but later into the main network.

Key factors to consider in optical switches given by Midwinter are:

- Unidirectional or bidirectional data flow in fiber
- Point-to-point or point-to-multipoint service
- Multiplexed or not
- Circuit or packet format data
- Synchronous, rigidly formatted data or variable bandwidth, mixed analogue and digital.

One approach to providing broadband services is through the use of wideband packet transmission. The network requirement appears to be for circuit and packet switches operating directly on wideband multiplexed data streams.

In his studies Midwinter deals with three distinct types of circuits: those with passive optical paths; those with active optical paths; and those using wavelength division routing.

Passive Pathway Switches

Of more interest than a two-port on-off switch is the three-port, which switches one input between one of two outputs, and the four-port device, which operates as an exchange bypass module. Two input ports can be connected directly (bypass) or crossed (exchanged) to the two output ports. Key operating parameters are the insertion loss, the cross-talk level, the wavelength response, the switching time, and precision.

The simplest form of array of exchange-bypass is the crossbar formed from a two-dimensional rectangular array requiring $N \times M$ units for an N input and M output assembly. Other matrix designs are possible which lead to more complex setting algorithms, since more than one crosspoint must be changed to establish a given circuit. Many arrangements take the form of a pipeline with data flowing from row to row in a parallel pipeline format. All paths traverse similar numbers of crosspoints leading to closely similar insertion loss characteristics for all routes.

Where bidirectional transmission is required to and from a terminal, a single-sided matrix may be desirable. In essentially all cases designs for such requirements have been largely electronic rather than optical.

Mechanical Switches. One family of mechanical switches is based on optical fibers. Optical fibers are connected through micro-optic elements (lenses, beam splitters) that are moved electro-

mechanically, or the fibers themselves are physically moved. Such devices for both multimode and single-mode operation generally have low insertion loss and good cross-talk characteristics but are slow in operation, imprecisely timed, relatively insensitive to wavelength or polarization, and are physically bulky. They can be used in simple wideband security networks and for block switching at major network nodes where the switch operation is infrequent and where simplicity and security are paramount.

Another class of fiber-based switches is based on interferometers or "waveguide directional couplers." An interferometer could be formed with two parallel single-mode fibers fused at two points to form two 3-dB directional couplers. This leads to a four-part coupler in which the transfer characteristics depend on the relative phase length of the two fiber paths between the two couplers. Changing one path relative to the other by a half wavelength switches the device from exchange to bypass, or conversely. Such a change can be induced by electrical heating of one arm. However, thermal drift will likely be a problem. Elements of this type can exhibit extremely low insertion loss and are potentially broadband. If the arms are of unequal length the transfer characteristic becomes wavelength sensitive and the device may also be polarization sensitive. Response time is likely slow--typically milliseconds--and the dimensions large (millimeters to centimeters). The devices are best suited to circuit-switched video surveillance or studio networks where switch set-up time is unimportant.

Electro-optic Devices. A different class of electrically controlled exchange bypass units uses the electro-optic effect in guided wave integrated-optic form and is usually made by titanium diffusion into lithium niobate substrates.

A typical exchange by-pass unit formed in this way has two diffused waveguides that for part of their length run parallel and sufficiently close for their evanescent fields to interact. Switching is achieved by suitably placed electrodes that change the relative refractive indices in the two guides. Such devices have low insertion loss, perhaps 1 dB or more, although low-loss coupling to fiber is difficult. Cross-talk can be a problem.

Fabrication of large arrays poses major technical problems since the devices are long and confined to a single wiring plane. Up to 16×16 may be possible on a single chip; impressive results have been reported for 8×8 arrays.

Most devices are polarization-sensitive but this can be overcome by

appropriate design. The devices can switch in the subnanosecond range, but present substantial capacitance to the drive circuit. Design compromises must be made concerning speed, polarization sensitivity, physical size, drive voltage, and electrical capacitance.

Since a complex matrix occupies square centimeters of area, exploiting the speed to synchronously reset/set is almost certainly more difficult to achieve than switching a monolithically integrated electronic cross point. However, once the optical path is established it offers unlimited and bidirectional bandwidth. Small arrays of elements are capable of very fast multiplexing or demultiplexing, given electrical synchronization. Wavelength is typically limited to a few percent of the center wavelength.

Holographic Techniques. Another proposal is to use optically written holograms in planary array to connect through free space a two-dimensional array of in/output fibers to a two-dimensional array of output fibers. This appears to present formidable engineering problems.

Wavelength Routing

Tunable sources and receivers allow the use of a passive guided-wave network in a communication mode like that of free-space radio communications, with optical frequency defining the communication channel. By assigning an optical frequency to a transmitter, a broadcast mode is obtained. Assigning a frequency to a receiver leads to a directed mode of communicationlike circuit switching while leaving optical frequency as a freely assigned variable. Thus a highly versatile network is available, supporting both broadcast and directed communication simultaneously. Such a network measured in kilometers would be a campus network, or, measured in meters, would be a switch.

Semiconductor lasers change their center (optical) frequency with drive current. This effect can be used to make controllably tunable sources covering a small range of wavelengths. Semiconductor lasers can also be made to tune by the use of an external cavity over a range of 50 to 100 nm, corresponding to more than 10,000 GHz, and for those developed for communication systems, can exhibit long-term optical frequency stability of more than 1 MHz. With channels accessible in a typical single-mode fiber centered around 1500-nm center wavelength. Tunable receivers might be achieved using optical heterodyne detection, so that receiver frequency would be controlled by a similar (local oscillatory) laser to that in the transmitter.

Through the use of less sophisticated lasers of the monolithically integrated type, up to hundreds of wavelengths are accessible by electrical control and can be exploited by using tunable optical filters and direct detection receivers. A variety of techniques exist for making such filters using:

- Electro-optic directional coupler designs
- Fabrication in fibers by means of grating structure impressed on the waveguide
- Bulk dispersive elements (gratings or prisms) interposed in the light path. Nonlinear interactions in the fiber may limit performance, causing crosstalk between different wavelength transmissions. However, in view of the low-power transmitter required this is probably not serious.

In all cases the network so formed is transparent and passive and generally could be bidirectional using a single fiber per terminal. A variety of formats is possible. In principle, such wavelength-switched networks look powerful, given good tunable sources and receivers. The use of tunable wavelength interfaces implies optoelectronic conversion at the input/output ports.

Active Pathway Switches

Switches in which the optical path is no longer transparent and bidirectional might involve the intervention of an active bistable device, or an amplifier, or it might involve optoelectronic conversion. Here is a scale of active involvements:

- All optical, reactive bistable devices
- Absorptive bistable devices
- Hybrid bistable and active devices (lasers)
- Optoelectronic hybrids.

Studies in nonlinear optics have led to a variety of optically activated switches, mainly based on optical bistability, that have caused speculation on optical computing (ESN 40-10:338-341). However, this has aroused little interest for switching. Optical activation raises new opportunities in control and interconnection, particularly when coupled with free-space (two-dimensional) optical wiring and the possibility of normally addressed planar arrays of devices, since the wiring rapidly becomes a limiting factor in other optical matrix concepts.

The switching speeds for optical logic gates range from picoseconds to nanoseconds with the reactive devices switching at optical frequencies and

absorptive devices characterized by real transitions involving real-time constants usually measured in microseconds or nanoseconds. They all require broadly similar switching energies. It is expected that picjoule sensitivities will eventually be possible with bistable laser and other hybrid devices reaching femtojoule levels. As such, they do not compare well with electronic logic.

Bistable gates are operated as threshold logic elements and incur the associated problems. Also, some of the specific design problems of bistable optical devices suggest even more intractable engineering problems to be solved.

An alternative approach is to explore hybrid optoelectronic matrices, combining global optical wiring and control with electronic logic. This requires good optoelectronic interface devices. Recent developments on multiple quantum well (MQW) materials suggest that photodetectors and electroabsorption modulators made from GaAs/GaAlAs MQW's in p.i.n. diode structure and monolithically integrated hybrid circuits using such devices to switch from optical to electronic domains--and conversely--may offer a solution.

Fast Synchronous Switches

Some hybrid combination of electronic and optical components seems most likely to lead to the ultrafast synchronous switches required in the future. Partitioning electronic circuits into small modules enables the true speed capability of electronic components to be realized, and optical technology can provide precision timing signals, zero time skew global interconnects, and wideband input/output as well as some useful wiring patterns.

Comments

The preceding paragraphs are essentially a summary of the third reference combined with conversations with Midwinter. It is clear that Midwinter believes that present-day optical logic gates are inadequate and that projected future performance will not make them competitive with well-established electronic gates. They are slower and require more power than electronic logic gates. The apparent advantages of digital optical computers arise from the optical interconnects such as parallelism, bandwidth, zero cross talk, and time skew.

For these reasons Midwinter's program at University College London will pursue versatile optical interconnects and try to achieve the advantages of optics and electronics in wafer-scale integrated circuits.

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7/25/87

Material Sciences

SOME OBSERVATIONS ON HYBRID MICROELECTRONICS IN YUGOSLAVIA

by Robert Vest. Dr. Vest is the Liaison Scientist for Electronic Ceramics and Materials in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave from Purdue University, where he is Turner Professor of Engineering in the School of Materials Engineering and in the School of Electrical Engineering.

Introduction

Yugoslavia is a colorful mixture of peoples (5 principal nationalities), languages (4 main ones), alphabets (2), republics (6, plus 2 autonomous provinces), and religions (3 main ones). From this diversity it is difficult to visualize how the Yugoslavs could join together for a united effort, but this is exactly what has happened in hybrid microelectronics. The cooperation is partly due to their unique brand of socialism under which all enterprises are owned and operated by the people who work for them, and each unit must make a profit or go out of business. The economic rewards for success are not as great as in the West, but the penalty for failure is the same.

I was in Yugoslavia for a week in May 1987 during which time I visited two of their major research institutes and participated in their annual microelectronics conference. This may seem like a small sample but one or more of the Yugoslavian scientists were with me almost every waking moment during that week, and they do like to talk about science and engineering. This report discusses

research at the two research institutes in Belgrade and reviews activities at the annual Yugoslav Conference on Microelectronics.

Mihailo Pupin Institute

The Pupin Institute in Belgrade is named in honor of the Yugoslavian-born professor who, at Columbia University in 1894, developed the use of induction coils which made long distance telephone and telegraph communications possible. The 1100 people at the Institute are involved in a wide variety of technical areas including measurement devices, control systems, and robotics. Their activities range from research and development to the design of prototypes and small-scale production.

My host at the Pupin Institute was Dr. Ljutica Pesic, Laboratory Manager for the Microelectronics Division. The major research project underway in his group is a study of aging of thick film resistors and the effect of diffusion of metal oxides into the resistors on the aging process. Aging is the phenomenon by which the resistance and temperature coefficient of resistance (TCR) change after exposure to elevated temperatures. Usually, the resistance increases and the TCR becomes more negative, but after very long aging the resistance often is observed to decrease. The group's approach to explaining the aging behavior is to begin with a percolation-tunneling model of charge transport where the dependence of resistivity (ρ) on temperature (T) is represented by

$$\rho = AT^{\frac{1}{2}} \exp \left[4(T_m/T)^{\frac{1}{2}} \right] \exp(BS) \quad (1)$$

where S is the tunneling barrier width and the other terms are constants. After some assumptions, most of which are reasonable if not justifiable, they get

$$\rho = C(BS_m)^2 \exp \left[4(T_m/T)^{\frac{1}{2}} \right] \exp(BS_m) \quad (2)$$

where S_m is the minimum gap distance between grains in the resistor microstructure and can be calculated from the experimentally determined gauge factor (GF), after assuming that the relative change in barrier width with mechanical stress is equal to the longitudinal strain and taking Poisson's ratio as 0.22. These assumptions lead to the simple relation $GF = BS_m + 3.44$. Their assumed model of the aging effect is shown in Figure 1, where the aging is seen to bring about an effective increase in barrier widths. The decrease in barrier height after very long aging is assumed to explain the decrease in resistivity after long aging. They then assume that the spreading of the barrier during aging

follows an Arrhenius behavior according to

$$BS_m = (BS_m)_0 [1 + \alpha t_a^n \exp(-E/kT_a)] \quad (3)$$

where t_a and T_a are the aging time and temperature, and the other terms are constants. From these equations, the aging can be calculated from the equation

$$\Delta\rho/\rho = \alpha(GF-1.44)t_a^n \exp(-E/kT_a) \quad (4)$$

The group at the Pupin Institute have subjected resistors having sheet resistivities from 10 to 10^6 ohms per square to aging conditions, and compared the results to the predictions of equation 4. For all of these resistors they found that the parameter n was approximately constant with a mean value of 0.6, and that E/k was also approximately constant with a mean value of 5300 K. This is the behavior predicted by theory for these constants, which gives the group more confidence in their model even though it is not a proof of its validity.

In another series of experiments they coated some of the thick film resistors with nine different oxides prior to aging for 22 hours at 650°C. The results of these studies allowed them to classify the oxides into three groups based on their effect on the aging results. The first group (Al_2O_3 , RuO_2 , ZrO_2 , Nb_2O_5) had no effect on the aging behavior, while the second group (CdO and Cr_2O_3) accelerated the increase in both resistance and TCR, and the third group (PbO , Pb_3O_4 and MnO_2) reduced the aging effect. Their model for the diffusion effect is a bit fuzzy at the present time. They postulate that some of the ions diffuse into the glassy barrier and serve as traps for tunneling electrons (e.g., Cd^{2+} and Cr^{3+}) while others form narrow conduction bands in the glass (e.g., Pb^{2+} and Pb^{4+}) or serve as resonance levels (Mn^{4+}). Research in this area is continuing, and they hope to develop a quantitative model for the effect of diffusion of oxides into the resistors during aging. In addition to providing data for their basic

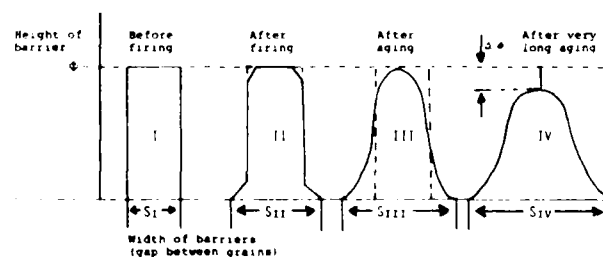


Figure 1. Model for aging of thick film resistors.

research for modeling resistor properties, they are also looking at the diffusion of materials into the resistors as a possible technological process for trimming the resistivity or other electrical characteristics of thick film resistors.

Research and Development Institute of Elektronska Industrija

Elektronska Industrija is one of the major organizations in Yugoslavia covering telecommunications, automation, computers, medical electronics, microelectronics, and special electronic technologies. The Research and Development Institute in Belgrade was established in 1967 as the scientific research department for Elektronska Industrija to provide technical services and develop new products for the organization. Within a few years after the Institute was founded, it was decided that they would develop the capabilities of producing thick film inks for hybrid microelectronics, and the necessary equipment for research and development and small-scale production was purchased. They have been moderately successful in that they have been producing silver conductor inks for the last 10 years, primarily for use as electrodes on disc capacitors. For the last 5 years they have been producing silver-palladium inks for thick film hybrid circuits as well as for electrodes for multilayer chip capacitors. They are having the same kinds of problems with their silver-palladium conductor inks as every other producer that I know of has from time to time; they have not as yet established the composition that will optimize both solderability and adhesion. They are currently developing other thick film inks including silver-platinum conductors, dielectrics, and resistors. Their goal is to have a completely independent production facility where they: make all of their own powders, including metal, metal oxide, and glass; formulate these into the appropriate inks; and characterize and perform quality control on the inks before going to production.

Whoever outfitted their laboratory some 12 years ago had plenty of money to spend. The Institute has have every type of apparatus that was then on the market for small-scale grinding, milling, and blending; these include ball mills, vibratory mills, planetary mills, a variety of mechanized mortar and pestles, eight three-roll mills of varying sizes, and three mixers. One of the problems of having all of these different systems for milling and mixing is that the personnel feel obligated to use them. For example, they are making reasonably good silver powder by chemical reduction from solu-

tion, which at this stage is mostly spherical particles in the 3 to 10 μm size range. They then ball mill this silver powder for about 24 hours followed by vibratory milling; add the glass frit and subject the mixture to vibratory milling, planetary milling, and automatic mortar and pestle; add the organic screening agents; and subject the formulation to three different mixers, the automatic mortar and pestle, and three-roll mills. At this point most of the silver is present as flake due to the coinage occurring during the extensive milling and blending operations. I tried to convince Milica Tomic and Nada Lekovic, the two principal researchers in the materials laboratory, that they do not have to use every piece of equipment in formulating every ink, and that in fact they can make better conductor inks if their milling of the very ductile silver powder is less severe.

Their facilities for characterizing both powders and fired films are quite extensive and adequate, although all of the equipment is 12 years old and does not include improvements made later to such equipment. They have DTA, TGA, x-ray diffraction, SEM, spectrographs, optical microscopes, light section microscopes, a shadow graph, several viscometers, profilemeters, and surface area apparatus. The latter is not useful because it must operate with helium, which is not available in Yugoslavia.

Another group in the Institute, headed by Lazar Lukic, is doing research on ferroelectric materials for multilayer capacitors. An ongoing project is the study of relationships between sintering, microstructure, and electrical properties of BaTiO_3 -based ceramics. They have determined the grain size as a function of sintering temperature from 1200-1400°C and sintering times from 0-360 minutes, and have developed correlations between the grain size and dielectric constant, dielectric loss, piezoelectric constants, and mechanical Q-factor. Lukic's group has concluded that for their applications a grain size in the range 10-20 μm is optimum.

MIEL-87

The 15th Yugoslav Conference on Microelectronics (MIEL-87) was held 14-16 May 1987 in Banja Luka. This annual conference, which moves from city to city, has become as much of a happening as it is a technical meeting. For example, there were over 300 attendees at the opening session to hear a welcoming address by R. Rocak, president of MIDEM, the Professional Society for Microelectronics, Electronic Components and Materials, and a welcome from the mayor of

Banja Luka. The rest of the conference consisted of parallel sessions, and there were rarely as many as 20 attendees at any one session. The majority of the scientists and engineers were always in the hallways and coffee shop talking to fellow scientists they had not seen since last year's microelectronics conference.

The influence of some processing parameters on the properties of diamond-like carbon films was discussed by A. Balasinski from the Institute of Electron Technology in Warsaw, Poland. The primary processing parameter studied was deposition time. The films were deposited by RF plasma techniques on silicon substrates, and ellipsometrical measurements enabled the determination of the refractive index and the thickness of the layers. Electrical parameters such as effective dielectric thickness, charge density, and dielectric constant were deduced from high-frequency capacitance-voltage curves and current-voltage plots measured for metal-carbon-silicon structures. It was found that during the growth of the carbon, the surrounding plasma may enhance the refractive index from 1.40 to 3.15 and reduce significantly the effective charge density in the layer. The optical and electrical dielectric constants changed in opposite directions, but the values of electrical and optical film thickness were in very good agreement. On the basis of the measurements, Balasinski suggested that during plasma processing the quantity of polymer phase in the layers decreases and at the same time the diamond-like phase quantity increases.

Application of the diamond-like layers was discussed by J. Szmjdt, also of the Institute of Electron Technology in Warsaw, Poland. He discussed the use of diamond-like coatings formed by the reactive pulse plasma (RPP) method as quarter-wave antireflective (AR) coatings to improve the efficiency of solar cells. The RPP method was shown to be applicable at temperatures sufficiently low that the silicon solar cells were not degraded during application of the coating. A theoretical analysis was conducted to determine the layer thickness to give the greatest increase in solar cell efficiency, and the calculated values of refractive index and reflectance were checked against experimentally determined values; good agreement was found. The improvement in efficiency of the solar cells due to the diamond-like AR coating was calculated to be 40-45 percent, and experimentally they observed a 30-45 percent improvement.

Several of the thick film papers presented by the Yugoslav scientists discussed studies which compared the performance of homemade inks to those commonly

used in the West. K. Milic from RO RIZ IETA in Zagreb discussed the applications of domestic epoxy materials for encapsulating hybrid microelectronic circuits. He found that thick film resistor networks protected by "CHROMOS SL," their domestic epoxy, gave satisfactory performance during thermal cycling, humidity, and burn-in tests as long as they first applied a silicone coating to the resistors. D. Rocak of the Jozef Stefan Institute in Ljubljana discussed the packaging of a hybrid circuit in an integral substrate package with a ceramic lid. They studied the packaging of naked silicon chips using different polymer adhesives and glass for the attachment of ceramic lids for the hybrid substrates. This packaging approach gave environmental isolation equivalent to that provided by a potted chip carrier mounted on the substrate.

A comparison of the properties of the silver palladium ink developed at the Research and Development Institute of the Elektronska Industrija in Belgrade with silver-palladium ink T-2785 from Engelhard was reported by Milica Tomic. She reported studies of adhesion, sheet resistance, solder leaching, solderability, and migration. Her conclusions were that the homemade silver-palladium ink was not quite as good as the Engelhard material but was satisfactory in all of the categories tested. The infrared (IR) firing of homemade thick film conductors and resistors was discussed by M. Hrovat of the Jozef Stefan Institute in Ljubljana. The properties of the thick film conductors were similar after IR firing compared to conventional firing, but for the resistors used the sheet resistivities were different and the TCR's were higher compared to conventionally fired resistors. A lively discussion followed this paper, which tried to reconcile the results due to the shorter time at high temperature with the theoretical processes of microstructure development. The best paper in the hybrid session of the conference from a scientific point of view was that given by Pesic of the Pupin Institute on his theoretical model for aging in thick film resistors. This research is discussed above.

All-in-all, the papers on hybrids at MIEL-87 were not outstanding with regards to their technical content. However, there was a very extensive interchange of research results among the people attending the conference. These exchanges took place in the corridors and the coffee shops where far more data were shown than in the technical sessions. It seems that everyone brought along their most recent results and were very willing to share them with researchers from other

institutes, universities, and industries in Yugoslavia. The conference was very successful in its stated goal of fostering dissemination of information dealing with research, development, production, and application of microelectronics. The method used to accomplish this was a bit unconventional, but the results were satisfactory.

Summary

Research and development activities in hybrid microelectronics are very vibrant in Yugoslavia. The quantity of work is surprisingly large compared to the population (23 million) while the quality covers the full spectrum. There are two main factors which impede research and development in microelectronics: the penalty imposed on poor performance by the social system and the shortage of hard currency. The first factor discourages high-risk, potentially high-return research. They are much more inclined to wait until a technology has been proven to a certain extent before initiating their R&D efforts. Copper thick film technology is a good example of a reluctance to take risks; several groups in Yugoslavia are very interested but none have been willing to commit the resources required until more positive results are available from other countries. The shortage of hard currency is beginning to have a severe effect on the basic research programs because very little of the capital equipment needed can be purchased with dinars. Some of the research institutes have not been able to purchase any capital equipment for more than a year, and the quality of the research will suffer significantly if this situation continues.

It is often said that the success of the program at the Office of Naval Research Branch Office, London is due to quid pro quo between its Liaison Scientists and the European scientific community, and that philosophy was amply demonstrated during my visit to Yugoslavia. I obtained the information included in this report, but I gave them at least as much information in return. While making arrangements for the trip, Dr. Pesic asked if I would be willing to give a seminar. I agreed and sent him two possible topics--he promptly accepted both, scheduled them on successive days in Belgrade, and had announcements placed in the local newspapers. In addition, he scheduled a roundtable discussion on thick film formulations at the Research and Development Institute of Elektronska Industrija, which can be best described as 2 hours of intensive consulting. After arriving in Banja Luka for the MIEL-87 conference, I was told that they had

scheduled a special session for me to deliver a lecture and answer questions. To say that the Yugoslavian scientists are interested in the basic research in hybrids being conducted in the US is a gross understatement.

7/21/87

ENGINEERING CERAMICS: A ONE DAY MEETING IN THE UK

by Louis Cartz. Dr. Cartz is the Liaison Scientist for Materials Science in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until June 1988 from Marquette University, College of Engineering, Milwaukee, Wisconsin.

A 1-day meeting on engineering ceramics was held at the University of Warwick, Coventry, UK, 1 July 1987. About 100 UK scientists participated. The goal of the meeting was to bring together a wide range of workers of different disciplines--mechanical and electrical engineers, physicists, metallurgists, ceramists, and material scientists from UK industry, governmental agencies, research institutes and universities--to forge a link and common purpose in developing the use of ceramics in high-technology industries. Another aim of the meeting was to contrast the behavior of ceramics with that of metals and to consider the changes necessary when a metallic component is replaced by a ceramic component.

The organizers, M.H. Lewis (University of Warwick) and T.F. Page (University of Newcastle-upon-Tyne), arranged two sessions, one titled "Engineering Applications and Property Requirements," the other, "Ceramic Engineering Materials: Properties and Limitations." All of the papers presented were general reviews by invitations, each paper dealing with a separate topic. No arrangements have been made to publish the proceedings of this meeting.

Engineering Applications and Property Requirements

The morning session was highlighted by a discussion by R. Slee (AE Developments, Rugby) on the use of ceramics in reciprocating engines. The use of alumina spark plugs dates back almost 100 years, and there were some experiments in the 1940's in Germany on the use of ceramic cylinders in diesel engines. One serious problem is the sorption of gases into

ceramic components. Fuel plumes from the fuel injector cause problems with absorption in the ceramic component. It is necessary to avoid all open-porosity, and only closed pores may be present in the ceramic. Snee commented on the need for nondestructive testing to examine for pores in the ceramic components.

D. Brandon (The Technion, Haifa, Israel, and the Department of Metallurgy, Oxford) discussed the design of ceramic components for heat engines. In particular, and because of their poor reliability, a large safety factor ($\times 8$) has to be used in the design calculations; more needs to be known about the failure modes of ceramics. Brandon pointed out that there is no standardization in test methods used for ceramics. The three important properties that Brandon stressed in ceramics are wear, thermal shock, and mechanical strength.

The use of ceramics, in particular the sialons for machine tool applications, cutting tools, dies, and welding system components, was described by N.E. Cother (Lucas-Cookson-Syalon, Solihull). Many of these are in current use (e.g., A.K. Sandvik cutting tools). Cother said that the ceramic part must be redesigned--it cannot be just a simple replacement of the metal component by a ceramic component. He said that, for example, sharp corners must be eliminated and replaced by smooth shapes; and that, in a particular component, an indent for an O-ring should not be made in the ceramic part but instead the indent should be cut into the surrounding metal casing. Again, Cother described the use of ceramic dies inside a metal restraining ring so that the ceramic die is under compressive forces.

Engineering Ceramic Properties

In the second session, the topics reviewed were SiC and Si_3N_4 monolithic ceramics, ZrO_2 -based ceramics, glass-ceramics, composites, surface modification by ion implantation, and metal-ceramic joining.

E. Butler (Rolls-Royce) discussed the properties of SiC and Si_3N_4 monolithic ceramics and reviewed the advantages and disadvantage of each type of ceramic processing: hot press sintering (HPSN), sintering with additives (SSN), reaction bonded (RBSN), sintered reaction bonded (SRBSN), hot isostatic pressing (HIP-SN), and chemical vapor deposition (CVD-SN). The ceramics SiC and Si_3N_4 do not sinter without special aid because they are covalent bonded; sintering aids have to be used, and these have important consequences on the final ceramic behavior.

M.P. Hitchiner (United Ceramics, Stafford) reviewed ZrO_2 -based ceramics. These are used as thermal barrier coatings and also as toughened engineering monoliths. Special methods of preparation are required for each use. The surfaces of ZrO_2 thermal barriers can be at 100°C above the temperature of the underlying metal substrate. Surface temperatures are limited to about 1400°C . Typically, a superalloy substrate is sprayed with nickel, chromium, and aluminum to overcome the thermal expansion mismatch on which ZrO_2 is plasma sprayed. The ZrO_2 layer will contain pores and microcracks which are found to improve the thermal shock characteristics. Surface thermal barriers have been successfully used with lifetimes $>10^3$ hours. There are difficulties with destabilization of the coatings by some fuels in aircraft engines, in obtaining the ideal thickness of thermal coatings, and in spraying into holes and around corners. Hitchiner described the advantage of partially stabilized PSZ, ZrO_2 , with MgO, and also with Y_2O_3 . There are some particularly interesting recent developments using 12- to 14-wt-percent CeO_2 as the stabilizer. This is a most promising material where the monolith behaves almost like a metal as far as fracture is concerned; the stress strain curve does not show an abrupt failure mode but is reminiscent of that of a metal. The system PSZ- CeO_2 is under further investigation.

G. Partridge (GEC Research, Stafford) described glass-ceramics. Various silicate glasses become crystalline if heated to one temperature to induce nucleation, then to a second higher temperature to induce crystallization. These glass ceramics are not, in general, highly refractory, and are usually restricted to temperatures under 1000°C . The glass ceramics are harder than metals, but undergo creep. Their thermal expansion properties are similar to some metal alloys, and for some glass-ceramics, the thermal expansion coefficient can be approximately zero. Uses for the glass ceramics include electromagnetic window material, where the crystallite sizes are kept to ~ 50 nm, so that there is no scattering of the wavelengths much longer than 50 nm.

R.W. Davidge (Atomic Energy Research Establishment [AERE]) reviewed ceramic matrix composites (Davidge, 1987). He said that either short fibers (0.1-10 μm thick and 10-1000 μm in length) or long fibers (1-100 μm thick and infinitely long) can be used for the composites. For structural applications, glass fiber composites, carbon carbon, and SiC-SiC composites are available. The stress-strain characteristics should be compared to

those of wood rather than to those of ceramics. The temperature limitations of use depend on such intrinsic factors as the melting point or on decomposition effects; for example, $\text{Si}_3\text{N}_4 + \text{Si}$ and N_2 , MgO solid+gas, ZrO_2 phase transition, microstructure coarsening. Limitations are also due to extrinsic effects such as chemical attack (for example, oxidation of SiC in air). The properties of these composites are very dependent on the behavior of the interface and also on the difference of the thermal expansion coefficients of the fiber and the matrix. In general, Young's modulus, K_{IC} and the work of fracture are increased in the composite, with an increase of tolerance for local and general stresses. There are not many continuous ceramic fibers available, SiC fiber being the most frequently used. The composite materials are not notch sensitive, so that methods of testing are different from those for monolithic ceramics.

The surface property modification of ceramics by ion implantation using 50-300 keV ions was discussed by T.F. Page (University of Newcastle-upon-Tyne). He described the different effects of ion fluencies from 10^{16} to 10^{18} ion cm^{-2} , at which point the surface becomes somewhat plastic; Young's modulus, K_{IC} and hardness increase with fluence, and there is also a change in the degree of absorbed humidity. Page also described the formation of amorphous surface or subsurface layers on such diverse ceramics as α -alumina, MgO , and ZrO_2 .

A very interesting review was given by B. Derby (Oxford University) of ceramic-metal joining. He described liquid phase brazing, direct active-metal brazing, and diffusion bonding. Massive stresses can develop at the interface due to differential thermal expansion effects. It is often necessary to coat the ceramic to produce wetting. Traditionally, Mo/Mn/glass frits are used or the vapor deposition of Ti, Zr, or Ni. The non-oxide ceramics are more difficult to braze; vapor deposition of titanium is used on Si_3N_4 . Alternatively, the thermal decomposition of Si_3N_4 gives rise to silicon, which forms a eutectic with nickel. Another brazing system for Si_3N_4 uses a reaction with molybdenum oxides and TiO_2 powder to give Mo-MoSi₂-TiN nitride interface layers.

Derby also reviewed diffusion bonding, which requires pressure, elevated temperatures, and special atmospheres. Strong bonding can result where alloying can be used to allow for the thermal expansion mismatch. Derby described the joining of Al_2O_3 -Nb, which have the same thermal expansion behavior. He said that some studies by high-resolution electron

microscopy (HREM) have shown no interfacial phases to be formed though other studies by optical microscopy have shown $\text{Al}_2\text{O}_3/\text{NbO}_x/\text{Nb}$ at the interface. The joining of alumina to nickel in air is believed to be due to an interface consisting of $\text{Al}_2\text{O}_3/\text{Al}_2\text{NiO}_4/\text{Ni}$. Bonding strength and fracture toughness measurements have been carried out by Derby on interfaces of Pd/ZrO_2 , Ni/ZrO_2 , Al/ZrO_2 and Zr/ZrO_2 .

Discussion

This 1-day meeting was intended to bring together workers in many different disciplines to aid in the planning of future joint investigations. Representatives of UK government agencies were present, but their participation was passive, waiting for the people from industry and universities to suggest programs, rather than encouraging the deliberate planning of future work.

Some specific points were made concerning problems arising when metals are replaced by ceramic materials.

- Sharp corners must not be present in the ceramic component so that redesigning is essential.
- Ceramics absorb gases and liquids, and precautions must be taken.
- Catastrophic failures in ceramics do occur so that a very large safety margin must be used in the design.
- There is no standardization in the testing of ceramics.
- It is best if the ceramic component can be held under compressive forces.
- It can be very difficult and expensive to obtain precise shapes of ceramic components; the use of diamond grinding is very expensive and should be avoided if at all possible.

A very promising ceramic material is PSZ stabilized by 12- to 14-wt-percent CeO_2 .

Some future meetings were announced. "Materials '88," being organized by the Institute of Metals and the National Physical Laboratory, will be held on 9-13 May 1988, at the University of Sheffield. A "ceramic testing" meeting to be held on 11-12 April 1988 (location to be announced) is being organized by the High Temperature Mechanics Testing Committee. This meeting is to consider the necessity of improvement in ceramic testing techniques, and to draft standards; further details of this meeting will become available from B.F. Dyson, National Physical Laboratory, Teddington, UK.

Reference

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8/12/87

MATERIALS MEETING IN LONDON, UK, MAY 1987

by Louis Cartz.

The UK's Institute of Metals held a meeting, Materials '87, in London from 11 through 15 May 1987. About 400 people attended the meeting, most from the UK, with about 15 from Sweden, 15 from Germany, 10 from the US, 10 from Italy, 10 from Japan, and 10 from the low-countries. Representatives from 20 other countries, mainly Western Europe and with a few from Hungary and Poland also attended. Extended abstracts were provided at the meeting, but it is not the practice of the Institute of Metals to publish proceedings of meetings.

Invited speakers reviewed the following subjects: tribology of materials, surface engineering and substrate development, plasma-spraying of ceramic coatings, transformation-toughened zirconia ceramics, ion implantation and micro-structure, and WC-Co cemented carbides. Summaries of the presentations are given below.

Surface Tribology of Materials

The subject of tribology of materials--the science and technology of surfaces in relative motion--was reviewed by W.H. Roberts (National Center of Tribology, Risley, UK). In particular, he discussed friction, wear, lubrication, and surface coating, giving several practical examples during the course of his talk. He also gave some details of UK government support programs of studies in this field.

Surfaces are not smooth, but are covered with asperities. Friction is related to these asperities, to surface damage, wear resistance, and hardness. Lubricants may be liquid, solid, or gaseous, and the true contact area of the two surfaces depends on the load. The lubricant thickness relative to the dimensions of the asperities gives rise to different lubrication effects. Wear characteristics depend on a wide range of parameters: lubrication, temperature, load, relative velocities, environment. The types of wear may be due to adhesion, abrasion, surface fatigue, corrosion, or other factors. Abrasion has a most important effect, and Roberts gave as an extreme example of this the case of mineral extraction equipment.

Surface films can protect surfaces up to certain relative velocities and loads, above which the surface films are broken; this effect also depends on temperature. Roberts described the use of soft metals and polymers as lubricants and noted that behavior of polymers varies depending on whether the polymers are with or without fillers, and that wear factors can vary by 10^4 . Surface properties are changed by coatings which can range in thickness from 10^{-4} μm to 1 mm and vary in hardness from that of Fe to that of diamond. TiN coatings, in particular, are very effective in increasing surface hardness; these coatings contain dense arrays of dislocations, imposing a high degrees of hardness.

Roberts gave several examples from bioengineering and from satellite technology. In the latter case, the satellite moving parts need to have a lifetime >10 years, and thin films of Pb (<1 μm in thickness) have been found to be very effective to lubricate moving parts.

Roberts discussed UK governmental programs of research, and said that the 3-year Plasma-Assisted Coating Technology (PACT) program sponsored by the Department of Technology and Industry (DTI), and involving over a 100 different companies, was recently completed. A new program to assist UK industry in the application of tribological surface modification techniques is being set up by DTI; the range of projects involves:

- Friction control through surface engineering
- Reducing wear in high-stress abrasive and corrosive environments
- Reducing wear in low-stress abrasive environments
- Optimization of substrate heat treatment for physical vapor deposition (PVD) coatings
- Improvements in tooling for difficult-to-handle materials
- Surface treatments and coatings for reducing friction and wear at elevated temperatures
- Research and development of quality control techniques and specifications for PVD coatings
- Preservation of sharp edges.

The Importance of Substrate

T. Bell (University of Birmingham, UK) gave an invited paper on surface engineering and substrate development which discussed the importance of the substrate and its correct preparation in relation to any surface treatment. Surface coatings and treatments can vary from 10^{-1} μm in thickness by (ion implantation) to 10^2 μm thickness (by plasma nitriding) to

$5 \times 10^3 \mu\text{m}$ (by carburization). To illustrate his talk, Bell gave as an example, the failure in torsion of a transmission rod; failure had occurred at the interface between the hardened surface and the substrate. Such a failure could have been avoided by increasing the thickness of the surface treatment or by adequate preparation of the substrate steel. The stress distribution in the substrate must be considered--particularly near the surface-treated interface--in relation to the strength characteristics of the substrate. The plasma nitriding of steels can be carried out on an alloy steel or on a hardened steel which results in an even higher hardness level at the surface. Thus, TiN on an untreated substrate may give rise to a totally unsatisfactory product, whereas TiN on a treated substrate may give rise to a valuable product. Bell pointed out that abrasive wear-resistant coatings of carbides and nitrides can be prepared having values in excess of 2000 Vickers hardness, but that such ceramic coatings need very careful substrate selection. Work is in progress on duplex treatments where plasma nitriding of the surfaces is followed by TiN deposited by PVD.

Plasma Spraying of Ceramic Coatings

The invited paper on this topic was given by P. Fauchais (University of Limoges, France). He reviewed the subject in a most interesting and useful fashion (see Boch et al., 1985; Vinayo et al., 1987). Solid particulates are introduced into a (d.c.) plasma at temperatures approaching 6000 K, and project forward with velocities of up to 500 m/s to splat onto a surface to form a lamella structure. Very careful control has to be undertaken to avoid nonmelting of the core of the ceramic particles. Again, oxygen should be avoided since it ionizes at about 4000 K and in so doing cools the plasma. The hottest central part of the plasma is surrounded by cooler gas at temperatures <3000 K, and increasing the gas flow may simply increase the flow of this cooler gas; optimum flow rates of ~20 liter/min are typical. The shape of the sprayer nozzle determines the jet shape, and there is an optimum condition of use in each case.

Ceramics have low thermal conductivities and the condition may arise where the outside of the ceramic particle is evaporating while the central core is not yet molten. Hydrogen gas has better heat transfer characteristics than argon, so a mixture of gases is used. Fauchais described his extensive work to characterize the plasma temperature distribution and powder temperature distribution measurements. Spectroscopic and Doppler

effect measurement techniques have been developed in his laboratory over the past 10 years to determine velocities, surface temperatures, and Biot heat transfer numbers.

All particles do not splat in the same manner. The particle choice is important: milled, fused particles are relatively dense; sintered particle densities depend on the temperature of sintering; agglomerates of tiny particles have very good heat transfer characteristics. In some cases, coated particles do not decompose.

The splat characteristics can give rise to patterns of exploded droplets in the form of flowers or into a variety of pancake flower shapes. These shapes have importance in the behavior of the final ceramic coatings, and heat treatments may be required. The surface may be water-cooled during the coating process. Fauchais gave the example of Al_2O_3 where a coating of thickness 0.3 mm at 1400 K may give rise to cracking parallel to the surface. It may be necessary to cool the front surface and to prevent the gas jet from hitting the surface. Thus for Al_2O_3 , with no airblast cooling of the front surface, the surface temperature is 1300 K, and 20 percent α phase is formed; using airblast cooling and keeping the substrate temperature to 300 K, only 1 percent α phase is formed. Fauchais concluded that there are very definite optimum conditions for plasma spraying. These involve knowledge of the heat transfer characteristics of the plasma and of the momentum of solid particles; plasma torch design and jet shape also need to be understood. The powder morphology is critical; for example, $\text{ZrO}_2 + \text{Y}_2\text{O}_3$ requires fine particles with homogeneous dispersions. Here, knowledge is necessary of the cold carrier-gas characteristics, the lamella formations from shock wave, and the pancake pattern of splat; the cooling of the deposits; and the postspray treatments, including machining. Fauchais pointed out that the adhesion of the coating is mainly mechanical.

Transformation-toughened ZrO_2 -based Ceramics

R. Stevens (University of Leeds, UK) gave the keynote lecture, entitled "Effect of Thermal Treatment on Ceramics," in which he reviewed transformation toughening of ZrO_2 -based ceramics (Stevens, 1986). Monoclinic $\text{ZrO}_2(\text{M})$ transforms to tetragonal $\text{ZrO}_2(\text{T})$ at 1170°C with a volume decrease, and $\text{ZrO}_2(\text{T})$ transforms to cubic $\text{ZrO}_2(\text{C})$ at 2370°C. $\text{ZrO}_2(\text{T})$ can exist as a metastable phase at room temperature if the

grain size is sufficiently small. The metastable tetragonal-to-monoclinic phase transformation is induced at room temperature by the presence of the stress field around a crack tip. It is the volume change and the shear strain developed by this phase transformation which opposes the increasing of the crack and so gives rise to the phenomena of transformation toughening.

Stevens discussed the microcracking induced around ZrO_2 particles by the volume change of the transformation T+M, and how the presence of such microcracks tended to cause a crack, propagating through the ceramic body, to become bifurcated, thus increasing fracture resistance. A toughening mechanism is also introduced by the elastic tensile stress around a propagating crack which, by releasing matrix stresses around metastable ZrO_2 (T) particles, permits the T+M transformation to occur with a volume increase >3 percent and a shear strain <7 percent. This represents extra work for the crack to move through such a region, hence an increase in toughness and strength. Stevens also discussed the compressive surface layers that develop in zirconia-based transformation-toughened ceramics. These compressive stresses develop from spontaneous T+M transformation of ZrO_2 near the surface, caused by absence of surface hydrostatic constraints. Stevens described partially stabilized zirconia PSZ and, in particular, MgPSZ--that is ZrO_2 with 3-wt-percent MgO, when lens-shaped ZrO_2 (T) precipitates can be quenched in. These precipitates have been observed and studied by transmission electron microscopy. Stevens concluded that one can control the properties to a limited degree by the microstructure of the zirconia ceramic.

M.A. Hepworth (T&N Materials Research Limited, UK) discussed partially stabilized zirconia PSZ ceramics, using CeO_2 . Submicron ZrO_2 powders <2- μ m particle size with average particle size $\sim 0.8 \mu$ m containing <10 mol percent CeO_2 sinter well to >95-percent theoretical densities TD in the temperature range 1350-1500°C: 97-percent TD has been obtained. At the triple points of the sintered ceramic, a silicate glass forms because the ceramics contain Si and Ti impurities to ~ 1500 ppm. Hepworth gave a demonstration of the cracking of a ZrO_2 ceramic with 12-mol-percent CeO_2 , when cracking noises could be heard as the ceramic piece was slightly distorted without catastrophic fracture occurring. The ceramics are characterized by a metastable tetragonal phase which transforms as a crack propagates. As the sintering temperature is increased to 1500°C, the indentation fracture toughness, K_{IC} , in-

creases from 10 to >20 MPa $\sqrt{m}$. The CeO_2 -PSZ is highly sinterable at lower temperature than Y_2O_3 -PSZ, can have a wide range of grain sizes, and is a toughened monolithic ceramic.

Ion Implantation and Microstructure

The effects of ion implantation on the microstructure and the tribology of ceramics was discussed by T.P. Page (University of Newcastle-upon-Tyne, UK). Irradiation by 50- to 500-keV ions causes compositional and microstructural changes near the surface. The ions are deposited under a Bragg-shaped curve within approximately 200 nm of the surface. The damage curve is displaced from that of the deposited ions curve. The surfaces of many materials are observed to become plastic with irradiation. Describing work on SiC, Page said that at 10^{16} ion/cm² the surface remains crystalline, while at 10^{18} ions/cm² an amorphous layer is formed; the surface is studied by Rutherford backscattering and electron microscopy. Page discussed how materials such as SiC, Si_3N_4 , GaAs, Al_2O_3 , ZrO_2 , MgO and WC become amorphous by metal ion irradiation. He discussed Al_2O_3 irradiated by Ti ion, and also MgO irradiated by Ti ions when a pseudo-plasticity is developed by the surface, and the H_2O absorption characteristics are modified. The irradiation of sapphire by Y gives rise to small bubbles. Page summarized his findings that irradiation by 10^{17} ion/cm² of Ti, for example, can give rise to changes in surface hardening, remove the H_2O layer, and can control the friction properties of surfaces (see Burnett and Page, 1987, and Bull and Page 1987).

WC-Co Cemented Carbides

The topic of one of the sessions was Hard Materials. Papers presented by E. Lassner (Wolfram, St. Peter, Austria) and S.B. Aronsson (Sandvik, Sweden) described the WC-Co system. Lassner pointed out how the subject of powder metallurgy had, in a way, grown up with the WC-Co system over the past 80 years. The production of WC-Co cemented carbides starts from yellow or blue WO_3 powder (either doped or undoped), which is reduced in H_2 to W powder. This is mixed with carbon black using a ball mill or a mixer, and the carburization is carried out in H_2 atmosphere or under vacuum to form WC powder. This is milled with Co powder, with the addition of wax and solvent, followed by isostatic compacting. Heating is then carried out to remove the wax, followed by a presintering treatment and then a full sintering to form the composite WC-Co. The W powder used is of a fine grain size, usually <1 μ m. The WC particle sizes and those in the final WC-Co

sintered condition are essentially the same, a typical value being 12 μm . The parameters that are important are: the compacting method used, the sintering condition, the carburization, and the WC-Co milling conditions.

The influence of carburization temperature was illustrated by considering a 6- μm WC grain powder. At 1650°C, WC grains of average size 6.5 μm are obtained. At 1800°C, 10.4- μm WC grains are formed. When these two powders are sintered under the same condition (6-percent Co, 80 min, 1480°C) the average WC grain size is 3.3 μm for that carburized at 1650°C, and 5.3 μm for that carburized at 1800°C. The larger grain size at higher sintering temperatures is due to the fact that at the higher temperatures the impurities are volatilized, and it is the impurities that act as inhibitors to grain growth. Lassner stated that many factors are still not understood in the production process.

Aronsson pointed out that there is no standardization of the WC-Co process, and that it is very difficult to relate the complex application requirements to basic physical properties. However, grain-size control, for example, is much better today (to within 0.03 mm) than 10 years ago (when it was to within 0.3 mm).

The performance of the cemented carbide depends on several intrinsic properties, such as elastic constants and thermodynamic and chemical properties. However, the microstructure is important in determining fracture toughness, hardness, and creep, which all depend on grain size. Defects determine the transverse rupture strength (TRS), and data is available of TRS versus defect size and versus porosity. The overall performance of the cemented carbide depends on the intrinsic properties, on the microstructure, and on the defects present, as well as on other factors such as the surface region, residual stresses, the homogeneity, and the testing conditions. Good wear characteristics of a tool depend on the contradictory properties of hardness of the surface, but also on the elastic deformability of the surface, so that a compromise is necessary. Different types of wear to the cutting tools such as crater wear, flank wear, rake wear, etc. are now recognized. The defects depend also on the trace elements present: oxides, phosphides, sulphides, and silicates (~ 100 ppm). Aronsson concluded that the performance of cutting tools is very complex and that there is only a fragmentary understanding of the process.

Panel Discussion on Cemented Carbides

Aronsson and Lassner answered questions during the panel discussion. Men-

tion was made of the fact that the tools do have a layered structure--an outer hard surface, below which there is a softer, ductile substrate layer on a harder substrate (the soft subsurface layer is for the surface to be able to adapt to microcracks). One comment indicated that there might be an interest in fiber composite structures to reinforce some of the more brittle WC-Co grades. Other questions were asked about the ball milling of the WC with Co and whether a lubricant was used. Several lubricants were mentioned, including alcohol, cyclohexane, polyethyleneglycol and some trade-name lubricants. Another question concerned competitive materials when diamond coatings on WC-Co compacts were suggested. The question was raised as to whether milling introduced oxygen into the system; it was pointed out that any oxygen present comes off as CO_2 during sintering with excess C; and that any uptake of oxygen comes from H_2O and not from the air. The question of the purity of WC was discussed; WC is always less pure than the W used, the contamination arising from the carbon black. Impurities give rise to a fine grain size by controlling grain boundary motion. Sintering is carried out in C atmosphere to reduce decomposition, so that impurities are always present. No systematic studies have been carried out of the effect of impurity levels on performance. Indeed, in earlier days when less pure materials were used, there was very little problem of localized grain growth; now that materials are purer, there is sometimes a problem with local growth.

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8/21/87

STRESS RELIEVING AFTER WELDING: EASTERN EUROPEAN APPROACHES

By Kenneth L. Willinger, Jr. Willinger is the ASME Senior Fellow, Director, Materials Laboratory, Ford Motor Co., Warren, Michigan. He is also an Associate Professor of Welding Engineering, Wayne State University, Detroit, Michigan.

The annual Assembly for the International Institute of Welding (IIW) was held in Sofia, Bulgaria, from 4 through 11 July 1987. In conjunction with the normal working meetings of the commissions, a symposium, "Stress Relieving Heat Treatments of Welded Steel Construction"--a topic of keen interest to the US Navy--was held. Since over half of the papers in this symposium discussed Eastern European research and applications, and since their approaches to the subject appear to be quite different from ours, I have highlighted the papers and the discussion of them in this article. In addition to discussing stress relieving by conventional heat treatment, the papers discussed mechanical stress relieving and a new heat source for processing non-metals (intense microwave radiation).

Background

During fusion welding, transient thermal stresses are formed which interact with the reaction stresses caused by the external restraint on a weldment. This interaction results in complex three-dimensional residual stresses in weldments which can cause many different types of cracking and shape distortions. Sometimes it is more damaging to a structure to attempt to remove or reduce these stresses than to leave them in. The topic of stress relieving--how and when to do it--requires a thorough knowledge of both the physical and mechanical metallurgy of the specific weldment and the effects of the service environment on these properties.

Postweld heat treatments (PWHT), e.g., stress-relieving treatments, are usually performed in order to:

- Relieve and reduce residual stresses
- Improve dimensional stability
- Decrease the weld heat affected zone (HAZ) hardness by promoting the decomposition of martensite
- Increase resistance to corrosion, especially stress corrosion cracking
- Improve fracture resistance.

Many papers in the symposium convincingly showed that many of the above improvements can be effected by mechanical, rather than thermal, stress relieving.

Examples of mechanical overloading, grinding, and vibrational mechanical stress-relieving techniques were discussed. To reduce the residual stresses constitutes a significant aspect of the risk of the initiation and propagation of brittle, corrosion, and fatigue fractures of the weldment. In addition, a reduction in the residual stresses also provides protection against dimensional changes during service. However, the thermal cycles required to reduce these stresses can sometimes lead to unwanted metallurgical changes such as embrittlement, sensitization, loss of strength, etc.

The subject of residual stresses and their effect on weldment integrity has been under investigation by Commission IX of the IIW for several years. The symposium papers represented a distillation of this work.

The proceedings of this symposium can be obtained from the publisher: Pergamon Press, Maxwell House, Fairview Park, Elmsford, NY 10523 (ISBN 0-80-035900-0).

General Assessment

Before presenting the details of the symposium, I want to emphasize that the Eastern European countries use mechanical methods of stress relieving in place of thermal techniques to a much greater extent than is the standard practice in the US. In many instances, described below, mechanical stress relieving offers advantages over the standard thermal treatments used in the US. It is my opinion that we should consider mechanical stress relieving much more often and also that more research is required to understand the mechanisms of stress relief by these mechanical means. There is no doubt that the techniques will reduce the residual stress, but there is still controversy over the mechanisms effecting the stress relief.

Symposium Highlights

Three invited papers were presented. The honor of the Portevin Lecture (presented annually) was given to the IIW president for 1987-1988, R.V. Salkin (Cockerill Mechanical Industries, Belgium), president of the IIW for 1987-1988. The title of his lecture was "Stress Relieving Heat Treatments." Two other invited review papers were presented: V.A. Vinokurov (USSR National Welding Communication), "Mechanical Aspects of Stress Relieving by Heat Treatment and Non-heat Treatment" and Academician I. Hrivnak (Welding Research Institute, Bratislava, Czechoslovakia) and K.A. Yushchenko (Director of Research, E.O. Paton Institute of Electric Welding,

Kiev, USSR), "Principles of Mechanical Stress Relief."

In addition to these review papers, 30 other papers, 19 of which were from Soviet bloc countries, were presented.

A New Heat Source for Materials Processing. An unexpected highlight of this meeting was a paper by B.E. Paton et al. (Paton Electric Welding Institute, Kiev, USSR) on the use of electromagnetic (microwave) radiation generated by a gyrotron for the heat treatment and joining of nonmetallic materials, particularly ceramics.

In summary, the authors explain that because electromagnetic radiation causes bulk heating in dielectrics and semiconductors, heat treatment and joining can be effected without the presence of significant thermal gradients, the cause of cracking in these materials during processing.

The Paton Institute has developed a heat treatment and joining facility centered around a 30-kW gyromonotron which generates electromagnetic waves at 83 GHz. Centimeter, millimeter, and sub-millimeter waves can be oscillated with this power. Plans exist to develop a similar device in the near future with capability of power in the hundreds of kilowatts. These high-power microwave oscillators operate with an efficiency of above 40 percent (much higher than lasers). The radiation is emitted in the form of a beam whose shape is controlled by the use of metal mirrors. The beam can be transported many meters, introduced into chambers with any gas atmosphere composition and pressure, and can be focused to a minimum diameter on the order of its wavelength.

Ceramic materials have been joined by the gyrotron radiation at the Paton Institute. Structural SiN-based ceramics up to 15 mm thick were joined by heating to 1300°C in a pressurized nitrogen atmosphere. Heating time to 1300°C was only 3 seconds and the total process required only 12 minutes.

Other applications include: (1) welding metals using an energy-absorbing dielectric (a welding flux), (2) surfacing metals with ceramic coatings, (3) enamelling, and (4) sintering of ceramic powders. To my knowledge, this is a new development that deserves very serious consideration by researchers in the US. The potential number of applications for the use of microwaves in the processing of materials would seem to be quite large.

Metallurgy of Stress Relieving. Nothing new or exciting was presented on this subject. Only two papers are noteworthy. In a study of PWHT on Nb microalloyed steels, Bosansky (Welding Re-

search Institute, Bratislava) concluded that if a PWHT is required, the thermal cycles must be designed to avoid the coherent precipitation of Nb(C,N). For this study, this meant that the postweld heat treatment temperature had to be less than 600°C. Bosansky found that even 550°C was sufficient to promote a substantial reduction in residual stress. In a careful transmission electron microscopy study of the dislocation-precipitate substructure, he found that when a loss in notch toughness occurred during PWHT of this steel, it was due to the formation of a <100> dislocations. These are sessile in the body-centered cubic material and thus act as barriers to dislocation motion. No discussion on how to avoid the formation of these sessile dislocations was offered; he only found a coincidence between their occurrence and a loss of notch toughness.

J.G. Blauel and W. Burget (Fraunhofer-Gesellschaft für Werkstofftechnik, Freiburg, West Germany (see ESN 40-5:157-162 [1986]) found that PWHT submerged arc weldments of TTSL E3C (on offshore steel) pipe had a lower toughness than the photon samples commonly used for laboratory test acceptance of the actual pipe welds. The laboratory tests resulting in fracture toughness (CTUD) comparable to that of the pipe welds in the as-welded condition, but a large discrepancy existed after PWHT--the pipe welds having a lower toughness than the laboratory welds. Although these results are important with respect to the validity of laboratory certification of welds, no exploration for the discrepancies could be determined. However, it is my opinion that the differences must be due to a difference in the changes in the residual stresses in each of the welds, since the CTOD toughness was the same before PWHT.

Residual Stress Generation. Many papers dealt with this topic and a related topic of local stress relief by local heat treatment, but the only paper worth mentioning was presented by P. Seyffarth et al. (Wilh-Piech-University, Welding Department, Rostock, East Germany, and coauthors from the Shipbuilding Institute, Leningrad, USSR). They report that, if properly controlled, the residual stresses in a weldment can actually be reduced by the volume expansion that occurs when austenite transforms to martensite. Although the thermal cycle caused by welding induces tensile residual stresses, which are always detrimental, control of the thermal cycle, under some conditions, leads to a reduction in residual stress. They used a 0.1-percent-C heavily microalloyed steel in their study. Their results have a bearing on whether to preheat or not because they

found that preheating up to 300°C can cause an increase in the residual of up to 100 MPa because the cooling rate is decreased, promoting the decomposition of austenite at a high temperature where the volume expansion is accommodated by plastic deformation. If the transformation occurs at lower temperatures (more rapid cooling) then the strength of the material is higher and the volume expansion results in a compressive stress that counteracts the normal tensile residual stresses caused by differential thermal expansion of the weldment.

These results are of interest because one normally believes that preheating will reduce residual stresses; these authors have shown that this is not always the case.

Mechanical Stress Relieving. Based on the content of the papers presented by Eastern European authors, I would say that this topic is actively researched and widely used in Eastern Europe. I believe that these techniques should receive more attention both in the research laboratories and in practical applications in the US. There are many instances where thermal stress relieving will produce undesired metallurgical changes even though the residual stresses may be reduced. Several papers in this symposium showed that, in many instances, mechanical stress relieving can reduce the residual stresses by up to 80 percent without any metallurgical changes.

An excellent review of the state of the art was presented by I. Hrivnak (Welding Research Institute, Bratislava) and K.A. Yushchenko (Paton Institute, Kiev). They review four different mechanical stress relieving methods that are in common usage in Eastern Europe: overloading, vibration, grinding, and peening. The most important point that I can make on this topic is that all of these techniques are widely used with what appears to be excellent success.

In addition to avoiding undesirable metallurgical changes, mechanical stress relief is often much less expensive than heat treatment methods. Hrivnak reported the results of using overloading techniques on heavily weld-repaired, large (18.5-m dia), thick-walled (35 mm) petrochemical gas storage tanks. The proximity of other tanks in use precluded the use of thermal techniques for fear of explosions. Three overpressurizing cycles up to 2.85 MPa pressure (causing a permanent volume increase of 4-8 m³) reduced the residual stresses in the welded regions from 240 MPa to 140 MPa.

Several papers dealt with vibratory methods of stress relief. This technique usually involves vibrating a structure through several resonant frequencies a

few times. There does not seem to be any argument that the techniques work, but there is considerable debate over the micromechanism that causes the local plastic deformation responsible for the reduction of the residual stress. Sedak (Institute of Welding, Gliwice, Poland) attempted to show that the stresses generated by the resonant vibrations are not large enough to promote the plastic deformation required. He proposed a mechanism where the vibrations produce a state in the material whereby low temperature microcreep is enhanced, causing a redistribution of the local stresses after vibration. However, I believe, as do many others, that the resonant frequency vibrations do cause the strains on a very local scale to become plastic, thereby reducing the residual stress.

Jesensky (Welding Research Institute, Bratislava) presented a paper which very convincingly showed that residual stresses due to welding are reduced by up to 80 percent by the resonant vibratory techniques described by Hrivnak. The figures below illustrate the reduction (in three dimensions) of the residual stress in a submerged arc welded 30-mm-thick steel plate caused by the resonant vibrational techniques.

Obviously the reduction in residual stress in the longitudinal direction (along the weld) is the greatest, reduced from 300 MPa to about 140 MPa. The overall trend is to smooth out the residual stress distribution and thus increase the dimensional stability. This result is typical of those presented by most of the papers on this topic. Jenensky also reported that in addition to the reduction

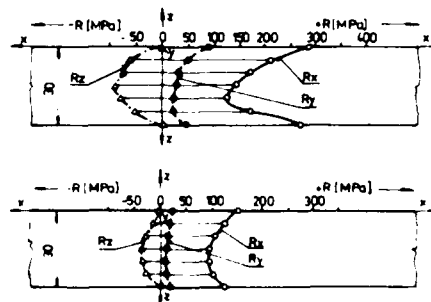


Figure 1. The course of measured three-dimensional residual stresses in X30 welded joint of Fe 430 D/CSN 41 1449.1/ steel. a=as-welded, b=vibratory stress relieved specimen, R_x =along the weld, R_y =normal to the weld, and R_z =along weld thickness, /+/ tension, /-/ pressure.

in residual stress, the ductile to brittle fracture transition temperature decreased somewhat (improved), and both the fatigue and the J_{IC} (elastic-plastic fracture toughness) improved as a result of the vibratory stress relief.

Explosive methods for stress relief after welding are also widely used in Eastern Europe. The mechanism of the stress relief is similar to that for the vibratory method in that the stress wave passing through the material combines with the local residual stresses to induce plastic deformation in the regions of the highest residual stress, thus lowering the overall residual stress. Plastic explosives are carefully shaped in order to control the magnitude and direction of the stress wave created by the explosion.

Summary

In all, very little new information was presented, but the paper from the Paton Institute on microwaves as a heat source for materials processing and those on mechanical stress relief are noteworthy. They indicate that Eastern Europe investigators studying stress relieving are using somewhat different approaches to the commonly encountered problems than the investigators in the West.

Also, although very limited detailed information is released by Eastern Europeans at this meeting, it is usually worthwhile for the West to participate because it is one way of following the research trends in these countries.

7/29/87

Mechanics

NATO WORKSHOP ON MATHEMATICAL MODELING IN COMBUSTION

by Eugene F. Brown. Dr. Brown was the *Liaison Scientist for Fluid Mechanics in Europe and the Middle East for the Office of Naval Research's London Branch Office until September 1987. He has now returned to the Virginia Polytechnic Institute and State University, where he is a Professor of Mechanical Engineering.*

The NATO Advanced Research Workshop on Mathematical Modeling in Combustion

and Related Topics was held from 27 through 30 April 1987 at Ecole Centrale de Lyon (ECL), France. The purpose of the workshop was to bring together experts in the field of combustion from both the academic and industrial sectors to discuss the state of the art in the modeling of combustion phenomena including mathematical models, numerical simulations, and industrial applications. Originally the meeting was proposed to the National Science Foundation through their cooperative Science Program with Western Europe and was intended to summarize the results of collaborative mathematical studies at Cornell University, ECL, the Los Alamos Scientific Laboratory, and the Université de Paris-Sud (Orsay). Ultimately, however, the scope of the meeting was enlarged to include a broader range of combustion problems, approaches (including experiments), and contributions from other organizations and countries.

The meeting attracted approximately 125 participants of whom approximately 100 were from France, 12 from the US, six from the UK, and the remainder from the other NATO countries plus Switzerland, and the USSR. Of particular interest were: high Mach number combustion, detonation theory, turbulent combustion, premixed flames with multistep kinetics, numerical simulation of combustion in reciprocating engines, and combustion stability.

During the 4-day meeting, 36 papers were given, 20 of which were from France, 10 from the US, and the remainder from Spain, Germany, and the USSR. The regular sessions were complemented by 11 poster presentations, the majority of which were from France. Only very brief (one or two paragraph) abstracts were made available at the meeting. A complete proceedings will eventually be published by Springer-Verlag in *Lecture Notes in Physics*.

Flame Structure

The process of combustion whether laminar or turbulent occurs in thin regions across which there are rapid changes in temperature and chemical composition. This places great demands on computational schemes. It is therefore not surprising that a good deal of attention was given to the behavior of solutions in the vicinity of flame fronts and detonation waves and the development of computational methods for handling these discontinuities. In these studies geometrical complexities were ignored. Instead, attention was focused on the localized behavior and structure of flames and detonation waves which, for the most part, were modeled by inviscid equations in a single spatial dimension.

global grid refinement procedures had been used. If, in addition, simplified reaction models such as those suggested by Williams were adopted in addition to the adaptive-mesh schemes, Smooke's methane-air diffusion flame calculations could be made on a Cray X-MP in as little as 15 minutes compared with the 4-5 hours required for a simulation using complete chemistry and a uniform computational grid.

Laminar Flame Calculations

A. Liñan (Polytechnic University of Madrid, Spain) presented his calculations of the distance between the base of a burner and the beginning of the flame. This necessitates a solution of the flow in the region at the base of the burner where the initial mixing of the fuel and air streams takes place as well as the region where the combustion begins in the fuel-air mixture. An important aspect of these calculations was the proper treatment of the boundary conditions on the burner lip. The standoff distance is not determined by a simple balance between the local flame speed and the fluid velocity but rather depends in a relatively complex fashion on the reactivity of the fuel-air mixture. Special cases of both constant temperature and adiabatic burner-tube wall boundary conditions were investigated.

In certain situations such as dust explosions, gaseous premixed combustion occurs in a region which is seeded with inert particles. G. Joulin (University of Poitiers, France) described his calculations which included the effects of particle radiative heat transfer in planar and weakly curved laminar flames. The method of matched asymptotic expansions was used to examine both steady and unsteady flames.

The numerical simulation of a confined methane-air diffusion flame, including nonequilibrium effects, was presented by B. Rogg, (University of Heidelberg, West Germany). The solution was carried out with a primitive variable modification of Smooke's implicit/adaptive grid technique. In comparing the results of a 25 reaction model with a reduced mechanism consisting of four global reactions good agreement was obtained with available experimental data. With only a simple one-step overall reaction model, however, discrepancies arose which indicated that the accurate numerical prediction of confined laminar diffusion flames requires specification of a more complete reaction mechanism.

As previously mentioned, careful gridding in the region of the high-temperature gradients associated with combustion processes is absolutely essential

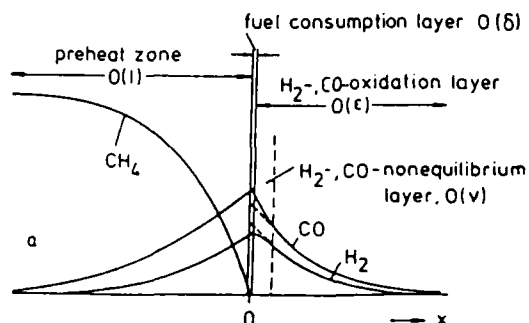


Figure 1. A schematic diagram of Inner Flame Structure.

if accurate simulations of reacting flows are to be constructed. To assure that adaptive gridding procedures provide a sufficiently fine mesh in such regions, it is useful to have an estimate of the thickness of the flame front structure. This was the purpose of the paper presented by N. Peters (Rheinisch-Westfälische Technische Hochschule, Aachen, West Germany) entitled, "Grid Requirements Due to The Inner Structure of Premixed Hydrocarbon Flames." Figure 1 shows a schematic diagram of the flame structure which resulted from his calculations. Four separate zones were identified--a preheat zone, a fuel consumption layer, an H_2 -CO oxidation layer, and an H_2 -CO nonequilibrium layer. These results were obtained using a three-equation methane-air global reaction model. Peters showed that if the overall flame thickness is on the order of 0.1 mm, the fuel consumption layer is on the order of 0.01 mm, and the oxidation layer on the order of 0.03 mm. In addition, he examined the effect of combustor pressure and preheat temperature in the range of 1 to 30 atmospheres and 500-700°C, respectively. As the combustor pressure increased, Peters found a sharp decrease in the thicknesses of the flame front.

Turbulent Flame Calculations

The calculation of turbulent flames is much more difficult than the calculation of laminar flames because of the lack of reliable turbulence models and because of the strong nonlinear interaction which occurs between chemistry and turbulence.

Recently it has been proposed that improvements in the understanding of turbulent flows and their modeling might be obtained by means of dynamical systems analysis and the theory of chaos. B. Nicolaenko (Los Alamos National Laboratory, New Mexico) presented his study of the Kuramoto-Sivashinski equation which models small thermal diffusive instabilities

Typical of such papers was the presentation by F. Williams (Princeton University, New Jersey) in which a combination of large activation energy asymptotics and small perturbation theory was used to postulate the structure of ozone decomposition, and of premixed hydrogen-halogen, and hydrogen-oxygen flames. The flow was assumed to be steady, spatially one-dimensional, and describable by the ideal gas equation of state. His results suggested that the flame consisted of preheat, reaction, and recombination zones. He concluded that, at least for the determination of flame structure, such "old fashioned" methods as large activation energy asymptotics and simplified reaction schemes still had a lot of mileage left in them and offered an attractive alternative to full numerical simulations of such problems.

J. Buckmaster, (University of Washington, Seattle) was interested in shock-induced combustion. By means of the one-dimensional Euler equations he investigated the mathematical character of the blow-up (infinitely large values in finite time) of postshock deflagration waves. The evolution of the blow-up singularity was also studied by Beberness (University of Colorado, Boulder), who considered separate models for both solid and gas-fueled ignition. J. Clarke (Cranfield Institute of Technology, Cranfield, UK) was also concerned with the behavior of shock-induced combustion, including the role which compressibility plays in the steady and unsteady aspects of such problems.

Related work was reported by S. Stewart (University of Illinois, Urbana), who was concerned with the modeling of thermal explosions by means of the reactive Euler equations. Of particular concern to Stewart was the existence of local heterogeneities produced by either material defects or hydrodynamics singularities which give rise to time scales considerably shorter than those associated with homogeneous flow.

Mesh Refinement

A. Dervieux (INRIA, Sophia-Antipolis, France) described his group's finite element combustion calculation. The problem of interest was the simulation of two-dimensional flame propagation in compressible inviscid gas mixtures. The flow was modeled by the reactive Euler equations and, to handle the temporal stiffness produced by the widely disparate flow and chemical time scales, a nonoscillating flux-splitting technique was used. In order to overcome the spatial stiffness produced by regions of large temperature and concentration gradients, adaptive mesh procedures were

used involving (1) local enrichment and (2) an interacting scheme in which the nodes were moved in order to keep up with the advancing flame front. It was found that the local enrichment scheme was far easier to implement than the interacting scheme and that use of implicit time stepping resulted in a 100-times faster calculation than when the previous explicit procedure was used.

Another presentation dealing with the problem of temporal stiffness was that of D. Gerasimov (Keldysh Institute of Applied Mathematics, Soviet Academy of Sciences, USSR), who described a number of industrially oriented codes developed in the Soviet Union not only for handling large systems of stiff ordinary differential and algebraic equations, but also packages for the solution of the incompressible Navier-Stokes and Euler equations. As examples of these two programs he showed the calculation of the flow over a circular cylinder, the computational grid on a Space Shuttle geometry, and the flow over the nose of a Shuttle-like reentry vehicle. Although allowance must be given for the industrial orientation of the code, I was struck by the fact that there was no evidence of sophisticated grid generation procedures (body-fitted grids, for example) and no evidence of grid refinement or adaptive procedures having been used. In addition, in the case of a normal-shock wedge interaction problem, there seemed to be a good deal of shock smearing taking place in the calculations. In the Euler code there seemed to be a capability for including combustion, although these results were not shown. These codes appeared to be primitive counterparts of the PHOENICS and FLUENT codes currently being marketed in the US.

Returning to the topic of mesh refinement, F. Rabie (Institut Francais du Pétrole, France) and J. Noel (ECL) also made presentations devoted to numerical schemes for handling the regridding required by advancing two-dimensional wave fronts and providing a self-adaptive procedure for concentrating mesh points in the vicinity of one-dimensional discontinuities.

Perhaps the most convincing demonstration of the importance of adaptive mesh refinement was given in the presentation by M. Smooke (Yale University, New Haven, Connecticut), in which he considered the numerical solution of strained premixed and diffusion flame problems with complex chemistry. He showed that a 40-point adaptive-mesh solution for the structure of hydrogen-air diffusion flame was superior to an 800-point uniform mesh solution. Even better performance could have been obtained if local rather than

in laminar flame fronts. By using inertial manifold theory he demonstrated that this model is strictly equivalent to a finite dimensional dynamic system. He investigated the impact of fundamental group symmetries on the cascade of bifurcations and their role in the generation of chaos.

In a related study, M. Marrión (Université de Paris-Sud, France) examined the existence and dimension of attractors for the model of constant density combustion. She found for the model of thermal diffusive instabilities which she used that there exists a maximal attractor which describes the long-term behavior of the solution. Moreover, she found that the dimension of the solution space is finite and that the maximal attractor was bounded in fractal dimension by a function which depends on the spatial dimension, the Lewis number, the order of the reaction, the Damköhler number, and the reduced activation energy.

J. Whitelaw (Imperial College, London, UK) has been involved in experiments on turbulent premixed combustion for many years. He described his experiments on disk-stabilized flames in which he made detailed measurements of the velocity, temperature, and concentration fields using both laser velocimetry and digitally compensated, small-diameter thermocouples and gas sampling probes. By means of temperature-conditioned velocity sampling he was able to show that the reactants move much faster than the products. Such nongradient diffusion phenomena has important implications for turbulence models for gas turbine combustors since it means that models exploiting Lewis number similarity to calculate the temperature field from the kinematics of the flow are fundamentally incorrect. He also looked at a series of experiments with bluff-body-stabilized premixed flames in ducts and examined the acoustic properties of the oscillations. This work is being done under ONR contract and is directed toward obtaining an improved understanding of combustion instabilities in ramjets.

Similar ramjet-related experiments were carried out by S. Candel (Ecole Centrale de Paris). His experiments were with V-gutter stabilized flames (ECL 41-3:156-175). In support of his experiments he developed a two-fluid, flame sheet model to represent the combustion process. In his presentation he reported on the results of his calculations and on the results of experiments conducted in a model ramjet combustor under various conditions of acoustic excitation.

At ECL itself (the location of the meeting) work by G. Brun was reported in

the form of a poster on an experimental and numerical study of a strongly heated annular turbulent jet. Measurements of the mean and fluctuating velocity components in the jet agreed reasonably well with simulation of the flow based on the $k-\epsilon$ turbulence model. The temperature profiles were in poor agreement, and Brun hypothesized that the assumption of constant turbulent Prandtl number was at fault.

A more fundamental study of the nature of turbulence (but at present without combustion) is also being carried out at ECL. The facility is too new for any publications to be available so I took advantage of a break in the proceedings to visit the laboratory where these experiments were being carried out. Dr. J. Gence is in charge of these experiments. They involve examining the structure of turbulence behind a 6x6-mm wire grid by means of laser-induced fluorescence. Experiments are being conducted in a small (7x7 cm²) water channel at a velocity of 0.5 m/s, corresponding to a grid Reynolds number of approximately 600. At present, these experiments (using rhodamine dye) have employed single point illumination to determine the power spectral density of the turbulence downstream of the grid. The intention is to verify Batchelor's predictions of turbulence decay. With this new equipment Gence is able to obtain 100 times the frequency response (and spatial resolution) of his old conductivity probe measurements (Bennani, et al., 1985). Although no chemical reactions are present in the experiments, his future plans include experiments with two dyes which fluoresce at different wavelengths and which react sufficiently fast that the course of the reaction can be followed in the time permitted by the length (approximately 1.5 m) of the test section.

Finally, H. Bockhorn (Technische Hochschule, Darmstadt, West Germany) presented his work on the modeling of H₂-air and CO-air turbulent diffusion flames with detailed chemistry. He used the $k-\epsilon$ turbulence model and the probability of density function (PDF) approach to model the interaction between turbulence and combustion. In order to produce accurate and reliable predictions of temperature and species concentrations throughout the flame, he took into account 42 elementary reactions involving 10 species in one case and 72 elementary involving 15 species in another. His calculations, obtained by means of a Patankar-Spalding-type integration procedure showed that temperature variations have a pronounced effect on the mean turbulent reaction rates.

Conclusion

This meeting was a "tour de force" application of mathematical methods to combustion, with presentations ranging all the way from dynamical systems and chaos to asymptotic models for ignition processes and flame structure. It was clear from the presentations and from private discussions with the presenters that Europe has a large number of fine applied mathematicians and engineers making important progress in obtaining an understanding of such problems.

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112-1

SHOCK/BOUNDARY-LAYER INTERACTION, VORTEX FLOW, AND PROCESS AUTOMATION RESEARCH AT RWTH AACHEN

by Daniel C. Collins. Dr. Collins is the Liaison Scientist for Aeronautics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until June 1988 from the Naval Postgraduate School where he is a Professor of Aeronautical Engineering.

The Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen is a large technical university (3000 researchers with graduate degrees) organized along the typical German Institute lines. Each of the many institutes are headed by a senior professor, who over a number of years, has developed the research and teaching program of the institute. The faculty of Mechanical Engineering, one of 10 departments at Aachen, has some 27 institutes. There are in the department, some 6800 students and 53 professors plus another 175 scientific staff. I visited three of its institutes; the Jet Propulsion and Turboengines Institute, the Aeronautics and Astronautics Institute, and the Control Technology Institute.

Jet Propulsion and Turboengines Institute

The head of the Jet Propulsion and Turboengines Institute is Professor H. E. Gallus. The turbomachinery laboratory, which occupies the entire ground floor of a large building, is quite impressive and is well equipped both in basic equipment and in modern data reduction devices. The

equipment is used both in research and teaching. Two other professors, U. Koschel and A. Beylich, about 15 students, eight research assistants and 25 diploma engineers are associated with the institute. About 50 percent of the funding for the laboratory is from the school, the other 50 percent comes from industrial contracts with the Deutsche Forschungsgemeinschaft (DFG), Verein Deutscher Ingenieure (VDI), and Volkswagen, among others. The laboratory is also used by the Steam and Gas Turbines Institute directed by Professor G. Dibelius.

Research is primarily directed toward investigation connected with turbines and axial and radial compressors. The students' research projects, largely experimental, are based in part on the use of the latest experimental laser measurement techniques. The projects also have a solid foundation in numerical calculations of the flow fields being measured. Facilities are available for research on subsonic, transonic, and supersonic flows in cascades and stages. Theoretical work is also going on in the development and application of two- and three-dimensional calculation methods for steady, unsteady, inviscid, or viscous flows in turbomachinery.

One of the recent publications on analysis (Broichhausen and Gallus, 1987) involves the influence of shock and boundary-layer losses on the performance of highly loaded axial flow compressor blades. The paper concludes that in addition to using the commonly used loss correlations one needs to consider bow-shock-induced losses, additional shock losses due to increased back pressure, shock-induced separation, and blade passage and loss-induced choking. The theoretical analysis of Broichhausen and Gallus is complemented by experiments (J.M. Henne et al.,) on the unsteady sub-, trans-, and supersonic flow in stators of axial compressors. The stator flow is measured by semiconductor (kulite) probes mounted in the blades and in probes. Spark schlieren techniques were used in the flow field visualization. Some very excellent flow field visualization was achieved. This type of measurement is currently being supplemented by laser Doppler anemometry (LDA) measurements and laser sheet measurements which are to be applied to a supersonic cascade.

In another theoretical and experimental effort secondary flow measurements in a turbine cascade were compared with a parabolic computational code. The incidence of the blades was varied from +10 degrees to -10 degrees, which varied the intensity of the secondary flow. By means of hot-wire probes 3-D measurements close

to the end walls were obtained which were then compared with analytical results.

In order to contribute to a better understanding of unsteady viscous flow in a subsonic axial compressor, H. Honen and H.E. Gallus made detailed measurements of the separated hub boundary-layer. This was thought to aid the mathematical modeling of the phenomena. Other work within the past year involves the application of a laser-density gradient technique and stroboscopic schlieren method to the characterization of movement of a self-excited blade in transonic flow and to the excitation of a transonic cascade. Further measurements are being made on the unsteady shock and viscous flow effects in order to be able to predict the occurrence of aerodynamically excited blade vibrations in transonic compressor and turbine cascades. Finally, using dye injection, photographs were obtained on the airfoil and end-wall boundary layers in a subsonic compressor stage. Coupled with other measurements of turbulence energy and a frequency analysis of the velocity fluctuations, a good characterization of the boundary layers was obtained.

The turbomachinery laboratory is one of the best I have seen in Europe or America. Excellent work of a high order--both theoretical and experimental--is being conducted in Professor Gallus's institute.

Aeronautics and Astronautics Institute

The Aeronautics and Astronautics Institute is headed by Professor R. Staufenbiel. My host for the visit was Dr. Neuwerth, who is one of the principal assistants of Staufenbiel. The institute has seven other professors associated with it, with about 200 students in its classes and 16 diploma engineers. Interestingly enough, all the researchers have a PC for their own use. Although I have found no lack of computer equipment in Germany, this is one of the few institutes that follows, essentially, the American idea of each person having his own computer. The institute has some very fine experimental equipment, particularly its water tunnel, which is devoted to the study of vortex flows on delta wings. This facility has a two-color LDA which is used in measuring the velocity components of the flow. The LDA apparatus is also being used in an investigation of free jet turbulence structure. The research in the institute is heavily oriented towards all manner of vortex flows, with the work divided into three project areas.

In the first project area work is directed at the study of the development of leading edge vortices and numerical

methods or modeling of flows with free vortices. Also considered is the study of vortex bursting, with particular reference to delta wings. I saw some excellent photographs of bursting vortices which illustrated the effect of confining the flow.

In the second project area work is directed at the growth and decline of vortices in wakes. Studies are directed at the strong unsteady vortices generated in the flow behind elastic rotor blades and at the interaction of the flow containing the vortices and shockwaves. Vortex structure near the speed of sound and wake flows involving vortices in unsteady flows are also being studied.

In the third project area, investigations are being made of the effect of winglets on mechanical load structure and lift of wings. Essentially, this is a study of the modification of tip vortices of a wing by means of modifying the wing tip--i.e., winglets. A stronger element of structure analysis of the wing and airplane is contained in this last project area. Specific studies are also conducted on agricultural aircraft and also on the spin behavior of aircraft.

Because the institute is interested in the development of new methods of measuring flows, I was introduced to Dr. C.G. Stojanoff, who is in the Forschungsgebiet Hochtemperaturthermodynamik at Aachen. Stojanoff was until recently at the Desert Research Institute in Nevada where he specialized in holography. At present he has 10 students working on multipulsed holography and on laser speckle interferometry as applied to flow field analysis. I have reported on these techniques before but what I find most interesting in Stojanoff's work is his development of highly efficient (97 percent) holographic optical elements (Windeln and Stojanoff 1985). Since publication of that 1985 report, further work has been done on holographic lens, notch filter, and filter stacks. I saw a very impressive dual-focus lens element. This work is similar to that in Denmark which I reported (ESN 41-7:390-395 [1987]), but high efficiency is a key factor in the success of this particular approach.

Clearly, the main focus for the research in the Aeronautics and Astronautics Institute is on all aspects of vortex flows. The institute has some fine experimental equipment for this research.

Control Technology Institute

The Control Technology Institute is headed by Professor H. Rake. I also talked to Dr. U. Hoffman, who is one of the chief engineers of the institute. The institute is located in the new

campus for RWTH Aachen which is on the outskirts of the city. The facilities are quite good with adequate computer equipment which includes a MODCOMP Classic 7870, a hybrid computer, and an analog computer. There are quite a few microcomputers and an interface to the RWTH Aachen central computer. About 15 diploma engineers work in the institute.

There are four areas of research:

- Automating industrial processes
- Designing control systems
- System identification
- Developing software and hardware.

A large part of the activity appeared to me to be concentrated under automating industrial processes, and there is some overlap between the different areas. Thus, the design of a sewage plant or a ventilation system might be considered either under the first or second area.

Automating of Industrial Processes.

Under automation of industrial processes is included the modeling and simulation of the process and the use of computer-aided control on the process. Applications include chemical engineering and heating and air conditioning. A current project in this area is concerned with heating and ventilating and air conditioning systems under varying flow conditions which might, for example, be dictated by energy savings considerations. They have been testing some of their theories on the heating and ventilating system of the large new building they occupy. A nonlinear model has been developed for a water-heated crossflow heat exchanger which will be used in simulation and verification of control concepts. There will also be tests conducted on the building ventilation system. Work in this area was reported in the International Federation of Automatic Control (IFAC) conference held in July 1987 in Munich. Other applications under investigation in this area include control concepts for a sewage works and a concept for the automatization of a coal processing plant.

Designing of Control Systems.

The designing of control systems involves the application of discrete time control, adaptive on-off control, gain scheduling, and state controllers and observers. On-off adaptive control along with parameter estimation techniques is being applied to the heating and ventilation systems discussed above. One of the projects in this area is concerned with coordinating path control of robot arms. Methods of process identification and adaptive control are used in the optimization. (In this respect it is worthwhile mentioning that almost all control groups in Europe

have some kind of activity in the area of robotics.) Another project in this area is concerned with the application of automatic control concepts to energy and material savings in process control.

System Identification. System identification is concerned with the application of the usual identification methods to industrial processes. Also under this category is included the stability supervision of the control system. A current project which was also reported at the 1987 Munich IFAC meeting is an investigation of whether the evaluation of frequency response from stochastic signals can be improved by means of randomly sampled signals. Results will be compared with estimations made with constant sampling intervals. A further investigation will be directed at the use of not directly measurable state variables and parameters in the supervision and diagnostics of manufacturing processes. Since the friction forces are a good indication of faults and damages in the manufacturing process, the immediate application of the research is to the estimation of the friction forces of manufacturing processes using hydraulic drives.

Developing Software and Hardware. In this area, software is being developed for process computers and microcomputers and for simulation of dynamic systems. Automatic control is also being accomplished by microcomputers and process control systems. A project in this area is the modeling and control of complex event-driven processes. A system of simulation and analyzing of complex control systems is to be developed based on the mathematical description of Petri nets. This work was reported in the Munich IFAC 1987 meeting. Further work has included the development of a software package for the optimal control of a glass cutting plant. In cooperation with an industrial company, software developed for the processing of cotton into card strips has been converted to hardware components, and these hardware components are used in the manufacture of the cotton card strips.

The Control Technology Institute appears to be very strong in the area of process control, as indicated by the many direct applications of control theory to industrial processes.

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7/8/87

Ocean Sciences

MARINE SCIENCE AT THE NETHERLAND'S HYDRAULIC LABORATORY

by Jerome Williams. Professor Williams is the Liaison Scientist for Oceanography in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until December 1987 from the US Naval Academy, where he is Associate Chairman of the Oceanography Department.

Remote Sensing

While in the Netherlands I visited with Dr. Daniel Spitzer, who is head of the newly created section on remote sensing within the Tidal Waters Division of the Ministry of Transport and Public Works. The objective of this section is to determine the remote sensing techniques that can best be applied to the assigned tasks of the division. Initially they will be working in three specific areas which include:

- The use of current-measuring radar, primarily for sediment transport studies
- Use of electromagnetic bathymetry systems, including both microwave (synthetic aperture and side-looking aerial radars) and laser techniques, not only to measure water depth but also to obtain information about the optical properties of the water column
- The development of improved methodologies to enhance interpretative skills in the analysis of passive sensor data from systems such as the Thematic Mapper.

At the present time the group appears to be concentrating on the effective use of data obtained from sensors flown from aircraft. In particular, they are attempting to develop algorithms that will improve the utility of both microwave and laser instruments and allow for the extraction of bottom information from

multispectral data. The group is small, but it includes a few people such as Spitzer who have an excellent record in previous activities of this kind.

The Hydraulic Laboratory

My visit to the Hydraulic Laboratory at Delft was a little different from most other visits made there, since I concentrated on the estuarine and coastal aspects of the laboratory. Dr. Robert Uittenbogaard, research engineer in stratified flows, showed me around the physical facilities of interest--in particular, the physical hydraulic model of the Rhine-Meuse estuary and the laboratory tidal flume.

The Rhine-Meuse model has a horizontal scale of 1:640 and a vertical scale of 1:64. It is very well instrumented and computer controlled, so it is particularly well suited to tidal motion, salinity intrusion, and pollutant dispersion studies. With the recent popularization of computer models, many physical models have fallen on hard times, but the Dutch are not giving up on the physical models completely without something demonstrably better to take their place. The Delft Laboratory's plan appears to be to gradually phase out the use of physical models as the computer models become reliable enough for operational use. Housed in a large, well-constructed building, the Rhine-Meuse model will be more than adequate as long as the staff wants to use it.

The tidal flume is an interesting device used primarily to study estuarine sediment transport and stratified flows. As may be seen from Figure 1, a model "sea" is connected to a long flume in such a manner that tidal motion can be simulated and sediment can be injected into the system at either (or both) the ocean or river end of the system. The flume consists of 21 replaceable sections, making a maximum length of 130 meters possible, which allows simulation of a complete tidal cycle. The width and height of the flume are both 1 meter, a tidal range of 0 to 15 cm with periods ranging from 30 seconds to 1 hour can be produced, and sediment concentrations of up to 3000 mg/l are possible. A special information system was developed to control sea and boundary conditions and to sample, store, and process data using a VAX 730 as a central facility. The system is designed so that data collection is initiated as soon as the flume reaches the required experimental conditions. It is possible to measure water level at 15 positions along the flume as well as vertical profiles (10 to 20 points) of salinity, velocity, and silt concentration. These data are continually

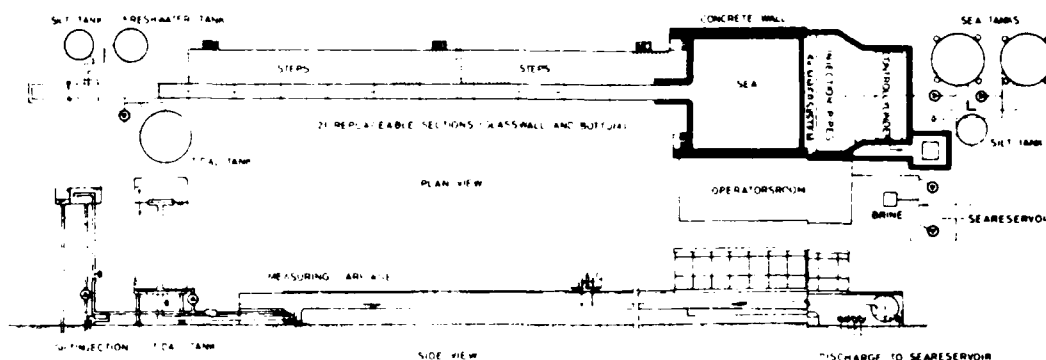


Figure 1. Top and side views of the tidal flume.

monitored by the VAX 730 to insure adequate data quality, and only those data meeting predetermined criteria are stored for final processing by the laboratory's main computer, a VAX 750.

The Delft Hydraulics Laboratory is run by the Ministry of Transport and Public Works, and it includes the following divisions: estuaries and seas; water resources and environment; rivers, navigation, and structures; harbors, coasts, and offshore technology; cutting and dredging technology; industrial hydrodynamics; hydrosurveys; and research and information technology. Of these, I was primarily interested in the work of the estuaries and seas division, which focuses on mixing, sediment transport, and pollution studies.

The Estuaries and Seas Division. This division is heavily involved in the development of mathematical models to support the mixing, sediment transport, and pollution studies, and has a large battery of computers (Cray-1, Cyber 205, and several lesser VAX, Sperry, and IBM units) available for their use. Dr. Herman Gerritsen of the division's coastal seas oceanography group filled me in on some of the ongoing work in storm surge modeling of the northwestern European continental shelf. This area, with a flushing time of several years, is extremely important to all of Western Europe. The model has a grid size of 3x5 nautical miles and has been used primarily for ship routing, but it has recently been extended for use in modeling the subgrid tidal circulation. So far the investigators have found a strong dependence on bottom topography and a marked disparity between vorticities determined at the small grid scale and those associated with larger grid sizes.

Another modeling project is concerned with fronts in the North Sea. They are using a combination of thermal and haline stratification in an effort to develop a model that can be used for pollution dispersion prediction. An integral

part of the effort involves the development of methods to facilitate the assimilation of satellite data, especially IR data, into their models. In this effort they are being funded by the European Space Agency (ESA) as part of the ERS-1 verification program.

Studies in Fine Cohesive Sediment Problems. Although he was just about to move to a new job with the Department of Public Works, Mr. W. Van Leussen took time to discuss the Hydraulic Laboratory's program in fine cohesive sediment problems with me. These problems develop as a result of dredging and erosion, and have pollution connotations as well as more basic ramifications. Various studies involving sediments are underway at the laboratory involving transport, using the tidal flume described above; bottom layer processes, using a specially designed bed model; and settling processes, using the laboratory's settling column.

The settling column is slightly over 4 meters high and 30 cm in diameter. It contains a series of oscillating wire grids which serve to maintain a minimum turbulence level in the tube (see Figure 2). This turbulence, which will tend to increase the frequency of particle collisions and therefore enhance flocculation as well as increase the shear stress (tending to limit floc size) is continually monitored by the use of a laser Doppler turbulence meter. Experiments to determine the change in settling rates with large and small particles present in large and small concentrations were performed. It was found that settling proceeded more rapidly under conditions of high concentration (1000 mg/l) than low (50 mg/l), probably due to higher flocculation rates. In addition to measurements of vertical velocity and sediment concentration made at various points in the column, movies have also been made which show very clearly the effect of increasing particle size due to flocculation.

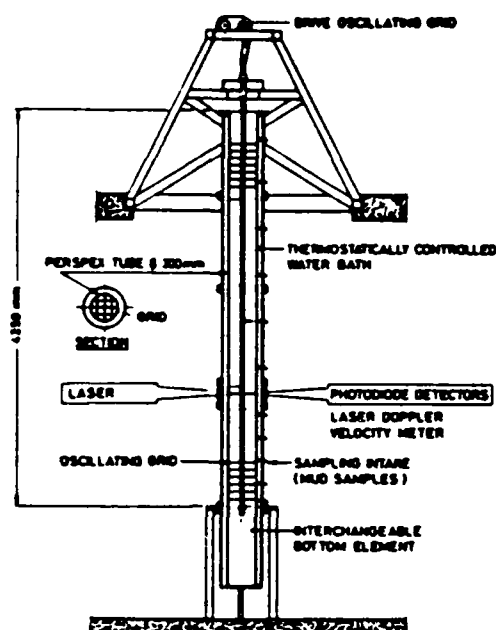


Figure 2. The settling column, showing many of its components.

Laboratory column studies have been supported by other laboratory studies and field work in addition to some modeling activity and by an active interest in the chemical uptake properties of sediments. These have been pursued both from the point of view of pollution prevention and the possible use of specific tracers for sediment tracking. There is also some interest in larger size particulates (sand), particularly with regard to the stability of coastal sand beaches. Wave effects on beaches and the stability of sand slopes are just two of the topics under consideration.

Conclusion

The Hydraulics Laboratory at Delft is a very impressive facility. It is very large, very modern, very well run, and very well maintained. The Dutch have a long tradition of world class excellence in this area, and I saw ample evidence that they intend to maintain world leadership. The fact that physical and numerical models are both being used, each for solution of the most appropriate problem, indicates an understanding of the nature of the real world which many other laboratories do not share. The level of technology demonstrated by this institution is impressive, but what is really impressive is the uncanny ability of these people to employ this technology as effectively and efficiently as they do. The people at Delft are well supported with exceptionally good tools to

do their job, and I got the distinct impression that they were well aware of the quality of this support.

7/20/87

OCEANOGRAPHY ON THE FRENCH RIVIERA--LABORATOIRE DE PHYSIQUE ET CHIMIE MARINES

by Jerome Williams.

The marine science laboratory of the Université Pierre et Marie Curie of Paris is located in a suburb of Nice called Villefranche-sur-Mer on the Mediterranean coast. It is the major French oceanographic laboratory devoted to scientific studies, including a physical-chemical group, a geophysical group, a biological group, and a very well equipped electronic instrumentation laboratory and workshop. The Laboratoire de Physique et Chimie Marines has a staff of 160 people, including 80 professionals, and is headed by André Morel, who also directs the activities of the physical-chemical group. It is housed in a series of reconditioned waterfront buildings that seems to be more than adequate for the program underway. In addition to the land-based physical facilities, the laboratory has two large vessels available, one 24 meters (78 ft) long dedicated to geophysics studies, and the other 19 meters (62 ft) long used for physical, chemical, and biological studies.

The Physical-Chemical Group

Since Morel's major interest lies in the area of optical oceanography the major effort of the physical-chemical group, as might be expected, is in this area. A rather complete image analysis facility has been available to the lab for the last 3 years, and much work in the analysis of coastal zone color scanner (CZCS) and thematic mapper (TM) images has been accomplished in that period. This group has been very successful in the development of atmospheric correction algorithms suitable for use in water types common to European waters, and they intend to continue their efforts with CZCS and TM, in addition to attempting their luck with the French SPOT and the Japanese MOS satellites. It appears that coastal area images from both these satellites will be amenable to the analysis techniques developed at Villefranche.

Most of the color analysis work has been directed toward the remote determination of either the diffuse attenuation

coefficient, k , or chlorophyll concentrations. There is also other work at the laboratory in the area of bio-optics. The optical properties of algal cells, including the measurement of absorption spectra of differing types of phytoplankton, is proceeding. Along with this, a sister study of the thermodynamic characteristics of phytoplankton is underway, including determinations of photosynthesis energetics and specific quantum yields for various species. In support of these activities, there is an elaborate phytoplankton culture facility and a well-equipped laboratory for the study of light scattering.

A large portion of the effort in this group is devoted to geophysical fluid dynamics and numerical modeling. A total of about 10 people are involved in large-scale dynamics under the leadership of C. Frankignoul and in mesoscale circulation studies led by L. Priour. They are looking at oceanic variations on scales of months to decades, with particular attention being directed at the air-sea interaction problem and with emphasis on feedback effects in the tropical ocean. The El Nino phenomenon is being addressed as attempts are being made in conjunction with some people at NASA to fit temperature data into general circulation models (GCM). The mesoscale effort is centered in the Mediterranean with attempts being made to assimilate SEASAT altimeter data into locally developed circulation models. There is also a strong interest in frontal dynamics, as both frontal genesis and frontal profiles are being investigated. Residence times for various parts of the Mediterranean are also being examined.

Marine chemistry has many facets at Villefranche. There is, for example, an ongoing study--as part of the larger Global Ocean Flux Study (GOFs)--of dissolved carbon dioxide off the coast of Peru. As at many other laboratories, some attention is being given to the problem of determining suitable natural tracers in the ocean, as well as experimenting with some manmade materials that have been suggested for this purpose. There is also some work going on in the analysis of heavy metals, both in suspended and dissolved states, as a tool in the study of geochemical time scales. A "superclean" laboratory is available for extremely delicate analyses, such as for dissolved lead.

The Geophysics Group

The geophysics group--the Laboratoire de Geodynamique Sous-Marine--includes a total of 25 to 30 people, mostly geologists working in geophysics, and is directed by J. Mascle. The focus of this

laboratory is toward rifted continental margins. Examples of this type of margin formation exist in the Central Atlantic (Bay of Biscay), North Atlantic (around Spitzbergen), and the Equatorial South Atlantic (around Nigeria and Mozambique), along with some of the basins in the Mediterranean. Although most rifted continental margins are of either the divergent or convergent type, Mascle and his group are particularly interested in the rift form typified by transverse motion of adjacent rocks. They are using seismic reflection techniques for data acquisition with pneumatic sound sources and multifrequency outputs from both single and multichannel transducers. Additional sensors include a multibeam sonar, a gravimeter, a magnetometer, and a sub-bottom profiler. The laboratory also has two research submersibles at its disposal for bottom investigations. A number of scientists from this group have been actively engaged in the Ocean Drilling Program, including two scientists acting as chief scientist on specific legs of the operation. A major US connection has been forged between the US and France as a result of this program.

The Marine Biology Laboratory

Station Zoologique de Villefranche-sur-Mer is the oldest component of the oceanographic complex at Villefranche. Plankton research was started here in 1809, but it was not until 1885 that a formal laboratory was created by a group from Russia. Occupying an old prison building, this Russian laboratory existed until the Russian revolution in 1917. It was abandoned until 1932 when it was taken over by the French Ministry of Education. The old prison still stands and is presently in use as the main building of the Station Zoologique. Other buildings have been added, and today there are laboratories, classrooms, dormitory quarters, and all the other facilities such as extensive seawater constant flow tanks that go to make up a completely equipped, modern marine biology field laboratory.

The work that is being done here is basically concerned with the characteristics of organisms and the relationships of these organisms to their environment, but the emphasis is on energy pathways from surface phytoplankton to the deeper water organisms within the Mediterranean Sea. Estimates are constantly being made of the total phytoplankton population and the structure of plankton blooms using both direct methods, such as fluorimetry, and remote sensing techniques employing visible color images. They are also experimenting with acoustic devices to measure plankton populations.

The portion of the Mediterranean closest to Villefranche contains cold core rings (off the island of Corsica), fronts (as close as 10 miles from the laboratory), and depths as great as 200 m almost immediately off Villefranche, with 2000 m depths only 10 to 15 miles away. Thus, an almost ideal natural laboratory is at their doorstep. With the data in hand, and working in close collaboration with marine scientists of other disciplines at Villefranche, a numerical ecological model is being constructed. Special efforts are being made to fill knowledge gaps such as those having to do with zooplankton distribution and populations.

Summary

The Laboratoire de Physique et Chimie Marines of the Université Pierre et Marie Curie at Villefranche-sur-Mer is the major marine science laboratory in France. It is well staffed, well equipped, and appears to be well supported. It is energetically directed, with purpose and warmth, so that the staff appears to be highly motivated and the work they produce is of high quality. The type of work being done is directed at problems that are of great interest, and the methodology used to approach these problems is often innovative and insightful. Although the facility is small by American standards, the quality of work being done here is such that Villefranche is making its mark on the international scene.

7/20/87

TRACERS IN THE OCEAN-A SMALL INTERNATIONAL MEETING

by Jerome Williams.

A meeting to consider the past, present, and future usage of tracers in the ocean was held at the Royal Society in London, 21 and 22 May 1987. About 40 participants from the UK, US, West Germany, and France discussed the use of both natural and anthropogenic tracers in a wide variety of studies. Abstracts of the presented papers are available now from the Royal Society, which also plans to publish a complete record of the meeting, including discussion comments, in the near future.

Tracer Characteristics

Two types of proposed experiments involving purposefully released tracers were described by A.J. Watson of the Marine Biological Association, UK. He indicated that releases of sulphur hexafluoride and perfluorodecalin had been used to measure wind-driven flow in the English Channel and diapycnal mixing in the Santa Monica Basin. The comparative behaviour of these two tracers was discussed within the context of the experimental objectives. With this as a background, Watson discussed the experimental designs for the studies involving the use of these two tracers. To successfully accomplish the experiments, it will be necessary to perform a series of further determinations of diapycnal diffusivities in the open ocean along with making some measurements of air-sea gas exchange rates in a shallow sea.

Trace metals in the ocean vary widely in their geochemical behavior and residence times, and therefore in their potential usefulness as tracers. J.D. Burton (University of Southampton, UK) addressed these characteristics of possible tracers, using manganese and aluminum as examples. Distinctive signatures of specific materials arising from localised sources may be seen in the plumes of estuaries and in surface ocean waters receiving inputs from atmospheric aerosols. They also arise at the seabed through diffusion from sediments and hydrothermal sources, particularly at mid-ocean ridge spreading centers. Even though many metals show markedly nonconservative behavior, distributions can be qualitatively related to transport and mixing processes. Manganese is of particular interest because of the diversity of its sources and its pronounced concentration gradients in areas of input from hydrothermal vents, reducing sources at ocean margins, and from processes in the upper ocean.

Another problem associated with the use of trace metals as tracers is that detailed knowledge of their scavenging rates (removal to sediments by uptake at the solid/solution interface) under the range of oceanic conditions is lacking. M.P. Bacon, Woods Hole Oceanographic Institution (WHOI), Massachusetts, suggested the use of specific tracers to measure these chemical scavenging rates, since results have shown that scavenging removal times are similar to within-basin lateral mixing times. It would therefore be expected that distribution of scavenged tracers should be related to the spatial distribution of their sinks, and this has been observed, especially in the case of ^{210}Pb . The distribution of ^{210}Pb suggests a strong reliance on intensified

uptake at boundaries, especially at ocean margins. Studies with isotopes of thorium, on the other hand, show that delivery of this element to the sediments is due to the local flux of settling particles. Thus, two scavenging transport pathways are readily apparent, one with a strong horizontal component due to intensified uptake at the margins, and the other with a strong vertical component due to the flux of settling particles. Separation of these two mechanisms is necessary since important large-scale chemical fractionation takes place by differential partitioning of elements between the two pathways.

Biochemical Processes

Some models of chemicals cycling in the oceans were considered by J.L. Sarmiento (Princeton University, New Jersey) with special emphasis on the carbonate cycle. He attempted to include the effects of biological processes, even though he considered their quantification to be the major stumbling block in oceanic chemical cycling modeling. For example, he calculates that atmospheric carbon dioxide would increase by a factor of three to four over a period of 100 years if all oceanic living organisms were to disappear. Attempts are being made to improve present models by including ecosystem processes, development of a source-sink function for phosphate, and combination with circulation models. The carbon cycle is probably much more dynamic than has been previously thought, with other processes for moving carbon vertically still to be considered. It appears that the indiscriminate use of carbon as a tracer is fraught with problems.

A review of the use that has been made of oceanic tracers in modeling the ocean uptake of man-made releases of carbon dioxide was presented by A.J. Crane of the Central Electricity Research Laboratories in Leatherhead, UK. He noted that the atmosphere-ocean system is apparently in equilibrium with respect to carbon dioxide with about 17 percent of the total CO_2 in the atmosphere and 83 percent in the ocean. The question Crane posed was whether this steady-state condition was due to air-sea exchange rates or internal oceanic mixing. This turns out to be very difficult to answer since diffusion is different for differing tracers with dissimilar reservoirs, major input geophysical processes, and equilibrium rates. In addition, there appears to be a large variation in air-sea interchange coefficients at different latitudes.

The oceanic chemistry of rare earth elements as tracers was discussed by H.

Elderfield (University of Cambridge, UK). Because of the unique chemical characteristics of this group of elements (the lanthanides), they can provide important information as oceanic tracers in a number of different ways. For example, the neodymium (Nd) isotopic composition of seawater reflects the relative importance of continental and oceanic crustal sources for seawater constituents. In addition, Nd isotopic inhomogeneities throughout the oceans are indicative of its oceanic residence time and may be useful in defining the effect of vertical particle flux on trace metal profiles. Since concentrations of rare earth elements are affected by interaction with both the marine biogeochemical cycle and chemical scavenging, we find cerium anomalies occurring in response to oceanic redox conditions while europium anomalies result from variations in hydrothermal input.

Air-Sea Interactions

Geographical and seasonal variations of the assumed ocean-atmosphere gas transfer coefficient were evaluated by J.F. Minster and his colleagues at Group de Recherches de Geodesie Spatiale, Toulouse, France, by using the Liss-Merlivat parametrization in conjunction with climatological wind and temperature data. The coefficient was found to be quite small (usually less than 5 cm/hr) except in latitudinal bands located in the tropics and near 50° north and south. Variations typically on the order of magnitude of a factor of five occurred within these bands, and these variations seemed to correlate quite well, both seasonally and geographically, with the few existing pCO_2 data. By comparison with the global average value deduced from ^{14}C decay it was suggested that the correspondence seems to be the result of high-latitude pumping and tropical upwelling degassing.

The use of tracers in the determination of transfer velocities (air-sea exchange coefficients) was addressed by P.S. Liss of the University of East Anglia, UK. He noted the difficulty usually experienced in the determination of this parameter and described some of the tracers that have been used. These include ^{14}C , ^{222}Rn , and sulphur hexafluoride. In experiments using Radon, it appears that wind speed is the controlling factor in the determination of the magnitude of transfer velocity, so that mass exchange rates are probably strongly affected by wind speed as well.

Physical Processes

A number of papers reporting on the use of tracers to track oceanic circulation were presented at this meeting, the

first being by W.J. Jenkins (WHOI). He described a dating technique using anthropogenic tritium and ^3He , which is a measure of time elapsed since sample contact with the atmosphere. Times between 2 months and 10 years may be reliably determined by this method as long as there is not an excessive amount of mixing. By using subtropical North Atlantic data Jenkins demonstrated that mixing is not a problem for those density surfaces whose wintertime outcrops lie within the region of Ekman convergence. In those regions where mixing is important, the two tracers must be interpreted as being individual but coupled.

Using tracer data from three areas, three different oceanic processes were studied. In the first exercise ventilation rates for isopycnals shallower than 27.1 were found to be several times greater than rates implied by Ekman pumping alone. Jenkins interprets this as an indication that wintertime convection and topography effects during the winter are largely responsible for ventilation under these conditions. In the second exercise, the tritium- ^3He age technique was used to estimate the oxygen consumption rate below the euphotic zone. From these estimates a vertical carbon flux was calculated which is substantially larger than that usually assumed by biological oceanographers for oligotrophic waters. No explanation was offered for this discrepancy. In the third exercise, the relation between ^3He and nitrate was used to estimate the upward flux of nitrate into the euphotic zone, thereby obtaining independent measures of "new" production. This result was consistent with values obtained from oxygen utilization rates below the euphotic zone.

Using the same tracers (tritium and ^3He), W. Roether and G. Fuchs of Heidelberg University, West Germany, studied the circulation of the main thermocline in the northeast Atlantic. In general, they found a southward drift of this layer.

The entire problem of the meaningful utilization of tracer data was addressed by J.G. Shepherd, Ministry of Agriculture, Fisheries and Food, Fisheries Laboratory, Lowestoft, UK. He offered no solution, but merely described the problem in some detail. In attempting to apply inverse methods to the interpretation of tracer data, solutions to the flux divergence equations, involving the exchange coefficients (Q) and concentrations (C) as a function of the sources and sinks (S), are required. The solutions result in values for S . However, what is really required is a set of values for the elements of Q which will give a satisfactory prediction of the

concentrations. Shepherd believes the two problems are not equivalent. It was not clear to him whether the standard methods of generalized inverse theory are applicable to the more difficult "real" problem, or, if they are not, what other methods might be used. It appears that if solutions to the "real" problem can be found, they would be more informative.

The Arctic and Mediterranean seas are both typified by thermohaline circulation with a strong advective component and deep ventilation processes. The nature of these circulation and ventilation processes was studied by H.S. Livingston (WHOI) using cesium and strontium tracers. The major input to the Arctic is from the Norwegian Atlantic Current, while input waters to the Mediterranean derive from the Norwegian Coastal Current. These two different source water masses contribute strongly to the observed differences in circulation and ventilation of the two regions.

Another type of tracer--the conservative chemical type--was suggested by G.R. Bigg (University of East Anglia, UK), and P.D. Killworth (Hooke Institute, UK). The authors believe that the use of this type of tracer leads to a better determined system of constraints to the flow and may result in knowledge about mixing processes as well as current systems. They are particularly interested in conservative combinations of nitrogen or phosphorus with oxygen (NO or PO) as suggested by Broecker, since it may be possible to obtain a large data set before other tracers have been adequately sampled in space and time.

Also describing some proposed work was C. Wunsch (Massachusetts Institute of Technology). He indicated that much data involving the distribution in space and time of steady tracers such as salinity and oxygen already exist, along with more recently derived anthropogenically derived transient tracer data. The extraction of quantitative information is not straightforward, however, primarily due to irregular coverage and the existence of large spatial and temporal data gaps. When used in conjunction with dynamical measurements and constraints, control theory provides a useful context in which to pose the problem of extracting information about the ocean from tracers. Wunsch plans to use a region in the upper layers of the eastern north Atlantic Ocean to demonstrate a synthesis that also leads to a quantitative measure of the relative importance of different observations.

Conclusions

Organized by H. Charnock (University of Southampton), J.E. Lovelock

(University of Reading), P.S. Liss (University of East Anglia), and M. Whitfield (Marine Biological Association), the meeting attracted some of the better known names in ocean modeling and in the use of tracer data in models. Consequently, the discussion was quite lively at times. Even though various tracers have been used for years, it was obvious from the discussion that many very basic questions remain unanswered. I got the impression that no one at the meeting had reached the stage where they were willing to make any unqualified statements regarding circulation or ventilation based solely on tracer data. On the other hand, there was very little pessimism regarding the potential value of tracer data and techniques. Certainly among the participants at this meeting, the use of tracers in the ocean remains an important tool for obtaining increased understanding of oceanic processes and phenomena.

7/22/87

Physics

1ST EUROPEAN WORKSHOP ON HIGH T_c SUPERCONDUCTORS AND POTENTIAL APPLICATIONS

by Ray Kaplan. Dr. Kaplan is a member of the Electronics Technology Division of the Naval Research Laboratory, Washington, DC. He has been on sabbatical at Imperial College, London, for the past year.

The first European Workshop on High T_c Superconductors and Potential Applications was held in Genoa, Italy, from 1 through 3 July. Its goals were to review European progress in this field and to formulate strategy and policy for the direction and support of future work, both in basic research and technological development. There was sharp awareness of the competitive nature of work in this field, and the need to at least keep pace with advances in the US and Japan. The outlook was intended to be European, rather than national, with the EEC fostering and to some extent supporting strong intra-European cooperation. Presentations on materials preparation and characterization occupied slightly more than 1 day of the workshop, and applications the second day and evening. The last day's activities included two in-

vited talks describing the status of American and Japanese work, and panel discussion on European policy and initiatives.

The general response in most European countries to the challenge presented by the new high T_c superconductors has been to organize interdisciplinary groups to provide a large range of sample preparation and characterization techniques. Many members of these groups have little previous experience in superconductivity, their expertise being in metal oxides, perovskites, and other relevant fields. Most of the presentations of research results at the workshop were in the form of posters, there being about 100 of these out of a total of about 150 contributions. In many cases virtually identical work was presented independently by several groups, with mutually consistent results. There was no representation from the USSR, and almost none from Eastern Europe.

Ideal Structures

There is now general agreement on the structures of the two classes of superconducting compounds exemplified by $Ba_xLa_{2-x}CuO_{4-y}$ and $YBa_2Cu_3O_{9-y}$, having transition temperatures T_c near 40 and 92 K respectively. The essential roles of O content and Cu valency were demonstrated by many groups, which described changes in particular properties as samples underwent compositional and structural transitions between superconducting and normal phases. These transitions could be achieved reversibly by annealing and cooling in O or inert gas atmospheres. Details of temperature, pressure, cooling schedule, etc. all affected the outcome. In the case of Y-Ba-Cu-O, for example, appropriate annealing in O yields the black, slightly O-deficient, orthorhombic, mixed Cu valency superconducting phase.

Several presentations dealt with the location of the O vacancies essential to the superconductivity. For example, F. Baudalet and coworkers (LURE, France), used extended x-ray absorption fine structure (EXAFS) to determine the average distance and number of nearest O neighbors for Y and Cu atoms in Y-Ba-Cu-O. Measurements at the Y K-edge showed no change with deoxidation by annealing in inert gas atmosphere. However, the Cu K-edge results indicated a decrease in the number of surrounding O atoms. This demonstrates that the superconductivity is associated with the appearance of O vacancies in the basal planes of the structure, which contain square planar-coordinated Cu^{2+} atoms. In these planes the Cu and O atoms form chains along the b-axis. Complementary results concerning

the location and ordering of O vacancies were obtained by electron microscopy by M. Alario-Franco (Faculty of Chemical Sciences, Spain) and others. In general, the structures of the ideal high T_c superconductors seem to be reasonably well understood.

Structure Defects

A general theme permeating discussion of nearly all measured properties was the role of grain boundaries, and the related problem of twinning. Put another way, one wonders whether measurements are indicative of bulk or surface/intergrain effects. That the composition, and therefore the structure of the surface and interior of the grains differed strongly, was demonstrated for Y-Ba-Cu-O by scanning Auger electron spectroscopy (AES) by R.O. Toivanen et al. (Helsinki University, Finland). Clean surfaces were obtained by ion sputtering, scraping, or breaking in vacuum. Compositional maps for the four constituents mimicked some features of the granular topography, and showed great irregularity. The altered "surface" compositions seem to extend hundreds of Angstroms into the grains.

No one seems to have observed single crystals of Y-Ba-Cu-O free of twinning. The twins appear upon transition to the orthorhombic structure. Measurements in an electron microscope by M. Marezio and his group at France's National Center for Scientific Research indicated a twin size and resultant domains of order 500-1000 Å. Heating in vacuum by means of the electron beam used for imaging caused reduction of the sample and domain wall changes, indicating the relation between O content and twinning. The orthogonal orientations of square planar Cu-O units in neighboring domains could be observed in the scanning electron microscopy (SEM) photos. A suggestion was later made by S. Amelinckx (SCK/CEN, Belgium) that growth under stress might yield untwinned single crystals. This is important since with twinned samples, investigation of the a/b anisotropy in the basal plane is difficult.

Many other classes of structural defect have been observed in otherwise "good" crystalline regions of samples. Some examples by B. Raveau (University of Caen, France) are: regions of order 100 Å with larger or smaller O content causing altered structure inclusion; sections of extra planar units which cause bending of the surrounding planes; shifts of registry of the La and Ba, or Y and Ba planes. These show up clearly in SEM photos.

Finally, there were many references to aging of the materials, even at 300 K, due probably to changes in O content and metal ion migration. This seemed par-

ticularly serious in the case of thin films.

$T_c > 92$ K

This subject was of major interest and concern, but the workshop produced no unambiguous evidence for higher superconducting transition temperatures than those already known. A number of participants described observations of T_c 's in the range 100-120 K, all in materials based on the Y-Ba-Cu-O system, but the results were erratic, usually appeared in multiphase samples, and could not be ascribed to an identifiable phase. Among these results, $Y_{1.2}Ba_{0.8}CuO_{4-y}$ was reported by A. Arestì et al. (University Dip. Scienze Fisiche, Italy) to lose its resistance around 110 K with a relatively narrow transition width (for these materials) of 1 K. Samples showed a Meissner effect, specific heat anomaly, and x-ray diffraction peaks which indexed to a superposition of two different orthorhombic phases. In a study which attracted considerable interest, D. Djurek (University of Zagreb, Yugoslavia) found that use of a pulsed electric field in sample preparation altered the resistance vs. temperature curve, shifting the onset of resistance loss to higher temperature, and yielding structure in the curve at around 240 K. This work was still in a preliminary stage and details were sketchy. During heat treatment, 10 msec, 1-10 watt electric field pulses were applied with a 10^{-3} duty cycle, to plates pressing on a Y-Ba-Cu-O charge in a capacitorlike configuration. The field strength was adjusted for changes in sample resistivity in order to keep the power approximately constant. Djurek suggested that the effect of the field might be to cause local heating at grain contact, or to enhance ionic diffusion.

On the subject of fluorine-substituted material there were several presentations and comments, but much skepticism was expressed. The latter was based on several unsuccessful attempts to reproduce the results reported earlier, on suspicion of contact effects, and on the facts that the role of the F, its location in the unit cell, and apparently even its very presence in the material after processing, have yet to be established. Nevertheless, reports of increased T_c after processing of Y-Ba-Cu-O with BaF_2 as a starting material, were presented. In what appears to be the most thorough study (though still incomplete), four samples with T_c in the range 110-120 K were obtained (J. Als-Nielsen, Haldor-Tapsoe Research Laboratory, Denmark). The samples had narrow superconducting transitions and were clearly multiphase; no Meissner effect work had

yet been done. It is still probably too early to form definite conclusions regarding the effects of processing with BaF_2 . Finally on this subject, reviews of work in the US (R.J. Cava, Bell Laboratories) and Japan (H. Takagi, Tokyo University) provided no grounds for expecting T_c 's substantially above those provided by the Y-Ba-Cu-O family in the immediate future. However, rumors persisted. In Japan, where apparently over 100 separate groups are engaged in research on high T_c materials, the latter are referred to as USO's, or "unidentified superconducting objects."

Theory and Superconductivity Mechanisms

The workshop included very little theoretical discussion and no new results in this area. Most theory thus far seems concerned with LaBaCuO_4 and related materials. According to T.M. Rice (IBM Zürich) this may in fact be the more difficult material to deal with, since its ground state appears delicately balanced between a large number of possibilities--for example, metallic, charge density wave, and charge ordered, dimerized, ferroelectric and antiferromagnetic insulator. However the theory for the Y-Ba-Cu-O compounds is said to be more complicated. The relatively high value and temperature dependence of the resistivity and non-Drude optical behavior in the normal state of La-Ba-Cu-O materials are not typical of metals, hence the conclusion that a strong coupling interaction is responsible for both the superconducting and normal properties. The model presented was essentially that of Anderson, but several other possibilities were considered; there is no resolution yet. Experimentally the situation is confused by the contradictory nature of the results so far, some implying the need for strong phonon coupling and others its unimportance. For example, the well-documented absence of an isotope effect in LaBaCuO_4 (shown by R.J. Cava) leads either to the conclusion that electron-phonon coupling is not responsible for the superconductivity, or to ingenious arguments for avoiding this conclusion. But preliminary work from Bell now shows a 25-percent isotope effect for Y-Ba-Cu-O. Are the mechanisms for superconductivity in the two known classes of high T_c materials different?

In a rather curious talk laced with references to the designs of Mother Nature, C.F. Van Bruggen (Groningen, Netherlands) suggested that the classes of materials under consideration are in fact metastable. Indeed, the question of long-term stability is crucial to applications but has received little attention as yet. Present samples are sensitive to moisture

and modest temperature rise and appear to age even under controlled conditions.

Applications

About one-third of the papers presented orally, and a smaller proportion of the posters, were concerned with potential applications. Major emphasis was placed on heavy industrial applications, perhaps reflecting one of the major sources of support for the workshop. As it turned out, concern for large-scale mechanical and electrical applications appears to be quite premature. In the short term, the new high- T_c materials probably will have most impact on electronics and, perhaps, magnets. The following comments apply to superconductors having T_c around 100 K, thus requiring liquid nitrogen cooling. Clearly the advent of room temperature superconductors would alter all of the views summarized here.

In his paper, F. Schauer (Institute for Technical Physics, West Germany) said that large-scale applications divide into three general categories. First are systems requiring superconductivity, such as fusion reactors. For these, the cryogenic portion of the cost is a small fraction of the total, and a switch to liquid nitrogen cooling would not offer very significant rewards. Second are applications in which the cost of cryogenics is a large fraction of the total cost (as, for example, scientific instruments, magnets for nuclear magnetic resonance (NMR) scanning, and accelerator magnets. In this case the new materials might effect a significant cost reduction, but the results would not be revolutionary. Third are cases where superconducting competes with nonsuperconducting technology, as for electrical power installations, power transmission lines, transformers, and levitated transportation systems. In many cases, elaborate studies have already been made for applications involving liquid helium cooling, and some prototypes have been constructed. In general it seems that replacement of liquid helium with nitrogen is not remarkably advantageous. Gains from use of the latter might include, in addition to reduced construction and operating costs, greater reliability and simpler design.

C. Benvenuti of the European Organization for Nuclear Research (CERN) and H. Desportes, Saclay, provided instructive examples by applications to high-energy accelerators. In its upgrading to 90 GeV the CERN electron-positron collider will use 256 superconducting rf cavities for particle acceleration. These will provide about five times greater efficiency than the normal Cu cavities. The superconducting lining of the cavities must

have a defect-free surface, without granular structure, and its properties must be stable against thermal cycling and radiation damage. Similar considerations, and, in addition, the question of critical current, I_c , are relevant to the superconducting magnets used by accelerators; the SSC would use more than 10^4 magnets.

Discussion of applications elicited a list of required properties as, for example, those cited by G. Gobner (Siemens, West Germany). These included: I_c in the range 10^3 - 10^6 A/cm², structural rigidity, small bending radius (for wire), environmental stability (thermal, atmospheric, radiation), good surfaces, and simple fabrication. Clearly, present materials do not approach these requirements; the crucial question is whether they can do so with further development.

The repetition of industrial interests prompted an unscheduled contribution by G. Donaldson (Strathclyde University, UK) suggesting a rich field of "small scale" electronics applications. These included circuit interconnects which could be fast, lossless, and dispersion-free, antenna structures of length much smaller than the wavelength for which resistive losses usually predominate, microwave cavities for high power and high Q operation, magnetically screened spaces from small equipment enclosures to rooms and buildings, Giaever and Josephson tunnel junction devices, SQUIDS, and perhaps computers. SQUID fabrication and operation was in fact described in several contributions C.E. Gough (University of Birmingham, UK, and G. Donaldson, Strathclyde University). Results on mm wave tunneling devices up to 560 GHz were presented by T. Claeson (Chalmers University, Sweden). These used E band waveguide, 1.5x3-mm cross section, in which an area in the broad side was replaced with Gd-Ba-Cu-O. This was contacted internally by a Nb wire or another high-temperature superconductor ground and etched in HF to a point approximately 20 microns in diameter. Operation was at 4.2 K. Tunneling characteristics were obtained but results were preliminary; upon thermal cycling it was found necessary to remake contacts.

A general view was expressed that, as the materials improved with further research, many new applications would appear.

Wires

A number of presentations (for example, those by R. Flukiger, [Institute for Technical Physics, West Germany] and P. Dubots [Laboratoire de Marcoussis CR-CGE, France]) dealt with superconducting "wires," both single strand and multifil-

ament. The only successful method thus far entails compaction of superconducting powder inside Ag tubes followed by drawing out and annealing in O atmosphere. The latter can be provided by inclusion of a substance which releases O upon heating, or by using a tube which is both O-permeable and O-resistant and heating in an external O atmosphere. Results seem scattered; nevertheless, a wire which yields I_c of about 10^3 A/cm² at 77 K was described. Problems include O-loss, formation of amorphous material, lowered density of superconducting phase, and thick nonsuperconducting outer layers on the grains. Since the properties of the material are strongly anisotropic, a method for aligning the grains to yield a common crystalline orientation would be useful.

Summary

A panel discussion following the technical presentations was concerned with summarizing progress to date, and considered short- and long-range goals, and the role of the EEC in nurturing the European effort. It was generally agreed that research in the following areas was essential: true single crystal preparation and analysis, microstructure and texture characterization, role of grain boundaries, mechanical properties, stability and aging, understanding superconductivity mechanisms, chemistry, and phase diagrams with a view towards finding other families of materials with possibly more attractive properties. Progress is needed in the growth of films, which so far seem to exhibit inferior properties (e.g., lower T_c 's, broader superconducting transitions, and instability). Interface reactions will be critical, in view of the intimate contact between film and substrate, wire filaments and sheath, and superconducting and insulating or metallic layers. Interfaces may be troublesome, in view of the high O and metal atom mobilities and reactivity. In particular, the nature of superconductor/normal-metal contacts has not received attention; experiments rely exclusively on conducting paint and epoxy or In solder for contacts, which display high resistance and age badly. Obtaining high values for I_c and the upper critical field H_{c2} , good mechanical properties and stability are clearly essential for successful applications.

Regarding EEC policy, among the actions suggested were aid to intercommunication, data banks, unfettered support for basic research, increased accessibility of major test and research facilities, and training programs.

2/21/87

QUANTUM OPTICS RESEARCH AT NAPLES UNIVERSITY

by Paul Roman. Dr. Roman is the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on assignment until September 1988.

When a country is on its way to successfully building up its capabilities for front-line research in some particular area, it is quite possible that a monitor pays close attention to work at the prominent national centers but overlooks smaller units, even though work, quietly done at such places, may be equally important. But there is also another reason why this kind of mistake must be avoided: in countries with developing technologies there is often a rapid shifting-around of key personnel, and it may very well be that a scientist, today at a minor university, will suddenly become a national leader in his field.

A case in point is the physics department of the University of Naples. While good work, in many areas, has been done there for quite a number of years, the more recent and rather rapid growth of Italian quantum optics, optoelectronics, and laser research changed the profile and level of work at Naples considerably. Actually, the changes were catalyzed by two events. First, in line with current governmental guidelines the faculty decided to do away with the traditional "institute" structure of research and join all physics institutes into one, centrally administered Physics Department. (The unification process is just being completed.) The Head of the powerful and big department is Professor B. Preziosi, a vigorous, mature, and noted theoretical condensed-matter physicist. The second major event in boosting physics research was the recent appointment of Professor M. Inguscio (formerly at the University of Pisa) as a co-leader of the quantum-optics and laser research laboratories. The other leading figure in this group (and its originator) is Professor S. Solimeno, a native Neapolitan, with a degree from Stanford.

In this article I give an overview of some areas of quantum optics research at the Physics Department that particularly caught my attention.

Multiphoton Processes in Molecules, Dissociation, and Ionization

This work is led by Solimeno; other prominent members in the effort are Drs. R. Bruzese, N. Spinelli, and R. Velotta.

A typical investigation in this area was begun in 1985. The researchers built

a sophisticated multi-ionization apparatus which utilizes a time-of-flight mass spectrometer as a detector of both parent- and fragment-ions. The most detailed studies concerned multiphoton resonant ionization and fragmentation of benzene. A strongly focused, tunable laser beam with very high peak intensity was used to tune in a number of resonance-enhanced ion yields, corresponding to 2 to 4 (or more) resonant photon absorption processes. In this way, a high-resolution multiphoton ionization spectrum was determined, under varying experimental conditions. Using a rate-equation approximation for the benzene level populations and a Gaussian approximation pattern for the focused laser beam, the spectrum measurements permitted an accurate numerical evaluation of the photo-ionization yields. (More recent work discards the Gaussian approximation and actually determines the focal-plane pattern in the re-expanded beam: this is done with a 128-element CCD detector.) The results can be used to calculate a rather accurate two-photon ionization cross section (relative to the $^1B_{2u}$ excited state of the benzene), which so far was not known better than within a factor of 10^4 .

A related line of research studies effects of the laser pulse transverse spatial distribution on multiphoton ionization processes. In particular, the two-step photoionization of benzene was investigated from this point of view. In addition, the role of an effect from a constant phase shift between different laser modes was also investigated.

Analysis of dissociation processes through interferometric studies of vibrational-translational relaxation times in polyatomic molecules is another area of concentration. A strong single-mode He-Ne laser beam was used for detection, and a phase-fluctuation optical heterodyne technique was employed. The setup was based on a Mach-Zehnder interferometer. (The gas in the cell in one arm of the interferometer was excited by a CW-operated Q-switched CO_2 laser, or by a tunable TEA CO_2 laser.) In most experiments the material used was SF_6 . One of the particularly interesting effects so far seen is that the onset of the dissociation processes causes a strong decrease of the vibrational-translation relaxation time. This decrease is seen, especially, at laser frequencies that are strongly red-shifted and broadened if compared to the linear IR absorption spectrum of the SF_6 molecules. The results indicate that, in specific experimental conditions, the relaxation process is characterized by two different rates. The first is related to the occurrence of

partial dissociation of the highly excited molecules. The scientists are also studying the (apparently significant) influence of the presence of some buffer gas on the relaxation process.

Interferometric studies of nonlinear relaxation processes in vibrationally highly excited SF_6 molecules are further material for study, and recently led to the tentative formulation of a simple, phenomenological model which actually assesses the influence of dissociation on the nonlinear relaxation time.

Liquid Crystal Optics

Drs. E. Santamato and A. Sasso are the leading figures in this area.

Continuous transfer of angular momentum from light to a nematic liquid crystal in the mesophase is the subject of a current study that was presented in the fall of 1986 to the ECOOSA conference in Florence. The researchers experimentally demonstrated that a circularly polarized laser beam, normally incident on a homeotropically aligned nematic film, can transfer continuously angular momentum to the sample. This transfer is evidenced by a collective procession of the liquid crystal molecules along the propagation direction of the incident beam. The effect is observed only if the laser beam intensity is above the threshold of the so-called optical Freedericksz transition.

The optical-field-induced first-order Freedericksz transition in nematic liquid crystals was actually another area where first results could be presented at the same ECOOSA conference. In particular, the Naples researchers produced evidence for two new nonlinear optical effects, arising when two laser beams interact incoherently in a homeotropically aligned liquid crystal film. The first is a remarkable optical transistor action, and the second is the demonstration of a mirrorless optical bistability phenomenon.

In the spring of 1987, research in both areas described above continued. In particular, it has been shown that the angular momentum transfer from light to the liquid crystal medium is intrinsically bistable. In regard to the two-beam optical bistability processes, the progress consisted in the careful determination of hysteresis loops. In addition, a simple theoretical model was proposed for the explanation of the observed bistability. Actually, two different approximations of the theoretical model have been explored. One is a linear time-dependent approach, the other a stationary nonlinear analysis. In particular, an analytic solution was found for the case of small angles of molecular reorientation, and an

exact numerical solution for the case of a steady-state regime was produced. In both cases, good agreement between predicted and experimentally measured values was obtained.

Optogalvanic Effect

Actually, it was earlier cooperation in this topic between Drs. E. Arimondo, M.G. di Vito, and A. Sasso of Naples on the one hand and, on the other, Inguscio, then still at Pisa (and previously well-recognized for his results in unusual laser-spectroscopic methods in the far-infrared region), that eventually brought the latter to accept Preziosi's invitation and became a new attraction for younger researchers to join the Naples group.

One of the earlier studies, begun in 1984, concerned laser cooling of a direct-current atomic discharge. In fact, the researchers demonstrated light-induced heating and cooling of a positive column discharge by combining the optogalvanic effect with optoacoustic detection. Phenomena were observed with laser radiation that was resonant with several Ne and He transitions. A somewhat oversimplified energy model was derived, and it accounted reasonably for the observed effects.

Later, direct evidence of heating and cooling in the optogalvanic effect's energy balance was found. The dependence of the effects on different discharge parameters was (and still is) investigated meticulously, and comparison with an extended energy model for transitions, both involving and not involving metastable levels is attempted.

Optogalvanic investigations in the cathodic region of a neon glow discharge are still in a preliminary stage. So far, analysis of the spatial behavior of the fluorescence intensity enabled the Naples physicists to obtain detailed information on the laser-undisturbed discharge. The current-voltage tube discharge characteristics could be well understood in terms of the discharge-maintenance mechanism through the secondary electron emission from the cathodic surface by the impact of ions, metastable atoms, and VUV photons. In addition, the laser-induced perturbation of the secondary emission has been understood to act as the main mechanism responsible for the optogalvanic production in the given discharge configuration.

The current status of the Inguscio-led research is hard to assess. As is always the case when a new, major laboratory is constructed, much of the effort is concentrated on actual equipment purchasing, local manufacturing, and installation. As a former

science-administrator, I was excited to see how quickly and how efficiently this procedure evolved. And, knowing the "players," I am sure that Inguscio's group will be often heard of in the future.

Free Electron Laser Theory

While it is not a central line of research at Naples, I found it remarkable how much Solimeno and Dr. A. Cutolo are involved in theoretical work related to free electron lasers (FEL). (Incidentally Italians, in general, are rather enthusiastic about FEL work, and, apart from the now reasonably well-functioning major FEL at Frascati, many less-well-known laboratories also do smaller-scale FEL experiments.)

Last year, the Naples quantum-optics group published two papers in FEL theory (see *Nuclear Instruments and Methods in Physics Research*, A250 [1986], 293-295; 413-417). The first analyzed problems encountered in the alignment of an FEL optical cavity. In particular, a new method, based on the synchronous detection of the spontaneous radiation, was proposed as an alternative method for aligning and tuning an optical cavity. The second paper was devoted to the study of guiding laser light by FEL amplifiers. The linearized Boltzmann equations are the basis of this study, and an approach based on the WKB solution of the transverse mode equation allowed investigation of the eigenvalue structure in terms of the prescribed electron beam transverse distribution.

Alignment and performance of almost concentric resonators for low-gain FEL's is one of the current interest of Solimeno and his associates. He is investigating the propagation of mismatched and misaligned laser beams bouncing back and forth between the mirrors of an almost concentric resonator. In addition, he analyzes the excitation of the cavity modes by the spontaneous radiation of a linear undulator.

Other Theoretical Studies in Quantum Optics

As a one-time theoretical physicist, I cannot resist the temptation to briefly call attention to purely theoretical work in optical wave propagation theory done at Naples by Solimeno and his associates, a group who are (as I hope is clear from the preceding) well-versed in broadbased experimental work.

In late 1986 (see *Physical Review A*, 34 [1986], 2646-2653) Solimeno announced work on algebraic time-ordering techniques in relation to the study of the evolution of quantum states ruled by a harmonic oscillator Hamiltonian with a

time-dependent frequency. He also noted an interesting analogy with the propagation of a paraxial beam through a self-focusing fiber.

In a sequel to this work, Solimeno and associates proposed an algebraic method to study the optical propagation in an inhomogeneous medium with a quadratic profile of the index of refraction. The crux of the study is the observation that the Wei-Norman algebraic procedure may be used to establish an analogy between the evolution operator and the optical propagation matrix.

Concluding Remark

Some people may think Naples University as "provincial," but watch out: we can expect first-class work from the quantum optics and laser-application people in the Physics Department.

8/24/87

News and Notes

STAFF CHANGES AT ONRL

As you may already know from the biographical notes preceding their articles, Drs. Eugene F. Brown and Robert W. Vest have completed their tours at ONR London and returned to their respective universities. Happily, we are still running articles by both of them.

Reporting in September is CDR Richard H. Taylor, who will be responsible for Undersea Systems. His most recent assignment was as US National Representative to Commander Northeast Mediterranean, Ankara, Turkey.

We will be joined in October by Dr. Alan F. Clark, who will report on superconductivity and electromagnetics. He comes to us from the National Bureau of Standard's electromagnetic Technology Division in Boulder, Colorado.

C.J. Fox
3/8/87

UK CREATES NEW ADVISORY BODY ON SCIENCE AND TECHNOLOGY

In its White Paper, *Civil Research and Development*, released in July 1987, the UK Government announced creation of

the Advisory Council on Science and Technology (ACOST). ACOST has absorbed and replaced the former Advisory Council for Applied Research and Development (ACARD), and will advise the government (including periodic meetings with the Prime Minister) across the whole of scientific and technological endeavor.

Sir Francis Tombs, chairman of ACARD from 1985 until 1987, has accepted the Prime Minister's invitation to chair ACOST. In accepting, Sir Francis said that ACOST's terms of reference "...are wide-ranging and should allow advice to be offered in a much more comprehensive and coherent manner than has been possible in the past. I have greatly enjoyed my period as chairman of ACARD and am honoured to be entrusted with this important extension of that work. I therefore willingly accept the appointment and look forward to making a contribution in this vitally important area."

Civil Research and Development, which is the government's full response to the First Report of the House of Lords Select Committee on Science and Technology: 1986-87 Session, is available from Her Majesty's Stationery Office, 519 Elms Lane, London SW8 5DR. Cost is £2.20 (about \$3.75).

C.J. Fox
9/14/87

CONFERENCE ON "SONAR TRANSDUCERS--PAST, PRESENT, AND FUTURE"

A special conference "Sonar Transducers--Past, Present, and Future," was held on 14 and 15 April 1987 at the University of Birmingham, UK. The conference was jointly sponsored by the university and the UK Institute of Acoustics (IOA), and is the fifth such conference on the subject of transducers organized by the Underwater Acoustics Group of IOA. Seventeen papers were presented. The 2-day program was organized into two categories: sources for the first day, and receivers for the second.

Frank Massa, a long-time US Navy contractor in Boston, Massachusetts opened the conference by presenting an invited review on sonar transducer developments during WWII and beyond. He described the developments of Navy transducers such as the TR208A and TR44, and the evolving application of piezoelectric ceramics, replacing early materials such as Rochelle salt and ADP crystal. Some British sonar transducers of the 1950's were also reviewed by R.J. Gale of the

Admiralty Research Establishment (ARE), Portland.

Flexensional transducers as underwater acoustic projectors were discussed: J.R. Oswin of British Aerospace demonstrated in a new design for a 3-kHz application the potential of using the magnetostrictive rare-earth iron alloy Terfenol-D, a material developed by Art Clark of the Naval Surface Weapons Center, White Oak, Maryland. J.L. Butler, Image Acoustics Inc. (Marshfields, Massachusetts) presented a desk-top computer program in BASIC, called FLEXT4A for the rapid analysis of the shell membrane mode and the quadrupole and octopole flexural modes of a Class IV flexensional transducer array by using a baffle model. This work was sponsored by the Naval Underwater Systems Center, New London, Connecticut, and Butler compared his prediction with the results obtained from the British Aerospace ceramic-drive units. The exchange of data has been valuable in validating the computer analysis, and the program is now available to other users upon request.

Another type of low-frequency projector was discussed by A.M. Young of NRL-USRD, Orlando, Florida. The concept of a Helmholtz resonator was applied to the design and fabrication of a 250- to 500-Hz source that is not limited by operating depth and produced a sound pressure level of over 200 dB re 1 μ Pa. W.J. Wood of Universal Sonar Ltd., Loughborough, UK, also presented the development of a 16x8 element dual array. The array consisted of 16 channels, each capable of delivering 1-kW power. It operated at 40 kHz, but had a wide bandwidth of 30 to 50 kHz. The steered beam had a width of over 3°.

J.N. Decarpigny of the Institut Supérieur d'Electronique du Nord, Lille, and his French colleagues contributed a paper on finite element analysis of low-frequency sonar transducers. A finite element code called ATILA was developed to perform modal analysis of both axisymmetrical and fully three-dimensional piezoelectric projectors for their impedance, near- and far-field pressure, transmitting voltage response, and directivity pattern under radiation loading. The code was written for both IBM and VAX computers. The authors also gave several analysis examples, including Tonpilz transducers, a deep submergence ring and a low-frequency flexensional projector. In a separate paper later in the program, they also discussed the applicability of this finite-element code to the modeling of a pressure-gradient cardioid hydrophone.

Two contributions came from the University of Birmingham. J.R. Dunn

discussed the problems related to the design of spherical-cap transducers that provide constant bandwidth over the frequency range of 27 to 54 kHz for determining the target strength of fish. The design was based on that of Rogers and Van Buren of NRL-USRD, but modified for improved sensitivity response. B.V. Smith and others from Birmingham described a technique for active electronic control of the response of a composite transducer consisting of a drive ceramic disk and a control ceramic disk. The passive control was achieved by loading the control ceramic with a variable inductor, but has a complicated frequency dependence. In the active control mode, predetermined voltages were supplied to the control disk, and high efficiencies were achieved with rather simple electronics. Both control methods were demonstrated to be effective for tuning the transducer from 250 kHz to 750 kHz.

The second day of the conference concentrated its program on the subject of underwater acoustic receivers. G. Hayward of the University of Strathclyde Glasgow, UK, opened with an invited lecture by reviewing the various linear electrodynamic models such as the Mason and the KLM models. By drawing the force/voltage and the velocity/current analogies, he discussed the advantages and the disadvantages of the equivalent circuit approach to the thickness mode and the multidimensional analysis in piezoelectric transducers. By using linear systems approach, he was able to better describe the physical mechanisms involved in transduction.

L. Lipscombe of DBE Technology, Aldershot, UK, addressed the reliability issue in the engineering design of broadband hydrophones. He described the DBE Technology design program in achieving long life, low noise and omnidirectional response up to 150 kHz in a 14-mm-diameter PZT-4 hydrophone. Z. Jagodzinski from the Technical University, Gdansk, Poland, also discussed the efficiency of receiving action of hydroacoustic transducers and the mechanism for the formation of the directivity pattern.

V.J. Hughes of the Cambridge consultants Ltd., UK, presented an interesting new concept for a particle velocity hydrophone utilizing an optical measurement technique. The device consisted of a thin leaf coupled into the acoustic wave field, an optical fiber sensor containing signals at two wavenumbers, visible and IR, to detect fiber displacement, and a signal processing unit. Preliminary results indicated that the technique may be applicable from 10 Hz to 1 kHz. The author also claimed a "sensitivity" of 135 kB re 1 μ Pa, corresponding

ing to a displacement resolution of 2.41×10^{-9} m.

The application of piezoelectric polymer PVDF in transducers was discussed by Q.X. Chen and P.A. Payne of University of Manchester in the design of an ultrasonic imaging transducer operating in the range of 20 to 40 MHz. The time and frequency domain response of this small device using 50- μ m PVDF film to a 50-ns pulse was predicted and compared with experimental results. R.Y. Ting of NRL-USRD, Orlando, Florida, showed examples of using PVDF thick-films in large-area hydrophone applications, and pointed out the inter-element coupling problem in the array of these PVDF hydrophones. As an alternative, a piezoelectric polymer-ceramic composite material was used to fabricate large-area hydrophones. It was demonstrated that this ceramic-dispersion in polymer matrix has a great potential in passive sonar applications. The material development was the result of ONR-funded research at the Materials Research Laboratory, Pennsylvania State University (PSU/MRL), University Park. The properties of other types of piezoelectric composite were also reviewed by D. Cannell of Unilator, Wrexham, UK, at this conference. The review was mainly based on the previous work of PSU/MRL.

Summary

The 2-day conference on sonar transducers stimulated many discussions. From the WWII design concepts and ceramics technology, the sonar transducer community has evolved to today's use of finite-element analysis models, modern-day electronics and computers, and new piezoelectric materials. More than 100 people from 14 different countries attended the meeting. Dr. B.V. Smith, the Organizing Chairman for IOA, noted that in the past such conferences had an average attendance of only about 70. It was a good indication that the field of sonar transducers is well and active. The US Navy was represented at the conference by NRL and NUSC personnel.

*R.Y. Ting and A.M. Young
Naval Research Laboratory
Underwater Sound Reference Detachment
6/15/87*

SCALES OF HYDROGEN-BONDING--AN ONRL WORKSHOP

About 25 chemists took part in the ONRL-sponsored workshop, "Scales of Hydrogen-bonding," held in London from 1 through 3 July 1987. The purpose of the

gathering was to discuss current activities in setting up scales of both solute and solvent hydrogen-bond strength.

R.M. Doherty (Naval Surface Weapons Center, White Oak) and J.W. Grate (Naval Research Laboratory, Washington) both lectured on the importance of solute hydrogen-bond scales in the understanding and prediction of effects in such diverse areas as solubilities in water and in blood, water-solvent partition coefficients, toxicological studies, and the response of chemical microsensor coatings to vapors. Fortunately, work on scales of solute hydrogen-bond acidity and basicity is well advanced, as was indicated by four other speakers. Most of these scales are based on log K values for hydrogen-bond complexation in dilute solution--that is, they are nearly always Gibbs energy related scales. Theoretical work by I.H. Hillier (University of Manchester, UK) has demonstrated that such scales are likely to be more easily handled than scales based on enthalpies of complexation. It was clear from the lectures and the subsequent discussion that there is considerable overlap between the main workers in this field, and the participants agreed to work together in an attempt to arrive at scales that would be generally approved.

Not so much work is ongoing in the area of solvent scales, and what work there is seems to be exclusively oriented to solvent hydrogen-bond basicity. P.-C. Maria and J.-F. Gal (University of Nice, France) described their multivariate analysis that leads to an angle θ , descriptive of the electrostatic:covalent ratio in the base:reference acid complex. M.H. Abraham (University of Surrey, UK) showed that it was possible to demonstrate the virtual equivalence of a solute scale and a solvent scale of hydrogen-bond basicity for nonassociated compounds, provided that the reference acids in each case led to θ values that were almost the same--around 65°. It was agreed that C. Laurence (Laboratoire de Spectrochimie Moléculaire, Nantes, France) would examine a solvent scale of basicity on these lines, and would then liaise with Drs. Abboud (Instituto de Quimica Fisica Rocasolano, Madrid, Spain) and Abraham and other interested workers, using the Kamlet/Taft β/ϵ formulation where appropriate.

A notable feature of the workshop was the extent of animated discussion, leading to reasonably general agreement as to the way forward. The workshop was thus very successful in bringing together chemists and in encouraging them to collectively approach the problems of hydrogen-bond scales. The eventual outcome could lead to major steps forward in this

important area. A final report is available at no charge from me, Dr. Michael H. Abraham, Department of Chemistry, University of Surrey, Guildford, Surrey GU2 5XH.

Michael H. Abraham
Department of Chemistry
University of Surrey
8/26/87

UK SILICON TECHNOLOGY--A NEW USER'S GUIDE

The Directorate of the UK's Alvey program (see ONRL Reports R-11-84 and C-8-85) has issued a new publication, *Alvey VLSI: A User's Guide to New Silicon Technology*. Its aim is to provide information on the availability and accessibility of the advanced silicon semiconductor processes being researched within the Alvey VLSI Program. The document was one of several publications produced by the Alvey Directorate during 1987 to inform the many potential Alvey technology users of the opportunities now offered for the commercial exploitation of this national collaborative research program.

Very large scale integration (VLSI) is one of four key enabling technologies supported under the Alvey Program. Its objectives are to carry out the research necessary to establish by the late 1980's internationally competitive VLSI process technologies within the UK and make these available to a wide base of users via the provision of advanced computer aided design (CAD) tools.

Some important areas of the Alvey VLSI Program in which commercial exploitation is already taking place are highlighted in the brochure. They include:

- The first Alvey-researched VLSI process already in production (1.25-micron bulk CMOS, STC Footscray).
- Plans laid for the production of five further UK VLSI process technologies before the end of 1988.
- Successful development of several advanced semiconductor process equipments and their introduction on to the market.
- Support for CAD standards in design (ELLA) and data interchange (EDIF) to enhance user access to UK technology.

Copies of the "guide" are available from The Press Office, Room 723, Department of Trade and Industry, 1 Victoria

Street, London SW1H 0ET. (No price is given.)

C.J. Fox
9/14/87

FIAT RESEARCH CENTER AT TURIN

The Fiat Research Center, one of the independent companies making up the Fiat group, has been in existence for about 10 years and employs about 600 people. Although originally involved in general energy research (windmills for example), the emphasis in the past 3 years has been on research on improvement in automobile performance. There may be a tendency to think of automotive research as somewhat pedestrian; however, future advances in engine technology require sophisticated techniques. Dr. Cipolla, the research director, indicated to me that performance improvements of 10 to 20 percent were fairly easy in the 1970's but that now fundamental understanding of the internal aerodynamics of the internal combustion engine will be needed to obtain performance increases of 1 to 2 percent. I also had an opportunity to discuss the research program of the laboratory with Dr. Rinolfi, the head of the Center. He expressed an interest in obtaining some practical results from, for example, applying the more advanced techniques of laser Doppler anemometry (LDA) in the laboratory. I am certain that he was aware of the difficulties involved.

Test Cells

I visited the engine test cells, but since I have not made a similar visit to such US facilities it is difficult for me to make comparisons with US technology. Fiat's test cells are all computer controlled. One of the first test cells contained a standard Fiat engine on which control strategies were being determined on a programmable Bosch controller; interest here was in pollution control and fuel efficiency through a variety of auto scenarios. Control studies such as I viewed on a four-cycle racing engine are reported through the Joint Research Committee (JRC [Volvo, Fiat, VW, Renault, etc.]) which, among its other functions, serves as a center for exchange of advanced research ideas. In another test cell, detailed heat transfer measurements were in progress. Only straightforward though cleverly applied technology was being used to characterize the cooling system of an engine. No effort was being made to determine the interior coolant

flow as is being done, for example, in a water tunnel in Aachen for the German automobile industry.

Laser Doppler Anemometry

The LDA effort at Fiat is based on the Wigley-design apparatus from Austria's AVL company (E.C. 41-3:163-164 [1987]). Fiat purchased a single-channel system in April 1986 and, in cooperation with C. Vafidis at Imperial College, London, UK, has already reported on some inlet flow measurements in a diesel engine. The special, Fiat engine that is being used in these experiments is also being studied by Dr. Coghe at the Technical University of Milan, and a somewhat modified version (see ESN 40-11/12:436-440 [1986]) by J. Whitelaw at Imperial College.

The codes used to analyze the results of flow measurements for this analysis are based on the work of A.D. Gosman at Imperial College and extended by R.J.R. Johns, his student. Thus, the origins of both the Fiat computational work and that at AVL goes back to Imperial College.

The Fiat Center retains F.V. Bracco, Princeton University New Jersey, as a consultant, and he and H.C. Gupta have developed a series of codes for the modeling of combustion in internal combustion engines. There are thus strong ties with both the US and the UK in Fiat's current research effort.

Tribology

Over 10 percent of the energy losses in an engine are due to internal friction. If it were possible to reduce these losses by 50 percent a fuel saving of 2 percent would be realized. There is a JRC and EEC program on measurement of these losses and an experimental setup at Fiat devoted to determining oil pressure and film thickness in bearings. Again, the computer codes for prediction and design of these experiments are based on work in the US--by Booker, at Cornell University.

Injection Sprays

For diesel engines there is a large experimental effort in Europe on analysis of fuel injection sprays. University work in sprays is going on at Milan, Pisa, and Naples. Spray investigations usually rely on the latest laser techniques. At Fiat, one investigation used flash photography to obtain shadowgraphs and schlieren photographs of a Weber injector and other nonconventional injectors. At present, Fiat is installing a commercial laser spray detector, which is based on light diffracted from the particles. To hear of spray studies such as this I sometimes

wonder if anyone ever reviewed the work of the 1950's. In 1955 I worked for Aerojet, who then had an active spray program in liquid rockets, but with different conditions.

Lasers in the Assembly Line

A rather large effort (25 people) is devoted to the application of lasers to the Fiat assembly line. This started in 1976 when a large AVCO welder of 15 kW with a 0.6- to 0.7-mm-diameter spot size was acquired. At the center there are now several commercial CO₂ welders in the range of 5 kW that are fairly advanced--with five-axis cutting systems. The welders are used for deep welding and heat treatment of interior cylinder surfaces. The application of CO₂ welders involves the use of robotic arms and vision systems which are parts of a flexible manufacturing system. The integration of these concepts into automatic manufacturing requires mathematical models of factories and assembly lines. The Fiat center has an active program in this area.

Auto Electronics

The interference effect on the electronic systems in the automobile is an important study recently begun at Fiat. Fiat has just finished constructing Europe's first anechoic chamber for investigation of electronic interference effects in automobiles, and is now in the process of calibrating it. In this particular case I have a direct comparison with American facilities; the chamber at Ford (US) is some two to three times as large as the Fiat facility.

Conclusion

Other activities at Fiat include:

- o Investigations of turbocharged engines (which can result in an increase in performance of up to 15 percent)
- o Advanced research in materials and ceramics
- o Finite element analysis of mechanical and thermal effect in cylinder blocks
- o Aerodynamic investigations of the rear-wing aerodynamic contour on the Lancia racing car to keep it solidly in contact with the ground.

In the part of the center that I visited it is clear that Fiat's research is more applied than basic. There appears to be excellent contact between the center and workers in Italian universities, and there are strong interactions with work in the US.

Daniel J. Collins
7/25/87

ACOUSTIC LEVITATION OF CERAMIC SPHERES

Interesting work is in progress in Karlsruhe, West Germany, in the European Institute of Transuranium Elements (EITE) on ceramic materials at temperatures above 3000 K. A group of workers have constructed a laser-autoclave-acoustic levitation system for containerless heating to temperatures of 6000 K and pressures of 1000 bar. Solids can be heated to above their melting point, and the molten material remains levitated and stable in position.

There are very many interesting features to this system, though it is the acoustic levitation which is of special note and which I describe in this note.

Laser-Autoclave for High Temperatures and High Pressures

The apparatus at EITE consists of pulsed multibeam laser heating of spherical specimens, under pressurized inert gas atmosphere with acoustic levitation. The system is shown in Figure 1. Acoustic levitation suppresses any need for a container for the specimen. Temperature measurements are carried out using a multiwavelength pyrometer and density measurements using a microfocus x-ray shadow technique. All of the systems have been constructed at EITE and are in working condition. Measurements can be carried out on solid and molten forms. The vapor pressures of solids and melts can be determined as well as temperature changes of density, heat capacities, and emissivities. The materials to be examined are UO₂, UN, PuN, and (U,Pu)N.

Background to Acoustic Levitation

Magill et al. (1987) reviewed the various possible methods of levitation before choosing acoustic levitation as the most suitable for the their application. The other methods of levitation are electromagnetic, electrostatic, optical, aerodynamic, ferrofluid, and dielectrophoretic.

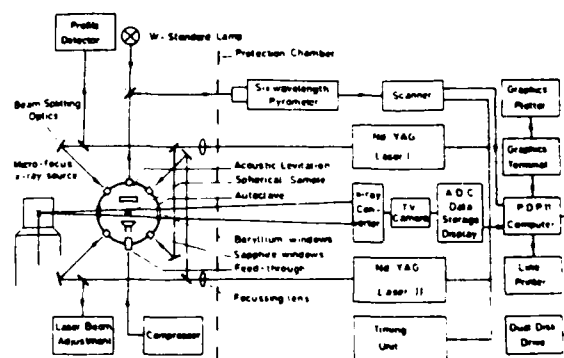


Figure 1. Set-up of laser autoclave technique with acoustic levitation (EITE).

Gorkov (1962) has shown that the force, F , on a small dense sphere in an acoustic standing wave is given by

$$F \propto D^2 \rho V_0^2 (\pi D / \lambda) \sin(4\pi z / \lambda)$$

where D is the diameter of the small sphere, ρ is the density of the gas, V_0 is the maximum velocity of gas displacement, λ the wavelength, z the distance of the sphere from the origin. Levitation occurs when this force is equal to the gravitational force on the sphere.

Some of the optimum and typical conditions discussed by Magill are:

- The maximum diameter, $D(\max)$, of a sphere to be levitated is given by $D(\max) \sim 0.7\lambda$. The optimum diameter, $D(\text{OPT})$, is given by $D(\text{opt}) \sim \lambda/3$.
- A water droplet, of $D=1$ cm in air at 1 bar requires a minimum value V_0 of 9.6 ms^{-1} , the minimum pressure amplitude to be 4×10^{-2} bar, which corresponds to a sound pressure level, SPL, of 163 dB at an optimum frequency of 11 kHz.
- In the case of a sphere of UO_2 , of diameter 0.5 mm, the minimum V_0 is 6.8 ms^{-1} , the minimum pressure amplitude is 2.8×10^{-2} bar, and the optimum frequency is 220 kHz.
- When spheres of diameters 500-1000 μm are used, the optimum frequencies are 100-200 kHz.

The Acoustic Resonator

A standing wave is excited in air between a piston sound source and a reflector, separated by a distance of $n\lambda/2$. The piston sound source consists of a transducer plus shaped horn (see Figure 2). A typical piston reflector distance is 1.2 cm for $n=5$ in air at a sound wave frequency of 70 kHz. The energy requirement is about 10 watts.

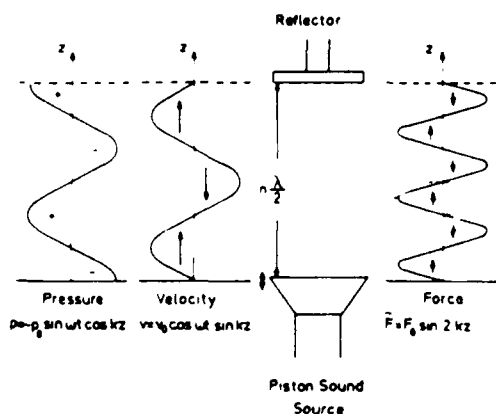


Figure 2. Levitation of spheres in an acoustic standing wave (schematic).



Figure 3. Four spheres are levitated, one at each node. The spheres can remain in position for hours. Sound wave diffraction effects cause the line-up not to be linear near the vibrator.

General Observations

Some general observations made by Magill concerning the experimental results so far are:

1. Spheres of UO_2 of diameter 3 mm, lead spheres of diameter 3 mm, steel spheres of diameter 1 mm, and H_2O spheres of diameter 3 mm have been levitated and remain in stable position for hours--even days.
2. Spheres can be located at each pressure node; in Figure 3, four spheres are levitated, one at each node.
3. The multiwavelength pyrometer constructed at EITE works well. The x-ray shadow technique is partially successful, though improved observational fluorescent screens are required. Atmospheric pressure studies and pressures to 170 bar have been undertaken so far and no difficulties are expected at higher pressures; argon is the only gas used so far. The laser heating system is fully operational.
4. The pulse laser heating induces instabilities at temperatures approaching 3000 K, when the microsphere is ejected sideways. This is considered to be due to the heating of the gas in the vicinity of the microsphere; Magill and coworkers plan to use other rare gases of higher thermal conductivity, such as helium, increase the pressure, increase the size of the oscillator plates, etc. These studies are in progress at present.

Summary

The acoustic levitation system as constructed at EITE permits levitation of spheres of metals, ceramics, and liquids. They can be kept in position for several days. The energy requirement is of the

order of 10 watts, and a simple system can be constructed for relatively small cost, although experience is required in the design of such systems.

Containerless experiments of all kinds can be undertaken using acoustic levitation. The laser system should permit temperatures of 10,000 K and higher.

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Louis Cartz
 8/21/87

CONTAINMENT OF ATMOSPHERIC CONTAMINATION

Important studies are being carried out by J. Magill and coworkers at the European Institute for Transuranium Elements, Karlsruhe, West Germany, on "acoustic scavenging"--that is, acoustic coagulation of aerosols followed by "averaged Oseen drift" collection. Magill is proposing a method of emergency cleaning of open air and water systems by a radically different approach based on high-intensity sound waves. Possible applications being considered are:

- Emergency removal of radioactive and toxic aerosols from the open air
- Removal of poisonous gases from the atmosphere
- Emergency removal of soluble toxic organics from water.

The method is particularly well suited to the case of accidental release of a radioactive cloud into the atmosphere.

The mechanism of acoustic scavenging depends on acoustic coagulation of the aerosol, followed by Oseen force drifting of the particles to the sound source. Acoustic coagulation is induced by high-intensity sound waves (Mednikov 1965), and has been demonstrated for latex aerosols and for $(U,Pu)O_2$ particles by Magill and Pickering (1987). Using sound pressure levels of 160 dB at a frequency of 20 kHz for 5 seconds, a flocculation index (final to initial diameter ratio) of 60 can be achieved. Particles sizes of 0.1 to 1.0 μm become 6 to 60 μm , after irradiation. Calculations indicated that

the coagulation is effective up to 10 meters from the sound source.

Oseen force drifting occurs by particles moving towards the sound source by the averaged Oseen force (Westervelt, 1951; Mednikov, 1965). This force is due to the nonlinear interaction of an asymmetric sound wave with a particle. Calculations indicated that a particle of diameter 10 μm will drift towards the sound source at $\sim 1 \text{ ms}^{-1}$ for a sound source of 160 dB. The velocity increases with the power of the sound source and with the size of the particle. The asymmetric sound wave is achieved by superimposing two sound waves of 20 Hz and 40 Hz with a phase shift of 90 degrees. Magill points out that a transducer array of area $5 \times 5 \text{ m}^2$ is feasible and can treat an air volume of $5 \times 5 \times 10 \text{ m}^3$ in a time of 5 seconds, and Magill has estimated that a cloud of diameter of 100 m and containing a total mass of particles of 500 kg, which is approximately 1 gm^{-3} , can, in principle, be scavenged in 1 hour using a 100-kW acoustic power source (Magill, 1987; Magill and Pickering, 1987).

Magill plans to extend the application to gases by spraying with an absorptive aerosol such as carbon or zeolite particles, and then proceeding to collect the particles with the absorbed gases by acoustic scavenging. It should be possible to carry out the same procedure with liquid suspensions and solutions.

Research Requirements Proposed by Magill

Acoustic coagulation is a relatively well-known phenomenon and has been used to filter out small particles in confined spaces in various industrial processes. Research is required to establish optimum frequencies for use in the open air. Coagulation rates are required for very low mass loadings--less than 1 gm^{-3} .

So far, the theory of particle drifting towards the sound source by the averaged Oseen force has been tested for particle diameter of 200 μm using 300-600 Hz. Research needs to be carried out to determine drift velocities for particle sizes of 5-100 μm under asymmetric sound waves of 1-40 kHz.

The effectiveness of scavenging toxic gases by spraying with absorptive aerosols, needs to be investigated. The absorption process should be enhanced by the presence of a high-intensity sound field, and this, too, ought to be studied. The removal of toxic organic materials from water can be undertaken by adding activated carbon or zeolite powders to the water. The presence of the high-intensity sound field should once again enhance the absorption process.

Further work on these methods should be encouraged because they appear to be

within the realm of the possible and practical.

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Louis Cartz
8/19/87

CERAMICS RESEARCH AT THE NUCLEAR RESEARCH ESTABLISHMENT, MOL, BELGIUM

Like many atomic energy research establishments, the Belgium Nuclear Research Establishment (Studiecentrum voot Kernenergie/Centre d'étude de l'énergie nucléaire [SCK/CEN]) at Mol has diversified into nonnuclear programs. Dr. G. Spaepen is responsible for the overall program and Dr. F. Casteels is responsible for the materials program, which is composed of sections from different SCK/CEN departments. For example, in the Physics Department, studies of metal physics, semiconductors, and amorphous materials are carried out; in the Metallurgy Department, extensive work on powder metallurgy (i.e., oxide-dispersion-strengthened ferritic steel tubes) are investigated; and the Ceramics Department (derived from the earlier nuclear fuel fabrication laboratory) has developed ceramics such as UO_2 and PuO_2 .

The Mol facility has extensive laboratories available for the preparation of ceramic materials. In this note I describe the facilities and research I found during my visit to the Ceramics Department, which is under the direction of Dr. A.J. Flipot.

The Ceramics Department

The clean ceramic preparation facilities that are available in the Ceramics Department date back to earlier work with PuO_2 when very great care was taken to overcome the dust problem when preparing the PuO_2 ceramics. This experience is put

to good use so that the sintering characteristics of ceramics are now being undertaken under very clean and rigorous conditions. The many furnaces are all computer-controlled for precise temperature control. Sintering can be carried out under controlled atmospheres such as N_2 . The preparation of reaction-bonded Si_3N_4 (RBSN) is being investigated--using a (1600°C) thermobalance--by study of the reaction of Si powder compacts with N_2 at 1400°C. The reaction is exothermic, and must be maintained below the melting point of Si; the delicate computer-controlled feedback system developed by the laboratory personnel enables the temperature to be maintained; the progress of the sintering of the RBSN can be followed from the thermobalance data. The computer program enables the nitration to be carried out at a constant rate, with the temperature of the furnace adjusted automatically for this to occur. This has been done with a small specimen that can fit inside the thermobalance. Subsequently, larger Si specimens have been heated in N_2 in larger furnaces, using the same computer program to control the time/temperatures, and this has permitted the nitration of large Si compacts to be carried out at a constant rate.

The department has several dilatometers, and these are used to follow the sintering behavior of ceramics up to 2000°C at pressures to 50 bar N_2 . It also has a Hg-porosimeter for specific surface area measurements, equipment for hot isostatic pressing (HIP) x-ray diffraction, gas permeability sensing, etc. Finally, it is equipped with a large-volume furnace 1 m×25 cm×25 cm capable of operating at 2000°C in a controlled atmosphere.

Lithium Ceramics as Breeder Materials

One particular study is of the sintering of Li_2SiO_3 and Li_2ZrO_3 ceramics that can act as breeder materials--i.e., as possible tritium sources (${}_3\text{Li}^6 + {}_1\text{H}^3 \rightarrow {}_2\text{He}^4$) for fusion reactors (Kwast et al., 1985). The department is also studying the sintering of Li_2SiO_3 and Li_2ZrO_3 ceramics under a multinational European Research Studies (ERS) program to examine a range of Li-containing ceramics.

Flipot et al. (1985, 1986) have been able to sinter Li_2SiO_3 to obtain 96-percent theoretical density ceramics, and the material has an extended open porosity. The characteristics of the raw materials used to prepare Li_2SiO_3 have been shown to be most important. The group uses a precipitated silica powder of high specific surface area in the reaction with Li carbonate; other SiO_2 powders do not react well. This forms a

powder of Li_2SiO_3 , which is found to be highly sinterable. The sintering is carried out at 925-950°C; higher temperatures are found to give rise to lower density ceramics. The presence of fluorine impurity was deleterious. Careful open-porosity measurements were made because of their importance to determine the amount of tritium and helium retained within the ceramic. The Li_2SiO_3 ceramics are being prepared with a range of grain-sizes from 0.5- to 1.2- μm , and a range of compositions to observe the effect of small amounts of a second silicate phase.

Sintering studies on Li_2ZrO_3 are in progress; this ceramic is believed to have the lowest level of retained tritium and helium, exhibits very little swelling, and is the most compatible with steel. The attack on the cladding on steel decreases in the order Li_2O , Li_4SiO_4 , Li_2SiO_3 , LiAlO_2 , and Li_2ZrO_3 . These Li compounds represent the range of ceramics under the ERS study at the various atomic energy establishments.

The Li_2ZrO_3 ceramics are prepared as follows: $\text{Li}_2\text{CO}_3 + \text{ZrO}_2$ are calcined together to give a powder that sinters well. Pressed pellets are sintered at 800-1000°C. Good sintering is attained at 850°C. At this stage, monoclinic and tetragonal Li_2ZrO_3 exist, and the percentage of tetragonal decreases on increase of the sintering temperature. Theoretical densities of 93 percent have been obtained; these densities retain an extended open porosity with mean pore diameter of 0.3 μm .

Experimental studies are continuing on grain size and open porosity, on the stability of the Li_2SiO_3 and Li_2ZrO_3 crystal structures to radiation damage effects of ion bombardment, and on tritium release rates.

Summary

Ceramic sintering and characterization studies are carried out at Mol under extremely clean and vigorous conditions. RBSN is prepared under constant reaction-rate conditions; the computer control for this was established using a thermobalance, and the same computer control program can be used on larger furnaces.

The lithium ceramics, Li_2SiO_3 and Li_2ZrO_3 , are under extensive study to obtain ceramics of high theoretical density yet with an open porosity; this is required for their use as a breeder material for fusion reactors.

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Louis Cartz
8/13/87

SOUTHAMPTON UNIVERSITY TO CREATE UNDERWATER ACOUSTICS CHAIR

The University of Southampton is planning to create a chair in underwater acoustics in the very near future, according to Professor S.A. Thorpe, one of the senior staff members in the oceanography department. If this comes about, Southampton may be the only university in Europe with such a chair. In support of this action, Thorpe expressed the belief that graduate students are not really given the opportunity to work in this field since so few universities offer pertinent courses or have staff members with acoustic interests. The number of marine scientists with strong backgrounds in acoustics is consequently quite small, making the delineation and solution of problems in underwater sound that much more difficult. It will be interesting to see whether other European universities will follow Southampton's lead.

Jerome Williams
7/29/87

REMOTE SENSING PROGRAMS SPONSORED BY THE FRENCH MINISTRY OF RESEARCH

Oceanographic remote sensing activities at the Ministry of Research (MRES) in Paris were described to me by Professor Joseph Gonella, the coordinator of French remote sensing efforts, when I visited him in June. As might be expected, the French are very interested in maximum use of the SPOT satellite, so MRES has an active program to explore novel techniques of extracting applications-oriented information from SPOT images. This program, called Programme Exploitoire et Propetoire SPOT (PEPS),

is being pursued by groups at IFREMER and the University of Marseilles.

One idea being examined is the possible use of sun-glint photos, since these pictures may contain information similar to that in synthetic aperture radar (SAR) images. SPOT is particularly well suited to obtain this type of scene because it is possible to vary both the sensor nadir and azimuth angles by appropriate ground commands. The panchromatic sensor is used, and it is pointed toward the east in the morning. These images have not only been used to study internal waves and eddies in the region of Gibraltar, but they are also being used in the intertidal zone to help in management of oyster fisheries. Work is also being done to directly relate "sea truth" to satellite measurements.

There is some activity by MRES in the area of active sensors as well. A group at the French Meteorological Office interested in scatterometer applications is operating with the TOPEX group in Toulouse in an attempt to enhance both scatterometer and altimeter data by coordination and concurrent use. The possibility of using active sensors in helping to solve beach erosion problems is being addressed by a number of groups working together. These include a modeling group at one branch of the University of Paris, and other modeling, data assimilation, and data validation groups at Toulouse. In addition, at another branch of the University of Paris some basic research involving the physics of radar backscattering is being pursued.

In summary, it appears that MRES is sponsoring a number of very interesting projects aimed at greater use of satellite data in the solution of many marine problems.

Professor Gonella is also connected with the Museum Oceanographie Physique, where, in association with the University of Paris, he is responsible for putting together an academic program in remote sensing. Such a course of study, called "Methodes Physiques de l'Interdetection," is now in place. Completion of this program leads the student to receipt of a Diplome d'Etudes Approfondies (D.E.A.), which is required of all graduate students in oceanography at the University of Paris.

Jerome Williams
7/29/87

DIRECTORY OF EUROPEAN "PHOTONICS" SUPPLIERS AVAILABLE

I have a mini-directory of European firms involved in the development, manufacture, and supply of optical, optoelectronic, electro-optic, and laser devices, and some related electronics. One part of the directory lists suppliers for specific areas (for example, one heading is "Optical components," with subheadings ranging from "Beamsplitters" to "Windows"). The other part of the directory gives an alphabetical listing of suppliers, with complete address, and telephone, telex, and FAX numbers.

I will be glad to send a copy of the 21-page directory to interested colleagues. Address your inquiries to me at ONR London.

Paul Roman
9/8/87

TOPICS RELATED TO NANOMETER ELECTRONICS-- A WORKSHOP SESSION SPONSORED BY ONRL

A small, well-focused, efficient Workshop on Quantum Transport Theory was held from March 2 through 6, 1987, at the conference center in San Miniato, Italy. The organizers of this enterprise were Professor C. Jacobini (Computer Science School, University of Modena, Italy), Professor J.R. Barker (Electronics and Electrical Engineering, University of Glasgow, Scotland) and, from the US, Professor D.K. Ferry (Electrical and Computer Engineering Center for Solid State Electronic Research, Arizona State University, Tempe). Special attention was given to the application of quantum transport theory to nanometer electronics, so crucial in the area of very large scale integration (VLSI).

The principal sponsor of the workshop was the Office of Naval Research in Arlington, Virginia. However, the ONR London Branch Office specifically supported six European scientists whose talks (even though not concentrated in one particular group) constituted a special session, entitled "Selected topics on the physical foundations of nanometer electronics." In this note, I give a brief review of the talks that were presented under ONR London sponsorship.

Jacobini gave a thoughtful introductory lecture on quantum transport theory. He reviewed critically the basic assumptions of the semiclassical treatment of electron transport in semiconductors.

Jacobini concluded that the critical parameter for evaluating the applicability of classical transport theory is the time τ between collisions (as defined by classical theory.) However, in modern devices with dimensions 100 nm or less, the average time between collisions may be as short as 10^{-14} sec, so that most of the classical approximations fail. In addition, the geometrical dimensions of the system become comparable to several characteristic quantum physics lengths (such as the DeBroglie wavelength, or the radius of electron orbits around impurities). Hence, a rigorous quantum theoretical treatment becomes imperative if further progress is to be expected.

Barker gave four presentations. The first three were fascinating discussions of the relation between Green's function techniques, Wigner functions, and quantum transport phenomena. More specifically, the first talk concerned the equations of motion--i.e., the quantum phase space descriptions of transport--and their relation to the thermodynamic Green's function and to the stationary Wigner functions. The nonlocality of the Wigner equation was well illustrated in the context of quantum ballistic transport. A new type of Monte Carlo method, valid for quantum distributions, was described. The second talk focused on transport in strong fields and on weak scattering. Here, again, the Green's function method was used to derive the quantum kinetic equations for weakly dissipative systems of coupled electrons, phonons, and impurities under the influence of strong driving fields. The third talk discussed nonequilibrium scattering. Barker showed that nonequilibrium screening can be described by a generalized dynamic dielectric response function which may depend on the strength of the applied fields. Applications to low-dimensional devices were also discussed.

The fourth talk given by Barker was not closely related to the previous, more general discussions. It concerned the special problems which occur with the description of transport in multiply connected structures (such as ring devices.) One interesting point was the demonstration of a close relationship between the phenomena of universal conductance fluctuations on one hand and the Bohm-Aharonov effect, on the other.

A.P. Jauho (Physics Laboratory, University of Copenhagen, Denmark), gave three talks on the use of Green's function techniques in the derivation of nonlinear quantum kinetic equations for semiconductors. After introducing the concept of contour-ordered Green's functions, Jauho explained how the Kadanoff-

Baym-Keldysh formalism for nonequilibrium quantum statistical mechanics can be derived. He derived general gauge-invariant transport equations for the correlation function, and demonstrated a connection to the Barker-Ferry transport equation. Much attention was given to interacting spectral densities.

While the previous two authors discussed exact, analytic methods suitable for discussing quantum transport phenomena, L. Reggiani (Physics Department, University of Modena, Italy) lectured on numerical techniques which recently have been applied to the analysis and solution of quantum transport equations; he also indicated how these techniques can be used efficiently for modeling nanometer electronic devices. In particular, Reggiani discussed three simple semiconductor systems: resonant tunnelling diodes, quantum-well structures, and high-field operation of silicon devices. The main line of thought of Reggiani's largely tutorial lecture was the illustration of the efficiency of quantum-Monte Carlo simulation procedures for the solution of the Liouville-von Neuman equation. Reggiani's short presentation served as an introduction to a panel discussion on numerical methods. (Unfortunately no records were taken.)

The two remaining speakers supported by ONR London discussed questions related to the quantum Hall effect.

N. d'Ambrumenil (Physics Department, University of Warwick, Coventry, UK) gave three, very thorough tutorial lectures, reviewing current understandings of the quantum Hall effect (QHE) and of the fractional quantum Hall effect (FQHE). He emphasized that the QHE (and also the magnetophonon effect) can be understood in terms of the energy levels for a single electron or quasi-particle in the presence of a magnetic field, the properties of the host lattice, and the electric field. On the other hand, the FQHE cannot be described in terms of a modified one-electron picture.

Finally, L. Eaves (physics Department, University of Nottingham, UK) gave lectures which described the recent experiments of Bliek et al. These studies investigated the size-dependent quantized breakdown of the dissipationless QHE in narrow channels of a two-dimensional electron gas based on GaAs/(AlGa)As heterostructures. Eaves then proposed a model involving quasi-elastic inter-Landau level scattering for explaining the three main features of the experiments. These features are the high breakdown current densities, the magnetic field values of the quantum steps in the magnetoresistance, and the quantized values of the magnetoresistance.

Eaves also talked on his (unrelated) current experimental research (done in cooperation with researchers at the Royal Signals and Radar Establishment and at two French universities) regarding three phenomena in the area of electron tunnelling through heterostructure barriers: magneto-tunnelling, pressure effects, and hot electron effects.

Further information on the entire workshop on Quantum Transport Theory can be obtained from Professor D.K. Ferry, Center for Solid State Electronics Research, Arizona State University, Tempe, AZ 85287, who may also supply interested colleagues the informal proceedings of the workshop.

Paul Roman
8/19/87

EUROPEAN ULTRAVIOLET SPACE OBSERVATORY

The European Space Agency (ESA) is planning to launch in the mid-1990's an ultraviolet space observatory, appropriately named "Lyman." This space observatory will operate in the largely unexplored far ultraviolet regions between 10 and 200 nm, and it is expected to provide important information on the chemical composition and physical characteristics of stars, galaxies, and other celestial objects. The observatory will consist of a special earth-orbiting spacecraft carrying a grazing incidence telescope which, in turn, will serve a set of ultraviolet spectrographs.

ESA already awarded a £250,000 (~\$400,000) grant to the Space and Communication Divisions of British Aerospace, to be used for conducting a detailed feasibility study.

Further information can be obtained from J. Humby, Public Relations Manager, British Aerospace, Space and Communications Divisions, Argyle Way, Stevenage, Herts SG1 2AS. Telephone: (011-44) 438-313456.

Paul Roman
7/23/87

"FRIL" IS COMMERCIALY AVAILABLE

About a year ago I reported in this journal on the development of a very promising new expert system language (ESN 40-7:229-230 [1986]). This language was

dubbed FRIL (Fuzzy Relational Inference Language) by its inventor, Professor J. Baldwin of the Artificial Intelligence Group, Information Technology Research Center, Bristol University, UK. Now I have learned that FRIL was perfected and documented to a degree which allowed for commercialization. It has been launched as a full commercial product by a Bristol-based company, Equipu A.I.R. It can run, among others, on DEC VAX, IBM PC/AT, Apollo, or Prime. Prices run from about \$800 to \$8000, depending on implementation.

FRIL can run all Prolog programs. It has an incremental compiler and, to ensure portability, it is written in C. Baldwin insists that FRIL is ideal for expert systems and adds that the name of the product is somewhat outdated because in the commercial version, while it can accommodate fuzzy sets and operations, the basic inference mechanism is modeled more on probability theory.

Most applications of FRIL, so far developed, are in the area of defense. Another interesting application is the learning theory. This is based on learning "things" not by definitions but rather by usage and function.

For further information, contact Equip A.I.R. Ltd, 184 Hotwells Road, Bristol BS8 4SG, UK, phone (011-44-272) 213427 extension 272; or Professor J.F. Baldwin, Information Technology Research Center, Bristol BS8 1TR, UK, phone (011-44-272) 303030 extension 3380.

Paul Roman
8/19/87

ONRL COSPONSORED CONFERENCES

ONR, London, can nominate two DOD employees for free registration in the conferences ONRL supports. Readers who are DOD employees and are interested in a free registration to one of these conferences should write to the Scientific Director, ONRL, Box 39, FPO New York 09510.

Hypersonics, to be held in Paris, France, 7-11 December 1987.

Controversies in the Social Explanation of Psychological Behavior, Paris, France, 14-16 January 1988.

ONRL REPORTS

To request reports, indicate the report number (in parentheses after the title and author's name) on the self-addressed mailer and return it to ONR, London.

Biological Sciences

Review of Cytoskeleton Research in Cell Differentiation and Development, by Claire E. Zomzeley-Neurath. (7-024-C) Papers given at this conference, held in April 1987 in Granada, Spain, are reviewed. The papers focused on the analysis of the assembly dynamics of microtubules, intermediate filaments, and action filaments to provide the structural basis of the role played by the cytoskeleton in differentiating a variety of cell systems, early embryogenesis, and the biological and genetic aspects of cytoplasmic organization.

Material Sciences

A Joint UK-West German Meeting Discusses Advanced Engineering Ceramics, by Louis Cartz. (7-029-C) Silicon nitride ceramic properties discussed at this meeting in April 1987 included sintering in the presence of silicon oxynitride glass, gas pressure sintering, oxidation problems, and reactions with silicon carbide. Silicon oxynitride glasses are shown to be inherently transparent.

Assessment of Electroceramic Research in Europe and the Middle East, by Robert W. Vest. (7-028-R) European/Middle Eastern research in microelectronics is discussed under four topic areas: dielectronics, sensors, hybrid microelectronics, and non-conventional processing.

Mechanics

European Reacting Flow Research: A Final Assessment, by Eugene F. Brown. (7-027-R) The author provides a sampling of combination research activities in Europe, with emphasis on the work in France, West Germany, and the UK. He states that there is a great deal of diversity in the projects, and in most cases there is strong industrial support. He also reports on the important new European initiatives--the European Communities Combustion Research Program and the European Center on Flow, Turbulence, and Combustion Simulation.

International Conference on the Aerodynamics at Low Reynolds Numbers Between 10^4 and 10^6 , by Thomas J. Mueller. (7-024-C) Presentation made at this conference are reviewed. Topics include airfoil design methods and verification, airfoil calculation methods, low Reynolds number research at NASA Langley, unsteady aerodynamic characteristics, wind turbine applications, separation bubbles, experimental facilities and testing, and remotely piloted vehicles.

AGARD--The NATO Advisory Group for Aerospace Research and Development, by CDR Dennis R. Sadowski. (7-025-C) The AGARD origin, mission, organization, and list of AGARD Panels is presented in this brief summary of an important aerospace advisory body.

Highlights of the 70th Flight Mechanics Panel Symposium on Flight Vehicle Development Time and Cost Reduction, by CDR Dennis R. Sadowski. (7-026-C) Selected presentations given at this meeting, held in May 1987 in Toulouse, France, are reviewed. Topics of the papers include cost estimating, use of CAE-CAD-CAM, prototype manufacturing, and computer-integrated manufacturing.

OVERSEAS TRAVELERS

Notes on trip reports to locations in Europe and the Middle East which have been received by ONRL are reported below. For details, contact the traveler directly.

Chemistry

Traveler: Dr. Alfred H. Lowrey, Laboratory for the Structure of Matter, Naval Research Laboratory, Washington, DC 20375-5000.

Dr. Lowrey attended the Quantum Chemistry Program Exchange (QCPE) Workshop, which was held in July 1987 at Oxford, UK. QCPE is an organization dedicated to

serving as a clearing house and distribution center for software and information relating to the entire field of computational chemistry. This year's workshop featured presentations of extended Hueckel theory, MOPAC/AMPAC (Modified Neglect of Differential Overlap), molecular mechanics and graphical display, and Gaussian-based ab initio theory.

Lowrey states that it is important to recognize that computational chemistry has become the foundation for large-scale efforts in the study of biological materials, pharmaceuticals, reaction mechanisms, and chemical reactivity as well as being integrated into the interpretation of experimental data in such fields as spectroscopy, crystallography, and many laser-based fields of research developed during the last decade.

Energetics

Traveler: Max J. Stosz, Energetics Materials Division, Research and Technology Department, Naval Surface Weapons Center, White Oak Laboratory, 10901 New Hampshire Ave., Silver Spring, Maryland 20903-5000.

Mr. Stosz attended two meetings in West Germany in July 1987. First was the 18th International Conference of ITC on "Technology of Energetic Materials," held in Karlsruhe. The theme of this meeting was "Manufacturing and Processing-Valuation of Product Properties." Since the papers and posters given at this meeting have been published in a bound proceedings (titled "Technology of Energetic Materials") Stosz reports on processor systems, work on insensitive explosives, and other topics of special interest to him.

Second was the annual DEA-AP-71-F/G-7304 "Physics of Explosives" meeting, which was held at Messerschmitt-Bölkow-Blohm (MBB) in Schrobenhausen. Stosz states that the presentation material used at this MBB meeting is being collected for future publication as the meeting minutes.

Oceanography

Traveler: Dr. Thomas Kinder, Naval Ocean Research and Development Activity, NSTL, Mississippi 39529-5004.

Dr. Kinder participated in two meetings of the World Ocean Circulation Experiment (WOCE) Science Steering Committee as a US representative. The first meeting was held at the Deacon Oceanographic Laboratory (DOL), Wormley, UK; the second at Imperial College, London. Both meetings were held in May 1987.

The WOCE has established an International Planning Office at the DOL at Wormley which serves as the staff and central point of coordination for the planning stages of the massive international physical oceanographic experiment that will occur during 1990-1995.

WOCE is a component of the World Climate Research Program (WCRP) which evolved from large global meteorological programs of the 1970's. The WCRP is aimed at improving the understanding of the physical basis for climate, and thus the ability to predict it. Among several goals of the WCRP is the improved understanding and predictive ability for time scales up to several decades, for which the oceans are believed to play a pivotal role. The specific WOCE goals are (1) to develop models for predicting climate change on decadal scales and to collect data necessary to test them and (2) to determine the representativeness of the WOCE data sets with respect to the long-term behavior of the ocean and to find methods for monitoring the long-term changes in the circulation of the ocean.

The international organization of WOCE is complex, involving both intergovernmental and nongovernmental groups. The SSG (Scientific Steering Group, presently chaired by Dr. Carl Wunsch of the Massachusetts Institute of Technology) is jointly sponsored by the Joint Steering Committee (JSC) and the CCCO (Committee on Climate Change and the Ocean).

Much of the active planning for WOCE is going forward under various working groups appointed by the SSG and by national committees. Active national groups have been formed in the US, France, Federal Republic of Germany, Japan, and the UK. Other countries have also expressed an interest or have individual scientists participating in WOCE planning activities (e.g., Australia and Canada). The SSG is actively seeking further participation from other countries.

The US WOCE and International WOCE planning offices have issued a number of useful reports, and the international office distributes a WOCE newsletter. The addresses are: Dr. George Needler, WOCE International Planning Office, Deacon

Oceanographic Laboratory, Brook Way, Wormley, Surrey, UK GU8 5UB; and Dr. Worth Nowlin, Planning Office for WOCE, Department of Oceanography, Texas A&M University, College Station, Texas 77843.

Optical/Optoelectronic Science

Traveler: Dr. Thomas A. Dow, Precision Engineering Center, North Carolina State University, Campus Box 7910, Raleigh, North Carolina 27695-7910.

Dr. Dow visited the Philips Research Laboratory in Eindhoven, the Netherlands, in spring of 1987 and then attended the Fourth International Symposium on Optical and Optoelectronics Science and Engineering, which was held at the Hague.

Dow states that as a corporation, Philips, spends about 7 percent of its annual budget for R&D and of that approximately 1.3 percent is for basic research. He adds that since the R&D entity is not directly related to the commercial units, it is flexible and can respond to basic research needs rather than to the individual operating units. He was given a tour of the Philips precision engineering research facility and was shown several diamond turning and other diamond tools. He also obtained a catalog listing a number of designs that are available from Philips.

Dow was privileged to discuss the current work of the laboratory with Dr. J. Franse, and concluded that the mechanical talent of the Philips staff for producing high-precision mechanical devices is impressive. The traction drives, the laser interferometer feedback technique, and the style of design and fabrication were all excellent.

Presentations at the meeting at the Hague--The Fourth International Symposium on Optical and Optoelectronic Science and Engineering (SPIE)--were grouped into three subject areas: sensors, precision fabrication, and control. Sensors, or sensor systems, discussed included one that uses a laser diode source and a pair of lenses to measure reflected light to determine if it is focused on the surface, and another that uses the reflection of a laser light in conjunction with rotating table to determine the angles of diamond tools. Phase measuring interferometers were also discussed.

The second general area of interest at the conference concerned the understanding of fabrication processes which could be used for precision optical or mechanical surfaces. Of particular interest here was the fabrication of ceramic and glass materials by single point diamond turning and grinding.

Very little was presented on the subject of control, and the author concludes that a particular need still exists to relate the understanding that is being developed of the fabrication process to control that process and improve the precision of the final product.

Ultrasonics

Traveler: Dr. Walter M. Madigosky, Non-Metallic Materials Branch, Naval Surface Weapons Center, White Oak Laboratory, Silver Spring, Maryland 20910.

Dr. Madigosky attended the 16th convention of the Ultrasonics International Conference sponsored by the journal *Ultrasonics*, and held in July 1987 in London, UK. This year's conference featured a full-day tutorial session, "Pathways of Ultrasound," which consisted of nine lectures by internationally known experts in ultrasound who sought new insights into the fundamental as well as the advances in applications. Madigosky states that this session provided a link between the basic physics of the various ultrasonics phenomena and the specific, highly specialized work that was presented in the general conference.

Topics of the sessions in the main conference were: visualization, propagation, acousto-optics, NDT composites, laser-generated ultrasound, nonlinear acoustics, medical and biological ultrasound, high-power ultrasonics, underwater acoustics, acoustic microscopy, signal processing, NDT mathematical, transducers, surface waves, transducer materials, measurements in physics, and materials characterization. Madigosky says that, overall, there appeared to be an increased use of surface waves, a revival of molecular acoustics, and rediscovery of ultrasonics for material evaluation.

REPORTS ON EUROPEAN SCIENCE AND TECHNOLOGY FROM OTHER COMMANDS

Information on each of the reports listed below was furnished by the activity identified by the abbreviations for that office. Requests for copies of or information about the document of interest should be addressed to the appropriate office:

USARDSG--US Army Research Development and Standardization
Group, Box 15/65, FPO New York, 09510-1500
EOARD--European Office of Aerospace Research and Development,
Box 14, FPO, New York 09510

Multidiscipline

Scientific Highlights, (Spring 1987), a quarterly report by the US Army Research Development and Standardization Group (UK). (28 pp) [No number assigned. Request by title from USARDSG.]

This report presents summaries of selected European research and technology projects concerned with physics, material sciences, chemistry, mechanics, electronics/computer sciences, and environmental sciences. The report also includes lists of future workshops and conferences in the various disciplines.

Chemistry

Propellant Research Activities at ONERA, by MAJ Scott Shackelford, European Office of Aerospace research and Development. (17 pp) [EOARD-LR-87-39.]

The Office National d'Etudes et de Recherches Aérospatiales (ONERA) belongs to the French Ministry of Defense and is a large laboratory which conducts fundamental in-house research for all facets of defense-related aeronautic development. ONERA's Chemical Propellant Division has completed a comparative fundamental combustion mechanism study on double base and HMX-containing composite missile propellants and reached some interesting conclusions which complement and support a recent Air Force in-house condensed phase deuterium isotope effect research study on the HMX combustion mechanism, theoretical performance prediction and experimental verification studies on propellant ingredients and formulations. These latter predictions and verification studies include modeling and performance behavior in rocket motor design for integrated rocket/ramjet application.

Life Sciences

6th Meeting on Aeronautic and Space Medicine, Paris, France, by MAJ Jim McDougal, European Office of Aerospace Research and Development. (2 pp) [EOARD-LR-87-57.]

The French Société SOFRAMAS sponsored a meeting on aerospace medicine at the Paris Air Show on 15 June 1987. Ten papers in French were presented and discussed. Four sessions included; (1) medical fitness aspects of helicopter, acrobatic and physically handicapped pilots; (2) ergonomics, medical fitness, and psychological profiles of air traffic controllers; (3) astronaut selection, cardiovascular and sensory motor adaptation to weightlessness, and disturbances in calcium metabolism due to weightlessness; and (4) air transportation of patients on national and international flights. These papers will be published in the Société's journal.

Material Sciences

Thermal Plasma Research, by LTC Jim Hansen, European Office of Aerospace Research and Development. (4 pp) [EOARD-LR-87-62.]

Some of the most advanced research in thermal plasma spraying in Europe is led by Professor Fauchais at the University of Limoges, France. They are world class in experimentation and diagnostics of thermal plasma sprays. Capabilities to measure sprayed particle surface temperature and evaporation in flight are remarkable. Coatings produced from their research include thermal barrier, wear resistant and corrosion resistant coatings of various ceramics. They also study plasma ejected during laser impingement on metals and laser chemical vapor deposition.

Damage Mechanics for High Temperature Materials at a Leading French University, by LTC Jim Hansen, European Office of Aerospace Research and Development. (2 pp) [EOARD-LR-87-59.]

The Laboratory of Mechanics and Technology, at a French university in Cachan, specializes in research of damage mechanics for sophisticated aerospace materials.

Materials tested include high-temperature metals for turbine disks and carbon-carbon composites. Basic research in damage evolution in these materials is carried out for large aerospace companies, such as SNECMA and Aerospatiale.

Mechanics

Unsteady Aerodynamics in Scotland, by LTC Robert C. Winn, European Office of Aerospace Research and Development. (34 pp) [EOARD-LR-87-75.]

Professor R.A. McD. Galbraith at Glasgow University has an outstanding experimental facility for the study of unsteady aerodynamics. He is able to pitch a large airfoil (1.5 feet chord x 6 feet span) at rates up to 350°/s. He is able to produce sinusoidal, sawtooth, or any other airfoil pitching motion. This report consists of a brief discussion of the capabilities of the lab and copies of some papers covering recent work.

Fluid Mechanics at Lyon, by LTC Robert C. Winn, European Office of Aerospace Research and Development. (2 pp) [EOARD-LR-87-71.]

The Institute that Professor Mathieu founded over 20 years ago is still producing excellent work in several areas of fluid mechanics. What began as an institute for studying turbulence has now grown to also include specialization in turbomachinery aerodynamics (velocity measurements between blades of a supersonic compressor), atmospheric modeling (earth boundary layer with a temperature inversion), acoustics (active and passive duct and jet noise reduction), and hydrodynamics (two phase flow). This report covers some of the potential areas of cooperative research.

Boundary Layer Transition Studies, by LTC Robert C. Winn, European Office of Aerospace Research and Development. (26 pp) [EOARD-LR-87-70.]

Researchers at the University of Paris are performing fundamental work in the transition of boundary layers from laminar to turbulent. They are studying the role of three-dimensional processes in the transition. Specifically, they are analyzing the formation, growth, and stability of counter-rotating vortices with axes aligned with the flow direction known as Gortler vortices. Using very precise test conditions and a very clever method of flow visualization, they have been able to pinpoint the conditions at which these vortices will form. This report consists of a brief description of their work and facility and a copy of a paper on the subject.

Physics

Laser Research at the University of Lyon, by Stacey Lazdinis, European Office of Aerospace Research and Development. (5 pp) [EOARD-LR-87-42.]

The Laboratoire de Spectrometrie Ionique et Moleculaire at the University of Lyon is performing research in COIL, Fast Ion Beam Laser Spectroscopy, Rydberg excitation spectroscopy, and new solid-state laser material development.

SCIENCE NEWSBRIEFS FOR NOVEMBER

The following issues of *Science Newsbrief* were published by the ONR, London, Scientific Liaison Division during November. *Science Newsbrief* provides concise accounts of scientific research developments, meeting announcements, and science policy in Europe and the Middle East. Please request copies, by number, from ONR, London.

Number

- 5-10 Meetings on: Polymer for Marine Environment (UK), 14-16 October 1987 Composites for Naval Construction (France), 16-18 March 1988
- 5-11 Polymer Science Meetings in Europe 1987-1988

NOVEMBER MAS BULLETINS

The following *Military Applications Summary (MAS) Bulletins* were published by the ONR, London, Military Applications Division during November. The *MAS Bulletin* is

an account of accomplishments in European naval research, development, test, and evaluation. Request copies of the *Bulletins*, by number, from ONR, London.

Number

- 41-87 New "No Sweat" Ventilated NBC Protective Suit
- 42-87 Advances in Laser Range Finding and Hi-Resolution CRT Display
- 43-87 Ocean Data Buoy
- 44-87 French Underwater Hull Painting System
- 45-87 Maneuverable Towed Survey Vehicle
- 46-87 Innovative Low/Medium Level Tripods and High Performance Tracking heads for
Electro-Optical Instruments
- 47-87 Ferranti Defence Systems Unveils "Penetrate"--An Integrated Mission Sys-
tem For Covert High-Speed Low-Level Penetration
- 48-87 Ferranti Experimental Underwater Laser Television
- 49-87 British Aerospace Conducts Study for European Mobile Communications Satellite
System

A NOTE ON THE NEW
ESNIB

Distribution of this document, ONRL's initial *European Science Notes Information Bulletin (ESNIB)*, marks an important and natural stage of evolution in the manner that ONRL informs the US R&D community of the current European scientific activity.

It is essential to the ONRL mission to report as much of that activity as possible. Over the past year, we have added new sections in *ESN* on trip reports by US scientists travelling to Europe, abstracts of reports by other commands, and items of interest reported by US embassies. Thus, our primary document, *ESN*, was gradually taking on a new shape, a new dimension, a new scope--even a new sort of function.

The next logical step in the process of supporting the mission--and our readers--is to issue the information we gather when, by topical importance, technical significance, breadth of coverage, or general interest it should be put in your hands. Thus, the new *ESNIB* will be issued according to the dictates of the information which becomes available to us. We do not know how often the information we are gathering will dictate its distribution. In any case, our aim is to fulfill our mission in the best possible manner, and that translates into serving your needs more fully and more efficiently....Incidentally, you, gentle reader, remain on the distribution list.

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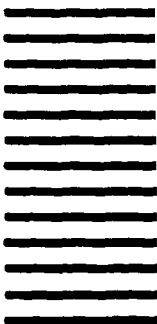
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