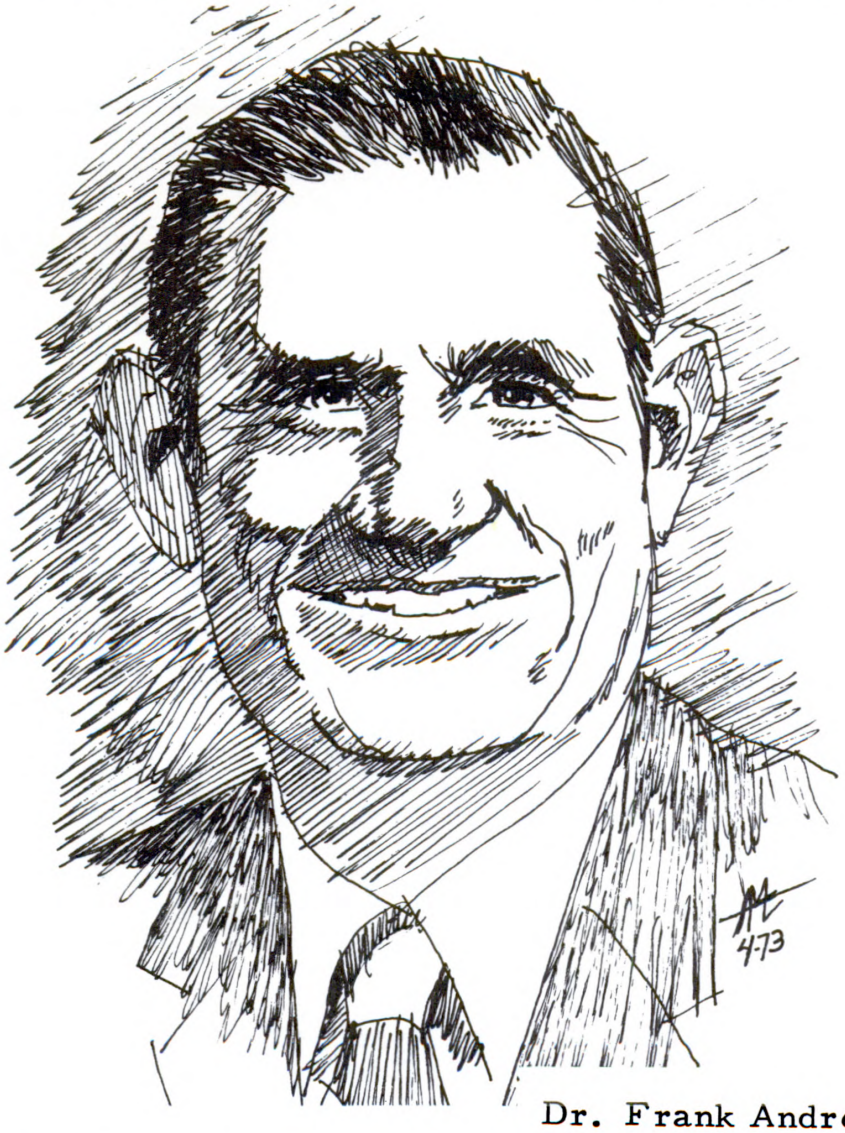
NAVAL RESEARCH

REVIEWS

APRIL 1973

PROFILES IN SCIENCE



Dr. Frank Andrews

Dr. Andrews is the first Visiting Research Professor at the U.S. Naval Academy. He is on sabbatical from Catholic University where he teaches in applied mathematics and sonar systems and is Principal Investigator for the Office of Naval Research sponsored acoustics research project.

While at the Naval Academy he is teaching midshipmen majoring in Operations Analysis the fundamentals of underwater acoustics as it relates to sonar detection phenomena.

Dr. Andrews graduated from the Naval Academy and received a Ph.D. in Physics from Yale. In 1964 he retired from the Navy as a Captain. While on active duty he commanded various submarines, was Chairman of the Science Department at the Naval Academy and was Commander, Submarine Development Group Two.

He has continued to make outstanding contributions to the Navy by participating in many significant projects. He served as a member of the analysis and technical advisory teams employed by the Navy in the search for the lost submarine SCORPION and the search for the H-bomb off the Coast of Spain. In addition, he has acted as an advisor to the Navy in several other technical matters including the MK-48-O va. MK-48-1 torpedo selection process. He is presently serving on the Laboratory Advisory Committee for Undersea Warfare Labs.

Overview of Research at the U.S. Naval Academy

Richard D. Mathieu*
U.S. Naval Academy

In order to make its activities better known to the Naval and research communities the Director of Research for the Naval Academy organized this issue of Naval Research Reviews. The Office of Naval Research provides the base or "seed money" for support of a broad program of independent research for faculty and midshipmen. When a project is started and looks promising it is usually funded in full by an interested government or civilian sponsor. The three articles which follow describe such projects.

Why Research

"There is wide acceptance of the proposition that scholarly activity other than teaching is a necessary aspect of academic endeavor. It is natural to assume that a faculty member who engages in such scholarly activity is more likely to be intellectually dynamic and more keenly attuned to advances in his discipline than one who is not. The professional growth that is a result of such activity increases the ability of the teacher to provide greater scope and depth to the inquiring student. In short, scholarly activity complements and reenforces good teaching." These words, which are taken from the Naval Academy research policy statement, provide the broad justification for research activities by the faculty at the U.S. Naval Academy.

No institution of higher learning can hope to attract or retain an intellectually vigorous faculty unless it provides and maintains a climate favorable to research. The Naval Academy is deeply involved, and properly so, in a variety of research activities, the principal objective being to expose midshipmen and faculty to the experience of *on-going learning* by offering them opportunities to participate in meaningful projects. It is quite clear that research is not the primary function of the Naval Academy, but it is an important auxiliary support to the teaching mission, and provides midshipmen with the best undergraduate education possible in the recently instituted majors.

Research opportunities also permit the Naval Academy to:

- Stimulate the professional growth of both civilian and military faculty members.

*Dr. Richard D. Mathieu is Director of Research at the U.S. Naval Academy. He was Liaison Scientist in Aeronautics at ONR London 1970-71.

- Employ distinguished scholars from other institutions as Visiting Research Professors.
- Expose midshipmen to the technical offices and laboratories of the Navy.
- Support Navy R&D programs, through basic and applied research, as well as project type work.
- Develop and maintain up-to-date laboratories.
- Make more effective use of laboratory facilities.
- Provide relevant educational feedback in elective courses, seminar courses.
- Invite timely guest lecturers.

To be meaningful, a research program must include both research conducted by the midshipman in connection with his major field of study, and research conducted by the faculty to insure that they remain current in their fields. The Naval Academy is currently engaged in both types of research.

Facilities

Through a forward looking modernization program, the Naval Academy has developed excellent facilities. A wide variety of up-to-date physics, chemistry, environmental, and electronics laboratories are housed in the relatively new Chauvenet-Michelson Hall complex. The very fine time-sharing computer system, with 150 remote terminals throughout the academic departments, has enhanced both the academic program and the research activities immensely.

The Naval Academy Library provides midshipmen and faculty members with comprehensive library service in support of the curriculum, research, and recreational reading programs. The new Nimitz Library building, Figure 1, to be dedicated in September 1973, will house approximately 750,000 volumes and accommodate approximately 1700 readers, using a combination of study tables, study carrels, over 200 listening stations, seminar study rooms and lounge furniture. A remote computer terminal with direct access to the Defense Documentation Center will also be located in the new library.

Completion of the new Engineering Studies Complex in 1975, Figure 1, will provide a full range of engineering laboratories equipped with the latest "state of the art" equipment. Included will be a fully computerized tow tank with low- and high-speed carriages, a coastal-engineering basin, rotor-lift laboratory, pressure-testing tank, structural-testing facilities, marine-propulsion test cells, and a greatly expanded aquarium system for biological and oceanographic studies.

Figure 1 — Artist's conception of the new USNA Engineering Studies Complex and Nimitz Library

All of this, when considered along with the continual up-grading of both the civilian and military members of the faculty, provides the Naval Academy with unique research capabilities.

Midshipmen Research Activities

A relatively strong midshipmen research program is now active in both the Trident Scholar program and research project courses. Each semester approximately 100 midshipmen enroll in engineering and science project courses for academic credit. Another 75 midshipmen enroll in seminar and independent study courses in fields such as economics, political science, and history.

During the summer of 1971, five upper class midshipmen majoring in Systems Engineering were engaged in research projects at the Naval Weapons Laboratory, Dahlgren, Virginia. Areas of investigation ranged from hybrid computer simulation of trajectories with realistic drag parameters to digital simulation of ASW tactics and optimization of weapons suits on DD963—class of ships. During the summer of 1972, five other midshipmen conducted research in similar NWL-sponsored projects in broad fields of weapons development and mathematical modeling.

During the present semester, several midshipmen are working closely with Dr. E. C. Fischer, Naval Research and Development Center Annapolis Division, to determine the pollution effects of anti-fouling paints.

Trident Scholar Program

The Trident Scholar Program came into being in 1963, during Rear Admiral Charles S. Kirkpatrick's tour as Superintendent. The purpose

of the program is to provide exceptionally capable students with an opportunity to engage in independent study and research during their first class or senior year.

Midshipmen standing in the top ten percent of their class are eligible to submit proposed research projects and programs of study for evaluation by the Trident Scholar Committee. Those selected are designated as Trident Scholars. A Scholar works independently on his research, under the supervision of one or more faculty advisors who are well acquainted with the field of study. He carries a reduced number of courses, his research and thesis constituting the major part of his academic program for the year.

The program was started with six Scholars in the Class of 1964 and has since had approximately fifteen Scholars each year. Topics range from "An Appraisal and Critique of Futurism with Special Emphasis on the Navy's Utilization of the Process" to "Gaseous Cavitation in an Acoustic Stationary Wave."

Very often the projects lead to significant publications. For example, Trident Scholar Robert D. Smith, Class of 1972 wrote a paper entitled "Parameters Necessary for Analyzing Thermal Bioassays on Marine Fish," which was published in the *Journal of the Sanitary Engineering Division,* American Society of Civil Engineers.

Others have received national awards. In 1969 Trident Scholar Donald H. Tanka received the National Undergraduate Student Award of the American Institute of Aeronautics and Astronautics. His project was an experimental investigation of turbulence on the wall of a pipe.

This program is particularly beneficial for those midshipmen who in later years may command naval laboratories or manage research programs.

Faculty Research Activities

Faculty research is also a viable program in which well over one hundred of the faculty participate in funded research projects. Space does not permit elaboration on or even a listing of the wealth of research activities being carried out by faculty members. The projects range from parachute aerodynamics, vortex dynamics, acoustics, cavitation, signal processing, cosmic-ray astronomy, and amorphous semi-conductors to studies of the economic development of Latin America, economic aspects of pollution control in the Navy, and occupation and race in the Navy. Three of the projects are discussed at length in subsequent articles in this issue of *Naval Research Reviews.*

During the past two years, emphasis has been placed on initiating interdisciplinary projects. The result has been development of significant efforts in the areas of acoustics, cavitation, and signal processing;

computer graphics; operations analysis; environmental protection; and quantitative political science.

Environmental Protection

The interdisciplinary Environmental Protection Project, sponsored by the Chief of Naval Development and monitored by Commander Paul Petzrick, USN, is of considerable interest. A team effort supported by ten faculty members from the disciplines of chemistry, physics, marine engineering, mechanical engineering, ordnance engineering, ocean engineering, economics, and political science, is being coordinated by Professor Jerome Williams of the Environmental Science Department.

The effort began by reviewing the Navy's R&D Environmental Protection program. A report describing the Navy's input to the Department of Defense Area Coordinating Paper on Environmental Qualtiy followed.

At the present time, team members are engaged in specific and applied research related to: ordnance pollution, oil pollution, with emphasis on source prevention; waste disposal; key parameters for a meaningful data base; and the political, economic, and legal aspects of environmental protection.

The goal of the interdisciplinary team is to develop expertise in environmental protection. The emphasis is on naval interests, and the involvement of midshipmen will assure that future naval officers are aware of the Navy's responsibilities in protecting the environment.

Cooperative Program

Special impetus has been given to our research activities by the recent signing of a memorandum of understanding that formalizes a Cooperative Program for Scientific Interchange between the Naval Research Laboratory and the Naval Academy. The joint interactions are expected to be of benefit to both parties. On the one hand, they should increase the scope and effectiveness of instruction provided to midshipmen at USNA, and provide them with more opportunities to become aware of areas of science and technology that will significantly affect future naval systems. On the other hand, they should permit the scientific expertise of faculty members to be applied to research projects at NRL, thus providing another opportunity for faculty members to do current research in a dynamic environment.

Additional and more specific programs are being developed in Electronics Engineering Research and Advanced Design Concepts.

Concluding Remarks

It can be said that in research, the Naval Academy is moving from a casual relationship with the Navy and other sponsors to one that is based upon faculty expertise and areas of mutual interest.

The increased research activity has resulted in both faculty and midshipmen participating to a greater extent in professional societies, presentation and publication of scholarly activities, and liaison with other research laboratories and academic institutions.

The over-all result is to bring more meaningful information into the classroom—and, consequently, to provide the Fleet with more knowledgeable Naval Academy graduates.

NRL Develops Technique to Determine Source of Air Masses

Scientists at the Naval Research Laboratory's (NRL's) Ocean Sciences Division have developed a technique using Radon 222 gas which is in the atmosphere, to determine the source of areas of air masses.

NRL investigators say fundamental knowledge of cloud and fog formation is necessary for improving the accuracy of weather forecasting and, more importantly, developing means for cloud and fog control. The Navy in particular is interested in different air masses which are associated with marine fog.

Since the sources of atmospheric Radon 222 are primarily from diffusion of this rare gas from land areas of the earth's surface, measurements of abnormally high Radon 222 help to identify air masses which had recently traversed land areas.

The NRL technique has been used to determine the types of air mass as related to marine fog characteristics. A recent expedition to the Greenland Sea has shown the feasibility of tracing air mass trajectories over long distances through Radon studies.

Radon 222 measurements made recently by NRL researchers on the windward side of the Hawaiian Islands and near the equator in the Pacific Ocean confirmed the constantly low concentrations in marine air masses. Kilauea volcano plume yielded no excessive Radon 222 concentrations.

Brain-Wave Research

Karel Montor*
U.S. Naval Academy

The primary emphasis of brain-wave research at the United States Naval Academy is on its practical applications, although theories are also investigated.

Research has been multi-dimensional, and this paper will report our areas of concentration and findings in a chronological order, rather than trying to establish an order of research importance.

During the spring of 1971 after an exhaustive literature search various researchers in the field were consulted. Among other things, it was learned that extensive sleep research was being performed as well as evaluation of individuals with abnormal electroencephalograms (EEG). It was decided that research at the Academy would not duplicate the work of others, and would build on the wealth of material available at the Academy—primarily the existence of a wide range of normal subjects who have indicated a keen interest in volunteering for neurological measurements.

In the summer of 1971 a laboratory capable of measuring one channel of EEG was established and, through the use of analog and digital filters, divided the wave form into three major components: 4 to 8 Hz (Theta), 8 to 13 Hz (Alpha), and 13 to 30 Hz (Beta). The equipment was designed in such a way that switches closed when the individual wave, Theta and/or Alpha and/or Beta, reached any level between 5 and 100 microvolts that had previously been determined (Figure 1). By using digital clocks and counters activated by the switch closures, it was possible to obtain direct readouts of individual brain-wave activities (Figure 2). The analog/digital filtering system is also capable of analyzing narrower band widths, *i.e.,* 6 to 7 Hz, *etc.*

The present equipment configuration can simultaneously analyze two different brain areas, provide written wave-form analyses, and tape-record EEG signals for future analysis of data. Besides the ability to record 8-channel EEG, the Academy can transfer brain-wave signals to its TD 100 and PDP-15 computers.

The first study, undertaken in the fall of 1971, involved the identification of those members of the upcoming graduating class whose cumulative grade point averages were either between 3.50 and 4.00 or between 2.00 and 2.25. Fifty percent of both groups volunteered, with EEG

*Karel Montor is involved in both teaching and research as an assistant professor in the Department of Management Science at the United States Naval Academy. His research has been funded by the Naval Academy Research Council.

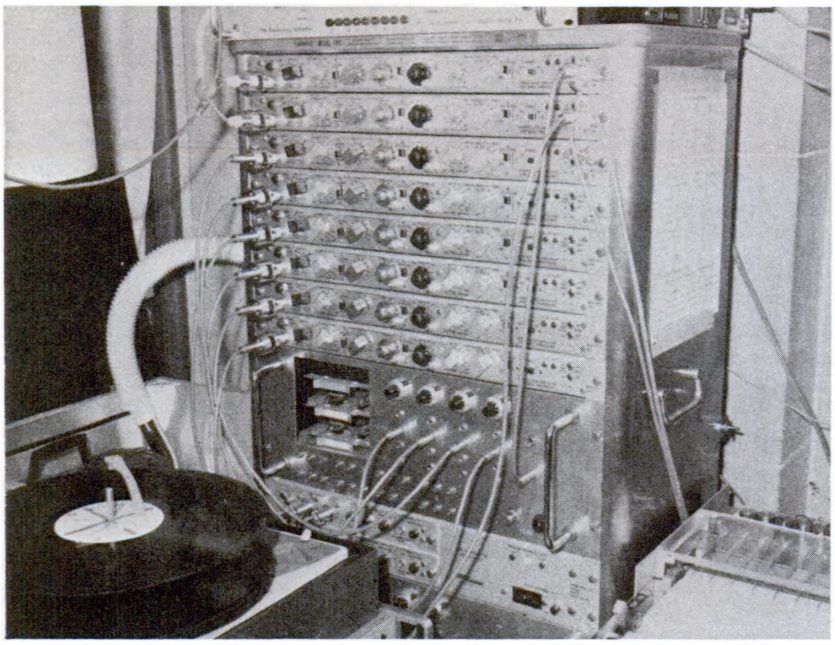


Figure 1 — Eight Channel EEG on top with A/D filter and converter system below.

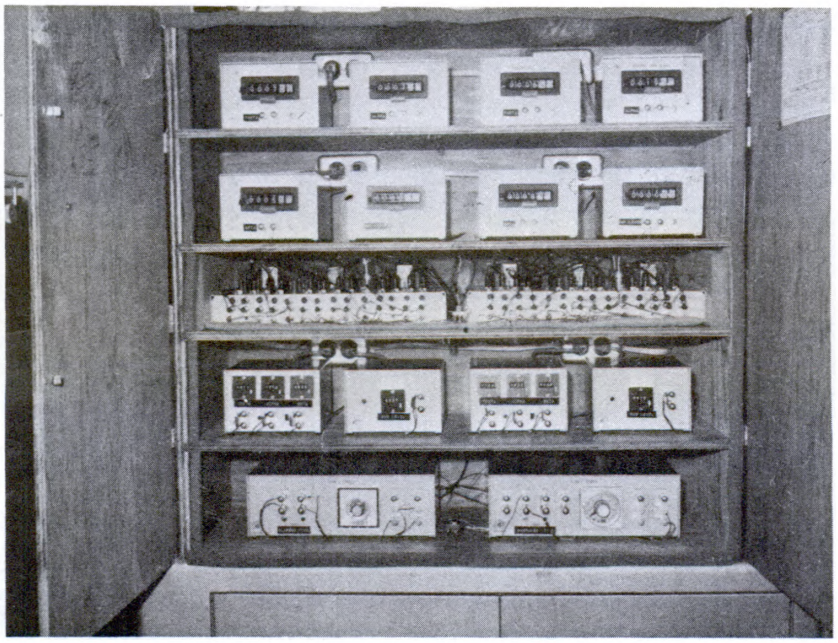


Figure 2 — Digital clocks top two rows, control and counters next two rows, Attention Level Analyzer—bottom row

analyses used to insure normality and detect muscle action that could interfere with neurological analysis. Twenty-five from each group were finally selected. It should be noted that the support and cooperation of the Neurology Branch of the Bethesda Naval Hospital under the direction of Dr. Brannon have been outstanding, and without them we could not have accomplished what we have.

The two groups of 25 were administered a variety of tests to measure their brain-wave activity while resting, solving problems, and under stress. The results indicated a significant difference in brain-wave activity between the two groups with the following differences being significant at the .05 level. The high group produced greater amounts of Alpha when they were resting and had significantly different brain-wave production when they were resting or solving problems or under stress.

In the winter of 1971-72 the volunteers were allowed to use the equipment to study their own brain-waves, or even learn to control them—this in return for their willingness to volunteer. The reactions of one such midshipman are interesting. He was a literature major who enjoyed writing. Using an insulated keyboard, he spent 20 minutes every evening for a week typing stories. As might be expected, the EEG record, except for one 10-minute period, was completely confounded by muscle artifacts. At the end of the week, the subject was asked which he thought was the best passage he had written—he immediately picked the material written during the 10-minute, muscle-free recording. Did his deep concentration block the muscle signals?

During the spring of 1972 twenty men were identified whose academic performance had remained the same for over six months during their plebe year and was in the range of 1.75 to 2.00. (A = 4.00, B = 3.00, C = 2.00, D = 1.00). Ten of these men were taught Alpha control. One man learned such fine control that he could send Morse code on command, though at a slower rate than with his hand. Another man learned to view his wave form on a scope, and control its amplitude.

This is a limited long-range study designed to determine whether this type of control can help a student with his academic studies. While, at this point, there is no significant difference between the two groups, it is interesting to note that those who learned Alpha control and who formerly had trouble going to sleep at night—now do not.

During the summer of 1972 the Laboratory was expanded and observations made as to wave forms exhibited when individuals shifted from concentration to aimless daydreaming. Significant variations were noted, and it became possible to tell when a person who was reading the words of a book—was thinking about something else; working a math problem—but thinking about his girl friend; looking at equipment operating—but thinking about what he would do during his next leave.

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These observations lead to the development of an "Attention-Level Analyzer," into which can be dialed the level of concentration an individual is using plus an allowable daydreaming factor (Figure 3). When the individual exceeds the allowable daydreaming factor, he will be so alerted by a tone. If he continues to daydream beyond an acceptable limit, a second alarm will sound, notifying a third person. The following applications for this development are suggested: Notifying a pilot, either on an approach or during a long-distance flight, that he is not applying his full capabilities, making sure that a long distance truck- or bus-driver cannot fall asleep at the wheel, allowing air-controllers, radar and sonar operators, and their supervisors to know when sufficient attention is not being paid to the task at hand. This device will work with about 75% of the population—and might in fact be a guide in selecting personnel whose attention levels can be monitored. It may also be useful in teaching persons how to concentrate—this will be investigated.

Forthcoming research will build on the developed ability to determine a person's anxiety levels while he is being conseled. It is now possible to tell on-line while talking with an individual and simultaneously looking at his EEG, whether he is reacting positively or negatively to words of the counselor, and even to tell his reaction to his own words. The effort will be directed toward measuring the effects before and after counseling to establish whether some accountability can be

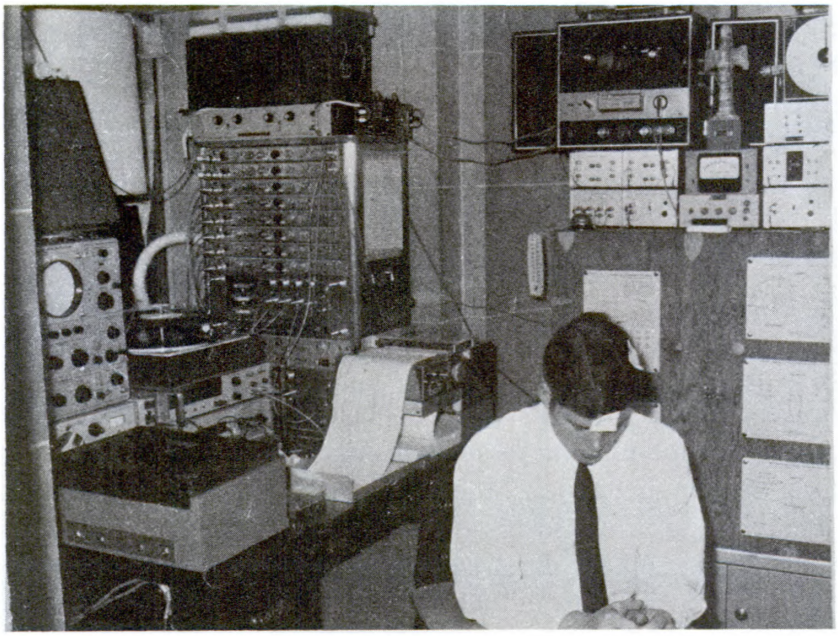

Figure 3 — Tone notification to midshipman who is not thinking about words he is reading

added to the counseling situation—whether an empirical change can be established.

The TD100 has shown that a light flashing, say at 14cps produces a brain-wave signal of 14 Hz, though there is a delay between the time when the light is flashed and when the brain-wave spike is produced (Figure 4). An attempt will be made to verify some of the efforts of Dr. Ertl, of Ontario, who has found some relationship between the through-put speed of a light stimulus and scores on conventional intelligence tests.

Another area we expect to look at is the wave form exhibited by an individual during his identification of oral or visual signals, thus permitting third parties an opportunity to evaluate the recommendations of persons making such identifications. In general, it can be said that there are unlimited areas for investigation and the Academy Brain-wave Laboratory is available for cooperative research with other agencies.

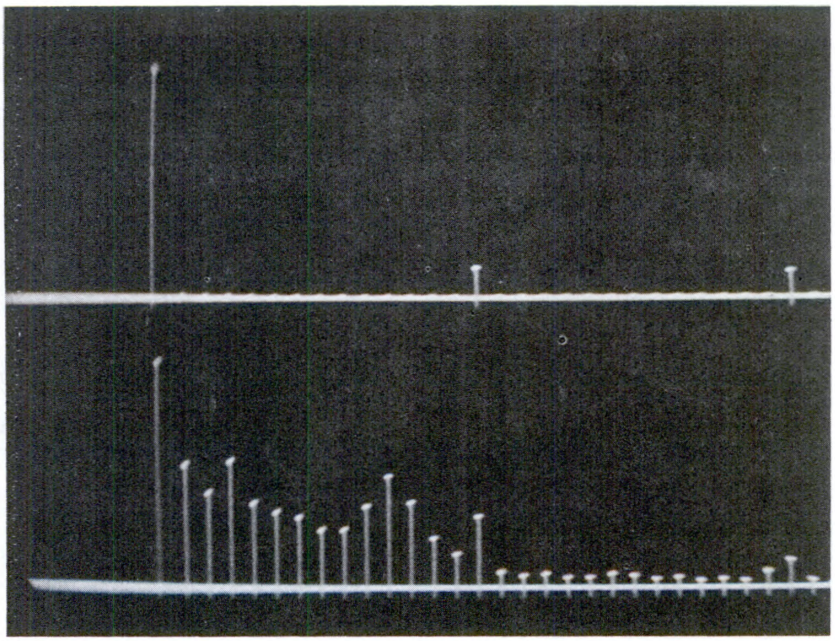

Figure 4 — Top line indicating a 24 Hz flashing strobe, bottom line indicating power at 14 Hz

Project FATHOM: Research in Foreign Affairs

Rodney G. Tomlinson*
U.S. Naval Academy

One of the important components of the National Security Studies Program at the U.S. Naval Academy is the study of foreign affairs. Midshipmen pursuing the National Security major may elect a number of courses that are heavily involved in the fundamental concepts of international politics.

The study of foreign affairs is divided into two camps—a traditional, or literary approach, which uses description as a primary tool to speculate on outcomes of political episodes, and a scientific approach, which seeks to classify international political phenomena by replicable, systematic, data-based research.

Verbal descriptions by participants, scholarly secondary studies, and a keen intuition are important resources of the literary approach.

The scientific approach, on the other hand, takes the same information and assigns it to categories which can be counted. The present trend seems to indicate that foreign affairs research is shifting from the literary to the scientific mode.

This move towards quantitative political studies means that we need better research tools and information-handling facilities to augment our traditional literary/descriptive sources.

Project FATHOM (Foreign Affairs Theory, Operations, and Monitoring) is the name given to the activities at the U.S. Naval Academy that support the scientific study of foreign affairs.

Its objectives are:

(1) To establish and maintain data files that will support classroom instruction in the fundamental concepts of international politics.

(2) To develop and maintain a set of complementary data-handling and statistical-analysis programs.

(3) To provide programs to students who wish to collect and study their own data. Useful products of such enterprises will be added to existing files for use by others.

(4) To support student work on models of the international system by providing test data.

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*Mr. Tomlinson is an Assistant Professor of International Relations in the Department of Political Science. His field of research is computer-assisted analysis of international political behavior.

FATHOM provides midshipmen with computer programs and quantitative data to study international political theory and to monitor the operations of international politics.

FATHOM is a potpourri of data files and computer programs, rather than a fixed package of formalized data-handling procedures. Its discipline lies in centralized coordination of data-file structures and the ways programs exchange operating commands and pass data to one another. All programs are written in modules, and each one needs only minor alterations for application to different data files.

Some features found in conventional social science data-handling packages are de-emphasized here. We do not, for example, develop "generalized" (or multi-task) programs if doing so means wasting computer space with esoteric program features and infrequently used control options. In the Naval Academy's time-sharing environment it appears preferable to concentrate on efficient and simple programs and to leave control functions to the user. For this reason program interfaces and data interchange receive primary attention. The thought behind this procedure is that a properly trained user can easily select appropriate specialized programs and operate them in their proper sequences. This experience, we believe, is a valuable part of problem solving. We observe that most students soon master the step-by-step approach and its essential program commands.

All midshipmen attend computer-programming classes, in which the essentials of computer operation and programming are presented. Thus, many of the fears about computers are dispelled before they begin using FATHOM programs. Most midshipmen can be described as "informed users." They require very little re-introduction to computer operations before they proceed to research.

The general classifications of our data originate in the Systems Perspective of Foreign Affairs pioneered by Charles A. McClelland of the University of Southern California. In the McClelland formulation, data are identified by "sets" of labels—"descriptors." These descriptors are useful because they act as links between levels of detail in the data, facilitating changes in the amount of specificity delivered in response to researcher's requests. For example, in one instance a "macro" view of the International Political System might be useful while, in another, "micro" analysis is appropriate. The former replies to the question "what's going on in world politics?" and the latter responds to queries about the state of affairs within a nation.

Two major data files—the World Event/Interaction Survey (WEIS) and the United Nations General Assembly Voting Record—have been implemented since FATHOM began in September, 1972. Charles McClelland created the former as part of the WEIS Project sponsored by Advanced Research Projects Agency (ARPA). The maintenance

activities for the WEIS data moved to the Naval Academy in October, 1972. Updated material for this file is forwarded to the U.S. Naval Postgraduate School, Monterey, California, and to the University of Southern California in Los Angeles. The collection is kept current by a professional foreign affairs analyst employed in Washington and funded by ARPA.

The UN Voting Record began as an experiment in converting tabular data collections to the McClelland format. The results proved so promising that the collection will be retained and augmented. A team of midshipmen and this writer are gathering additional information for inclusion later this year. We are gratified by the interest that other federal agencies have shown in these data collections. On recent occasions the U.S. Department of State found these files useful in addressing substantive foreign policy questions.

We have on hand three large collections of data on the attributes of nations and a file showing world trade for the past seven years. All this information is scheduled for implementation this summer.

Figure 1 shows the linkages between programs. Five classes of data have been identified as being unique enough to warrant special attention. Because the Naval Academy computer services about 50 customers simultaneously via time-shared terminals, and more than 90 users are connected during peak hours, program speed and size are important design criteria. In order to allow optimum adjustments for each file, all programs in development are modular. Although, to the present, we remain within the maximum core limit of sixteen thousand words per running program, we do on occasion exceed the thirty-two-second run time allowance. While these criteria are advisory and not absolute limits on system capabilities, multiple violations of these ground rules could seriously degrade the system's performance.

Data retrieval programs are tailored to each data file. They are: (1) a cross-tabulator for WEIS-type files; and (2) a Table Retriever for conventional tabular structures. As we noted earlier, the WEIS structure has more flexibility, including a narrative-text-handling option, but it demands more computer resources than do most of our tabular files. It remains, however, our best compromise between file flexibility, program speed, and overall operating effectiveness.

Figure 2 illustrates the narrative-text processing program. The output shown is the result of a keyword search of the Political Behavior File for "PUEBLO."

The analysis of contingency tables is the heart of quantitative research. We see this process as having three parts: (1) The storage, retrieval, merging, and transformation of tables; (2) Statistical analysis; and (3) graphic presentation of the inferred relationships. We chose not to use

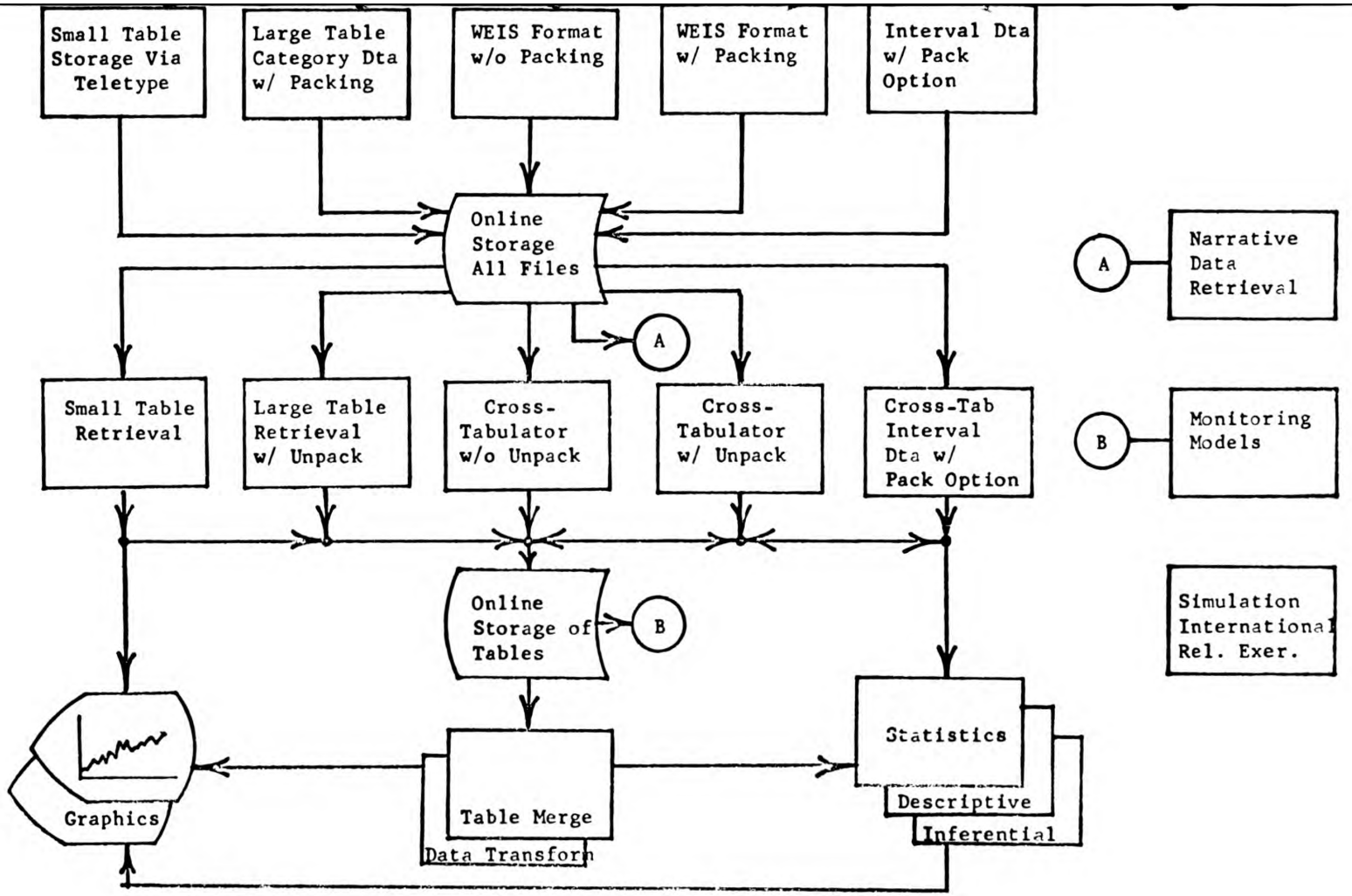

Figure 1 — The linkages between programs. Five classes of data have been identified as being unique enough to warrant special attention.

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RUN

TEXSCAN   (COMPILED)  19 JAN 73  11:50

ENTER DATA BOUNDARIES(LOW,HIGH IN THE FORMAT YYMMDD)
? 680101,681231
ENTER ACTORS
? ALL
ENTER EVENTS
? ALL
ENTER TARGETS
? ALL
ENTER ARENAS
? ALL
DO YOU WANT TO USE TEXT SCAN OPTION? YES
INPUT KEYWORDS SEPARATED BY COMMAS(UP TO 5 MAX)
? PUEBLO
DO YOU WANT TO SEE THE ANALYTIC DATA? YES


 680124                                              740  23  999  0
JAP OFFICIALS EXPRESSED DOUBT THAT PUEBLO INCIDENT WOULD DEV-
ELOP INTO DECISIVE MILITARY CONFRONTATION BETWEEN USA AND KON

 680125                                              2  142  731  0
USA SAYS CONFESSION ATTRIBUTED TO PUEBLO CMDR BY KON PROPAG-
ANDISTS WAS TRAVESTY ON FACTS

 680125                                              2  94  399  0
USA CALLED FOR URGENT MEETING OF UNO SC TO CONSIDER GRAVE
SITUATION ARISING FROM SEIZURE OF PUEBLO BY KON

 680125                                              365  23  999  0
USR PRM ASKED FOR REACTION TO CAPUTRE OF USA PUEBLO TOLD RE-
PORTERS TO ASK KOREANS

 680125                                              732  121  731  0
KOS FM SAID HE HAD SENT UNO SG MEMORANDUM DENOUNCING KON COMM-
ANDO INFILTRATION AND SEIZURE OF PUEBLO AS MOST GRAVE THREAT
TO PEACE

 680125                                              2  94  399  0
USA REQUEST FOR UNO SC MEETING ON SERIES OF DANGEROUS AND
AGGRESSIVE ACTIONS BY KON CULMINATING IN SEIZURE OF PUEBLO

 680125                                              2  121  731  0
USA REQUEST FOR UNO SC MEETING ON SERIES OF DANGEROUS AND
AGGRESSIVE ACTIONS BY KON CULMINATING IN SEIZURE OF PUEBLO

 680125                                              732  102  2  0
KOS PRM URGED USA TO TAKE STERN ACTIONIN RESPONSE TO KON SEIZ-
URE OF PUEBLO AND RECENT INCREASE IN INFILTRATION INTO KOS

 680125                                              365  121  2  0
USR ACCUSED USA OF DANGEROUS PROVOCATIONS BY SENDING INTELLI-
GENCE SHIP PUEBLO NEAR KON COAST

 680125                                              731  111  2  0
KON REJECTS USA DEMAND FOR RETURN OF PUEBLO
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Figure 2 — Narrative text processing program. The output shown is from the political behavior file for "PUEBLO."

multi-task programs in these applications, because in our local time-sharing environment they appear to waste resources.

We see active user participation in table creations, merges, transformations, analyses, and display as a valuable methodological exercise. The graphics tasks have been simplified and expanded, thanks to the generous assistance of Professor David A. Rogers, of the Department of Aeronautical Engineering, who has made available to us his computer graphics programs.

In addition to our general data-handling group of projects, we have a number of special-purpose projects underway. The most ambitious is the implementation of LCOL George Draper's "International Relations Exercise" (IRE) simulation now in use at the Industrial College of the Armed Forces.

Midshipmen first class Gary T. Ariniello and Mathew C. Lechleitner are constructing specialized mathematical models for monitoring international behavior. Midshipman Ariniello's device measures a variety of actions of nations with the Information Theory statistic "H"-(uncertainty). His work follows earlier efforts by Charles McClelland and this writer. The previous findings suggest that measurement of the actions cast on the international stage by nations as they conduct their foreign affairs might help to detect the onset of crises. Ariniello's model will assist in studying this important proposition.

Midshipmen Lechleitner is looking at ways to monitor behavior with volume measures of international political events. His model uses the statistic "standard deviation" as a yardstick to compare present levels of international activity with those that past practice and history would lead us to expect. Figure 3 is a computer plot of the behavior pattern of the Soviet Union and Czechoslovakia before and after the 1968 invasion. This illustration was prepared from data contained in the political behavior file and passed to a model similar to Lechleitner's.

Professor John A. Hutchins' World Communications file is well underway. Using "circuits per month" as his unit of analysis, Hutchins measures the formation and decay of nodes of international communication. His effort lays a groundwork that enables midshipmen to study international communications flows.

Recent experiments by Professor Charles A. Cochrane and this writer suggest FATHOM programs could also be useful in handling data on domestic affairs.

In the past 5 months Project FATHOM has appeared to be gaining support among faculty members interested in pursuing quantitative studies of politics. Its broader applications are beginning to appear; hopefully this trend will continue and will lead to increased multi-disciplinary contributions to political studies at the Naval Academy.

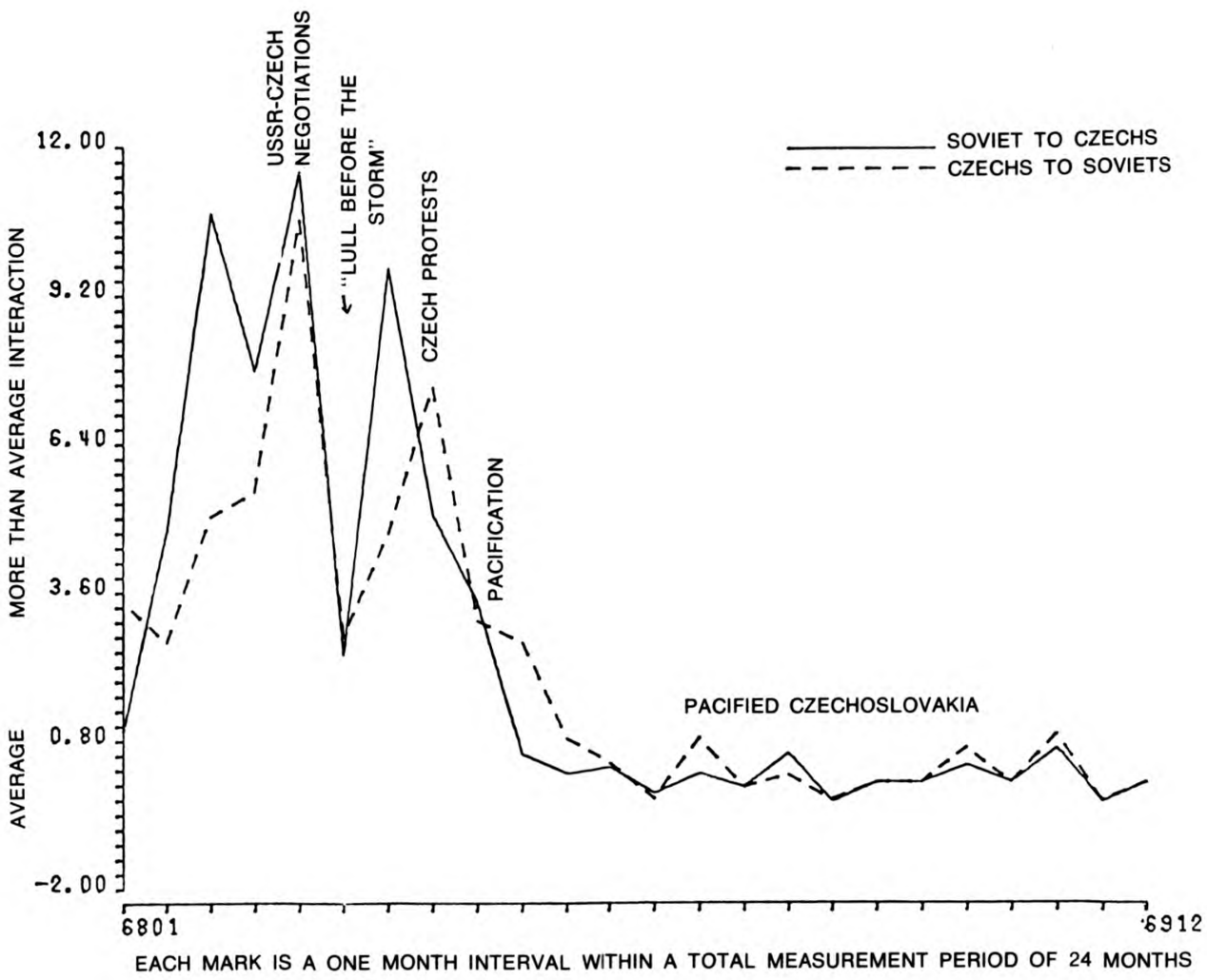

Figure 3 — A computer plot of the behavior pattern of the Soviet Union and Czechslovakia before and after the 1968 invasion.

Acoustic Cavitation Inception in Water

Lawrence A. Crum*
U.S. Naval Academy

Introduction

Cavitation is a major engineering problem of great interest to the Navy because of its effect on various hydrodynamic and acoustical systems. Cavitation erosion of ship appendages can be a major problem; an upper limit to the sound intensity radiated by an active sonar array is introduced by cavitation in the water in the vicinity of the array; and a major source of ship noise that can be monitored by passive sonar systems is associated with collapsing bubbles, or cavitation.

Cavitation is also of interest to the pure scientist as a physical phenomenon. The collapse of a spherical vapor cavity in a liquid may produce temperatures as high as 6000 degrees Centigrade and pressures as high as 10,000 atmospheres (1). If gas is contained within the collapsing cavity, the high temperatures and pressures often causes the gas to luminesce brightly enough to be seen by the naked eye. Cavitation inception can signal the incidence of a high-energy particle, provide a measure of the tensile strength of liquids, and accelerate the rate of chemical reactions (2-4). Cavitation has also been used to study the rupture of living cells by sound fields and to verify the existence of macroscopic quantized vortices in liquid helium II (5,6). Cavitation is often initiated by the physicist through acoustical means. The development of modern ceramic transducers that can produce sound pressure amplitudes of several atmospheres has allowed cavitation to be easily generated in the laboratory with a minimal amount of equipment.

Of primary interest to the pure scientist is the question of the threshold for cavitation inception. Normally, experimental values of the cavitation threshold are much below that predicted analytically. For example, vaporous or transient cavitation can be produced in degassed, distilled water with negative sound pressures on the order of 5 atmospheres while the theoretical value may be as high as several hundreds of atmospheres (1).

It is the purpose of this paper to describe a simple experiment that was initiated at the Naval Academy by Midshipman J. B. Gallemore, Trident Scholar 1971, and continued by the author who served as his

*Dr. Lawrence Crum is an Associate Professor in the Department of Physics and is currently ONR Research Professor at the Naval Academy.

project advisor (7). The project was concerned with the nucleation problem in acoustic cavitation—specifically, to determine the role surface tension plays in nucleation and its effect upon the threshold for cavitation inception.

First, the experimental conditions of the problem will be presented, showing how the threshold for cavitation inception was obtained as a function of surface tension. Next, a discussion will be given of a simple equilibrium theory which attempts, unsucessfully, to predict how the threshold should vary with surface tension. Finally, it will be shown that a successful explanation can be made of the dependence of the threshold upon the surface tension if proper account is made of the role of surface tension in the critical nucleation process.

Experimental Measurements

The resonator used to produce the cavitation was simply a cylindrical, ceramic transducer, filled with water and driven at one of its natural frequencies by an oscillator and power amplifier. The transducer is shown in Figure 1. The cylinder was closed at one end by cementing over it a tightly-stretched, stainless-steel foil membrane, and open at the other. The transducer dimensions, 3 in. high by 3 in. o.d. by 0.25 in. thick, enabled it to be driven in a stationary $(r, \theta, z) = (2, 0, 1)$ mode at 35 kHz, the mode normally used to produce cavitation.

The stationary sound field produced within the liquid could achieve pressures as high as 25 atmospheres with the power amplifier used. It is perhaps in order now to carefully describe the type of cavitation observed.

Three types of cavitation can be observed when a liquid such as water is placed under acoustic stress. At acoustic pressure amplitudes of the order of less than 1 atmosphere in a stationary sound field, water that has not been sufficiently degassed will effervesce bubbles that appear to originate from the interior of the liquid and then rise to the surface. This behavior is pseudo-cavitation in that it really involves the rapid growth of small air bubbles by rectified diffusion and not the violent growth and collapse of a cavity that signifies cavitation. When pressure amplitudes approach 1-2 atmospheres, streamers of air bubbles will be seen throughout the intense portion of the sound field; this behavior is often accompanied by "hissing" and "frying" sounds that probably signify true cavitation, *i.e.*, growth and collapse of cavities. Since this behavior is basically associated with air bubbles, it is commonly called "gaseous" or "stable" cavitation (8). Finally, at pressure amplitudes above approximately 5 atmospheres in water, audible snaps can be heard and feathery tracks can be observed that signify the violent "vaporous" or "transient" cavitation that will be discussed herein. It

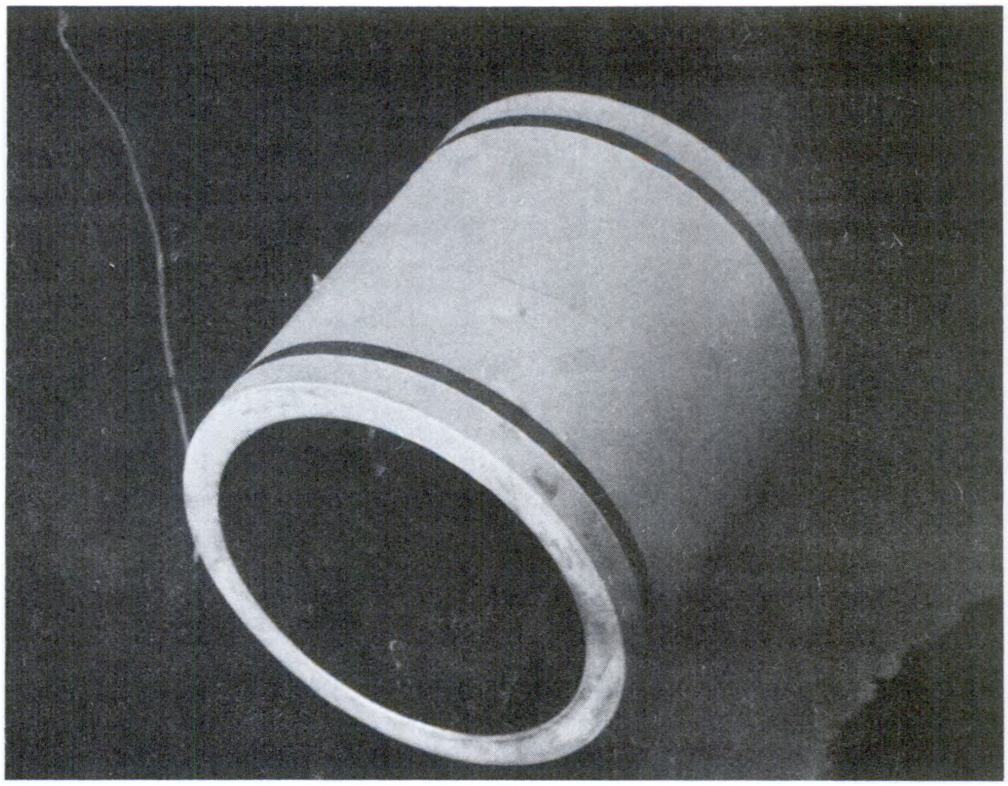

Figure 1 — Photograph of acoustic resonator used to produce cavitation

is interesting to note that Greenspan and Tschiegg (2) have observed that if water is meticulously cleaned to remove from it all traces of particulate foreign matter, often called motes, there appears only one type of cavitation—the transient, violent type at thresholds on the order of 250 atmospheres. It is commonly assumed, then, that in liquids that are not meticulously cleaned, there are sites or centers where cavitation originates called nuclei. These nuclei could be small air bubbles, gas entrained in cracks on the surfaces of imperfectly wetted, microscopic pieces of solids, or other devices that would allow cavitation to originate without rupturing the bonds between the liquid molecules themselves. The specific role that nuclei play in cavitation inception and growth is a source of major concern.

In the experiment discussed here, the water in which cavitation was generated was degassed so as to prevent the two types of gassy cavitation from occurring and only transient cavitation, which has a well defined threshold was observed. Figure 2 shows a photograph of cavitation taken under stroboscopic illumination (9). In the figure, cavitation occured in the approximate center, and the collection of microcavities associated with the event was propelled out of the more intense portion of the sound field toward the transducer walls. The time-exposure photograph made under stroboscopic illumination thus shows the cavitation

Figure 2 – Photograph of transient cavitation. Here the stroboscopic flash interval was 2.4 msec, the acoustic pressure amplitude at the antinode was 4.7 atmospheres, and the maximum velocity achieved about 100 cm/sec. The diameter of the largest cavity was approximately 1 mm.

zone of microcavities as it moved through the sound field. The velocity of the particular cavity here was approximately 100 cm/sec and its lifetime about 10 milliseconds.

The experimental situation that was used to obtain the variation of cavitation threshold with surface tension was then quite simple. Degassed, distilled water was placed in the cylindrical transducer, its surface tension measured with a tensiometer *in situ* and the threshold for transient cavitation then obtained. A small amount of surfactant, or surface tension reducing agent was then added, the surface tension remeasured, the threshold remeasured and so on.

Figure 3 shows the variation of the threshold for transient cavitation inception *versus* the surface tension for degassed, distilled water; the circles are the experimental points and it is noted that in general, higher values of the surface tension give lower values of the threshold pressure.

Some Theoretical Ideas

It is appropriate now to see what would be expected on the basis of theory. Little work has been performed on the theoretical threshold for transient cavitation, probably because little is known about the early stages of cavity growth. Since cavitation nuclei may take on a variety of forms, it is difficult to construct an appropriate model.

Blake (8), however, has applied simple equilibrium theory to determine an approximate threshold for transient cavitation that depends upon the surface tension. It is instructional to consider some of his ideas.

Suppose that there exists in the liquid free nuclei that are composed of small air bubbles. Of course, surface tension would undoubtedly

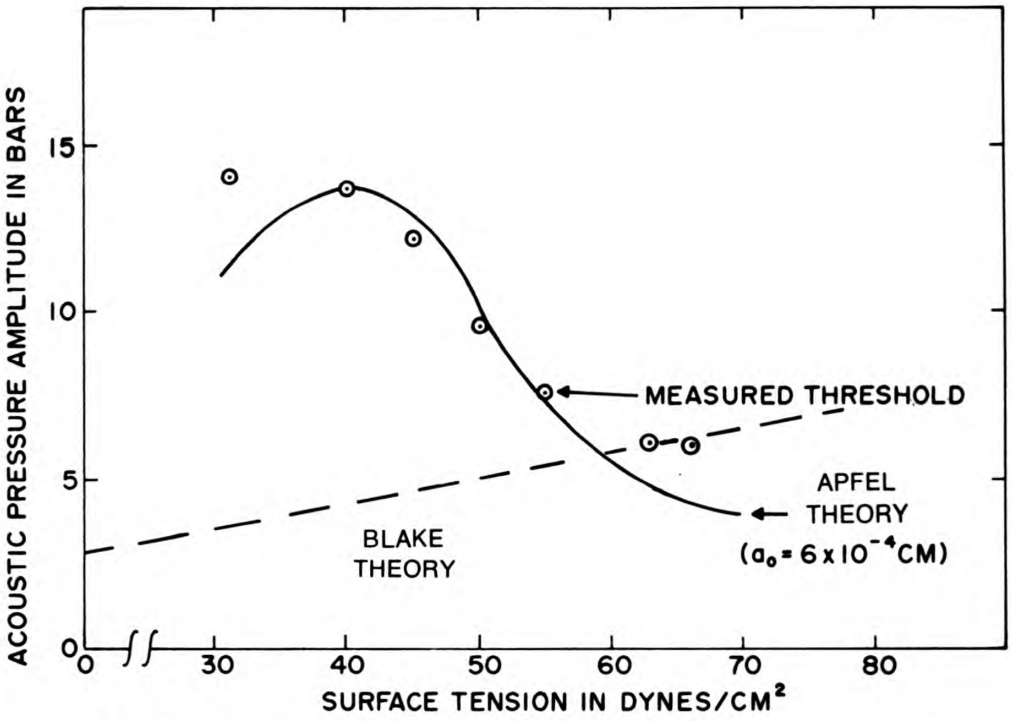

Figure 3 — Variation of the threshold for transient cavitation inception versus surface tension for cavitation in distilled water at 35 kHz. The circles are the experimental points, the dashed line the theory of Blake and the solid line the modified theory of Apfel.

cause them to dissolve rather quickly but it is useful to consider the relation of free nuclei to cavitation thresholds by this simple model.

If one assumes that these free nuclei exist in the liquid, then it is easy to determine the conditions that will determine whether they will grow or dissolve. Specifically, the pressure balance at the interface of a gas bubble or free nucleus of radius R_n is given by

$$P_n + P_v = P_{L_0} + 2\sigma/R_n, \tag{1}$$

where P_n is the pressure of the gas within the nucleus,
P_v is the vapor pressure of the liquid,
P_{L_0} is the ambient pressure, and
σ is the surface tension.

It is seen that due to diffusion of the gas through the liquid-gas interface, free nuclei will normally dissolve due to the surface tension. They may be stabilized by various means, however, and this concept shall be treated later. For the present, let us assume that the nucleus is present in the liquid with the above equation applying. If the pressure is now suddenly reduced, say with the application of a stationary sound field

of pressure amplitude P_A, then the maximum negative pressure in the liquid, P_L, in the vicinity of the bubble will be

$$P_L = -P_A + P_{L_0}. \tag{2}$$

The nucleus will then tend to expand to some critical size, R_c. The concept of critical size means that a nucleus with a radius greater than R_c will not exist in equilibrium. It will become "unstable," and its radius will increase without bound. Although its motion can no longer be predicted by a simple equilibrium theory, it can be predicted by dynamical theory. In principle, then, once a nucleus grows to a radius greater than R_c, the cavity size will increase without bound and the threshold for cavitation is said to have been achieved. The threshold for acoustic cavitation P_t is given by the equilibrium theory of Blake to be

$$P_t = P_{L_0} - P_v + \frac{4\sigma}{3\sqrt{3}\,R_n}\left[1 + (P_{L_0} - P_v)\frac{R_n}{2\sigma}\right]^{-1/2} \tag{3}$$

A plot of P_t *versus* σ for typical values of the other parameters is shown in Figure 3. It is obvious that very poor agreement is obtained between theory and experiment. We must conclude that the surface tension must affect the threshold in a very different way other than that described by equilibrium theory.

The Effect of Surface Tension Upon Nucleation

The poor agreement between the simple equilibrium theory of Blake and the experimental data is most probably due to the basic assumptions concerning the nuclei that initiate the cavitation. It is generally assumed that motes or solid, particulate impurities present in most liquids possess cracks and crevices that contain entrained gas. The gas in these crevices is probably released during a negative pressure cycle and can serve as a nucleus for cavitation. Surface tension largely affects the way entrained gas is stabilized in a crevice in a mote and the poor agreement between theory and experiment implied that proper account must be made of the effect of surface tension upon the nucleation process.

Figure 4 is intended to depict a conical-shaped crevice, containing entrained air, in a mote. Here a_0 is the radius of the crevice mouth, R is the radius of curvature of the spherical gas-liquid interface, 2β is the apex angle of the cone, and α_R is the receding contact angle of the gas-liquid interface.

Various authors have discussed how nucleation could occur from gas entrained in such a crevice (10,11,12). The basic idea is that in the

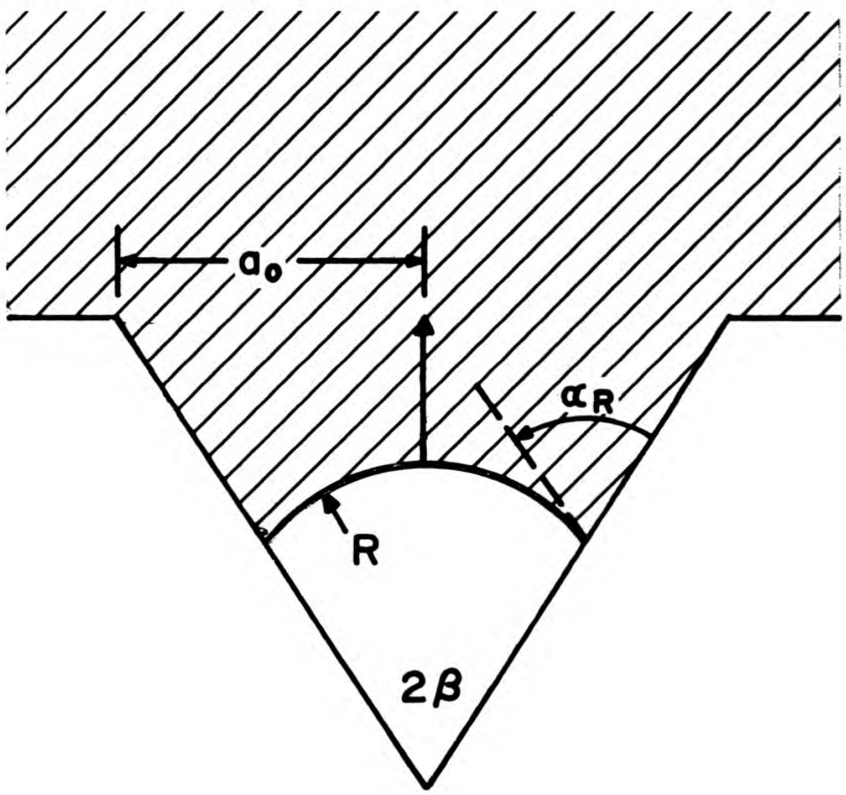

Figure 4 — Diagram showing model for nucleation of entrained gas from a conical crevice in a mote

negative portion of the pressure cycle, the interface will recede whenever the contact angle of the gas-liquid interface reaches the receding contact angle. If the interface recedes to the crevice mouth, then it is possible for nucleation to occur. It is obvious that surface tension would greatly affect the curvature of the interface and play an important role in determining what particular conditions are necessary for nucleation. Because motes are microscopic and the behavior of entrained gas in crevices has never been studied in any detail, the exact conditions for nucleation that depend upon the surface tension have never been determined.

In order to obtain more knowledge concerning nucleation from a mote, we have constructed macroscopic models of a mote and made quantitative measurements of the radius of curvature, and receding contact angle of the receding gas-liquid interface.

The macroscopic motes or "macromotes" were constructed by heating and drawing down glass capillary tubes until they formed conical crevices. Because glass is hydrophyllic and most motes are thought to be hydrophobic, the crevices were coated with a transparent, hydrophobic substance, polyethylene. Air was entrained at the bottom with water at the top and then the pressure was slowly reduced until the

interface receded up the crevice. Motion pictures were made of the receding interface for various surface tensions and analytical measurements determined from prints made from the movie film.

Figures 5 and 6 show frames taken from a movie of the receding interface for two surface tensions. In Figure 5 the surface tension was approximately 70 dynes/cm; in Figure 6 it was approximately 30 dynes/cm. It is obvious from the figures that surface tension affects the behavior of the nucleation process tremendously. From analysis of the movies it is also possible to qualitatively explain how surface tension affects nucleation, and how these nuclei lead to the particular dependence of the threshold upon surface tension. As the interface recedes with high surface tension, it remains nearly flat, probably not producing a nucleus until it reaches the mouth of the crevice. The nucleus thus formed is relatively large. On the other hand, the interface that recedes with low surface tension becomes very bowed, and can produce a nucleus long before it reaches the crevice mouth. The nucleus thus formed is relatively small. Since the pressure required to cause the nucleus to grow is proportional to the ratio σ/R, it is possible that the small nuclei formed at low surface tensions gives a larger value of the ratio σ/R than the larger nuclei formed at high surface tensions. This possibility is made rather convincing by the quantitative measurements of the receding contact angle determined from the movie and applied to the theory of Apfel (12).

Apfel has treated the problem of nucleation from a conical crevice in an imperfectly wetted solid and his analysis can be modified to apply here. He has shown that a relationship exists between the receding interface and the threshold for cavitation inception. Specifically, his equation for the threshold acoustic pressure amplitude is given by

$$P_t = \gamma P_s + P_v - 2\sigma/R_0, \tag{4}$$

where P_s is the equilibrium pressure of the gas dissolved in the liquid,
P_v is the vapor pressure of the liquid, and
γ is a constant between 0 and 1 that depends upon the rate of cavity growth.

Also, R_0 is the effective radius of the cavity nucleated from the crevice and is related to the geometry and parameters of Figure 4 by

$$R_0 = a_0/\cos(\alpha_R - \beta). \tag{5}$$

It is possible to use the movies of the receding interface in the macromotes to determine the variation of the receding contact angle with surface tension and some representative values of its absolute magnitude.

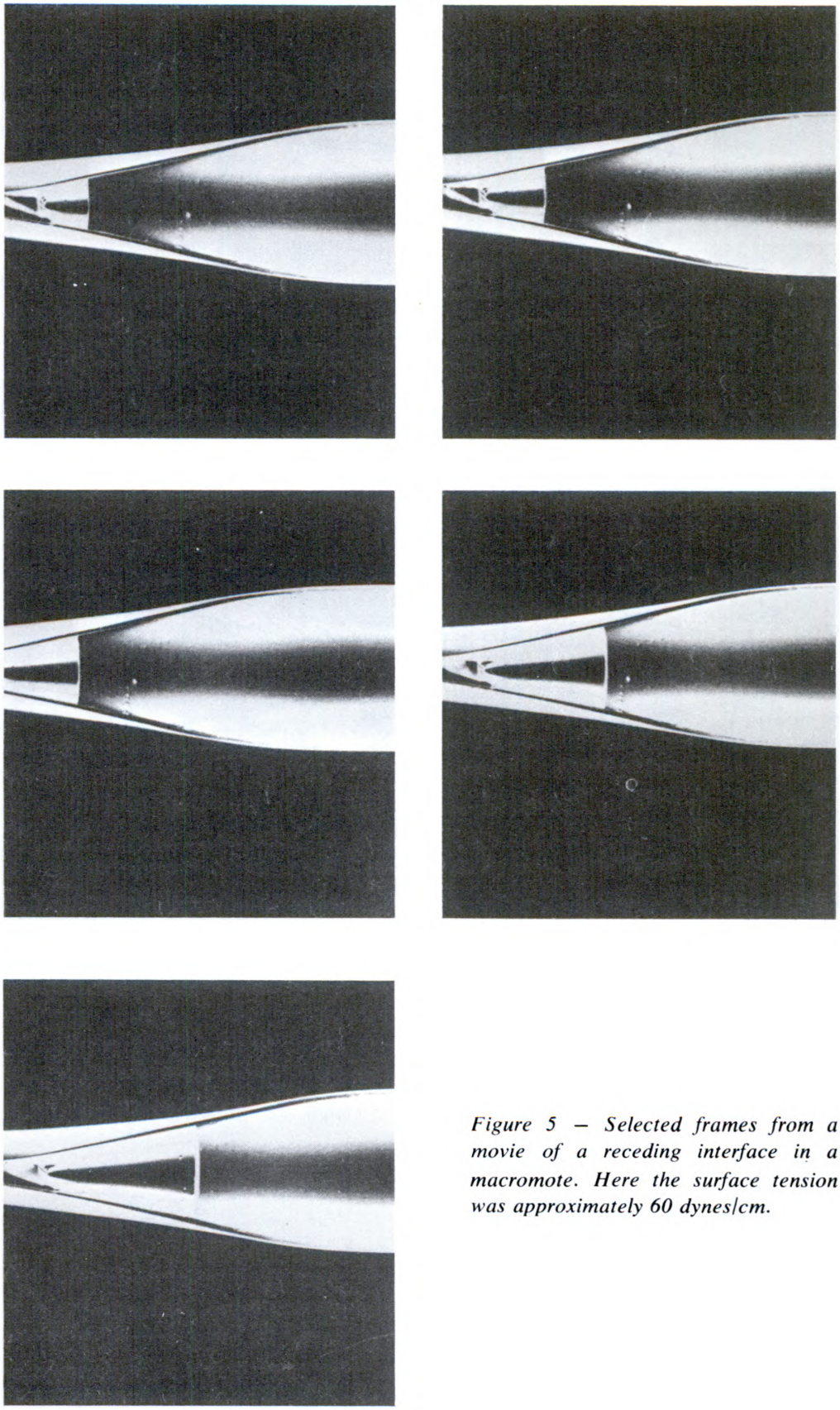

Figure 5 — Selected frames from a movie of a receding interface in a macromote. Here the surface tension was approximately 60 dynes/cm.

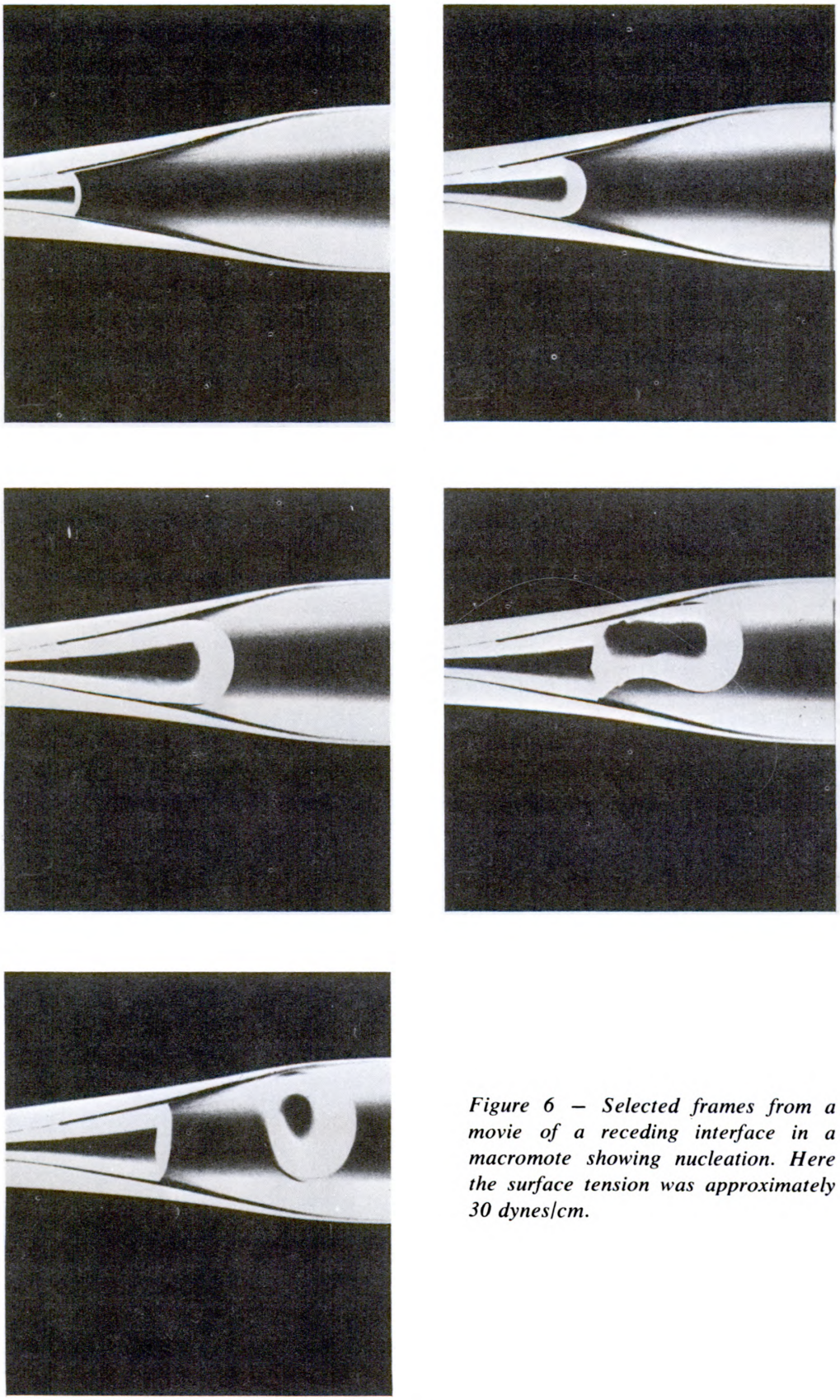

Figure 6 — Selected frames from a movie of a receding interface in a macromote showing nucleation. Here the surface tension was approximately 30 dynes/cm.

This data can be used in Eqs. (1) and (2) to obtain a semi-empirical estimate of the variation of cavitation threshold with surface tension, shown as the solid curve in Figure 3. The value for the radius of the mouth of the crevice was chosen so as to give perfect agreement at $\sigma = 54$ dynes/cm. If this semi-empirical approach is viable, then the variation of the threshold with surface tension should agree with the experiment and this is seen to be true, even to the peak observed at low surface tension.

Conclusions and Caveats

It is seen that surface tension greatly affects the threshold for cavitation inception, increasing it by a factor of nearly three from its lowest to highest value. Furthermore, the dependence of the threshold on the surface tension is unexpected according to conventional arguments. Agreement between theory and experiment is obtained only if the role surface tension plays in the critical nucleation process is accounted for. Finally, it should be noted that the dependence of the cavitation threshold upon surface tension applies only to acoustic vaporous cavitation in a mote-nucleating liquid, and thus it should not be assumed or expected to apply to gaseous cavitation induced by hydrodynamic means.

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Laser Oscillation-Range Technique and Flame Lasers Now Being Used by Industry/Government

Scientists from the Naval Research Laboratory's (NRL), Optical Sciences Division report two recent developments, a laser oscillation-range technique and the development of the first flame laser.

The laser oscillation-range technique, which measures the oscillation-range of the longitudinal cavity modes is an extremely sensitive way to determine optical gain or loss. The development of this probe technique was reportedly crucial to the discovery of the first flame laser.

The flame laser is said to be the second purely chemical laser. The scientists involved, Drs. Nicholas Djeu and Stuart Searless of the Optical Sciences Division and Dr. Herschel Pilloff of the Chemistry Division, in the research said a carbon disulphide-oxygen flame supported on a surface-mixing burner was found to sustain laser oscillation on several vibrational bands of the CO produced by the combustion process.

Flame lasers require no electrical energy and will eventually be used where laser sources without electrical energy are required.

NRL Develops Time-Saving Hydrophone Calibration Technique

Scientists at the Naval Research Laboratory (NRL) have developed a digital measuring system that would by-pass or eliminate most of the manual operations of the data-reduction process in the calibration of hydrophones.

Performance specifications for the system, which evolved from the initial design objectives, include: 30 Hz to 150 kHz frequency range operation; analog measurement accuracy to ± 0.1 dB; dynamic range of 50 dB for a single measurement; and a comparison or reciprocity calibration within 5 to 10 minutes after completing measurements.

The NRL system based on these design objectives is now in regular use on an experimental basis and appears to be more successful. More than 1200 hydrophones of various types have been calibrated with the system—as many as 60 in a single day.

With large numbers of hydrophones of the same type, the point is reached where calibration procedure is limited by the time required for rigging each hydrophone into position for measurement, thus saving hundreds of man-hours in the scaling of the recorded charts that result from calibration measurements.

The NRL time-saving system is controlled by a minicomputer to perform the hydrophone calibration.

On the Naval Research Reserve

Promotion Selections

Congratulations are extended to officers listed below who were selected for promotion by the Fiscal Year 1973 Reserve Selection Boards.

Line

There were 316 Naval Reserve line officers selected for promotion to Captain. Three (3) were members of the Research Reserve Program:

BALO, Harold A.	NRRC 4-11
REAM, James W.	NRRC 13-4
SIEBERT, John C.	NRRC 9-1

There were 133 officers selected for promotion to Commander. One was a member of the Research Reserve Program:

SAGE, Clarence E.	NRRC 6-3

Staff

There were two Medical Service Corps Naval Reserve officers selected for promotion to the grade of Captain. Both of these were members of the Research Reserve Program:

BROWNSON, Robert H.	NRRC 12-6
CAPPS, Daniel W.	NRRC 11-7

A. Hoyt Taylor Award—1972

Rear Admiral Carl O. Holmquist, USN, Chief of Naval Research, recently presented Naval Reserve Research Company 9-21, Denver, Colorado, with the A. Hoyt Taylor Award for Fiscal Year 1972. The Commanding Officer, LCDR Robert D. Price, USNR, and former Commanding Officer, CDR Donald R. Lawson, USNR, received the award in behalf of the unit which is comprised of engineers, physicists, chemists, teachers, dentists, lawyers and geologists.

The Award is presented each year to the outstanding Naval Reserve Research Company in the United States. The Denver Research Reserve Company has been active with numerous research projects and

has participated in judging scientific projects for the Colorado State Science Fair and the International Science Fair which is held at various locations throughout the United States.

The A. Hoyt Taylor Award was presented at Fitzsimmons Officers Club in Denver, Colorado with approximately 175 Navy, Naval Reserve, associated guests and wives in attendance.

Navy Rear Admiral C. O. Holmquist presents top National Award to Lieutenant Robert Price (left), Commanding Officer of Naval Reserve Research Company 9-21

NRL Detector to Observe Cosmic Rays from Skylab

S-009 is a detector which will be used in several experiments being prepared by Naval Research Laboratory (NRL) scientists here for NASA's Skylab, which is scheduled for launch late this spring.

Dr. Maurice M. Shapiro, Chief Scientist of NRL's Laboratory for Cosmic Ray Physics and the Principal Investigator for the S-009 said the experiment is designed to study the heavy atomic nuclei present among the cosmic ray particles constantly bombarding the Earth from outer space.

In speaking of cosmic ray studies, Dr. Shapiro stated that most available data on the energetic particles have resulted, thus far, from the exposure of sensitive detectors flown on high-altitude balloon flights. However, he added,

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interactions between incoming cosmic rays and the Earth's upper atmosphere break up some of the primary nuclei and distort the arriving composition of cosmic rays obtained during the balloon flights.

The S-009 apparatus, unaffected by the upper atmosphere, will obtain a more accurate measurement of the relative abundances of various nuclei in the primary cosmic ray influx.

Revealing comparisons have already been made between the source composition of cosmic rays and the element abundances in the solar system and in nearby stars. These suggest that certain nuclear processes occurring on a very short time scale during the explosion of a supernova could play an important role in the production of cosmic ray nuclei.

The S-009 detector, which contains many sheets of nuclear photographic emulsion stacked together, will operate in two modes. One, the data-collection mode, will operate while Skylab is in near-equatorial portions of its orbit. The second, the data-rejection mode, will be operated while the spacecraft is in the region of the South Atlantic anomaly and during high latitude portions of its orbit.

In the latter mode, the configuration of the detector is altered to discriminate against low-energy cosmic ray nuclei that reach the Earth at high latitudes and against Van Allen belt protons that dip down close to the Earth over the South Atlantic. The instrument will be located in the multiple docking adapter on Skylab.

Recently, laboratory beams of heavy ions have for the first time been speeded up to cosmic ray energies at the Princeton Particle Accelerator and the Berkeley Bevatron. These new beams of man-made "cosmic rays" have made it possible to measure some important nuclear reactions, and have brightened the prospects of understanding the origins of the cosmic rays observed in our local region of the Milky Way. As a remarkable "spin-off" from the cosmic ray studies on nuclear fragmentation, the knowledge thereby gained is already being applied to radiation biophysics and it may soon be helpful in experimental cancer therapy.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Arlington, Va. 22217. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $3.00 per year in the U.S. and Canada; $3.75 per year, foreign; $0.35 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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Cover Caption

Michelson Hall, which houses the Division of Mathematics and Science, is named after Nobel Prize Award winner, Dr. Albert Michelson, Naval Academy Graduate, class of 1873.

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