Bulletin 43
(Part 1 of 4 Parts)
(Part 2 of 4 Parts)

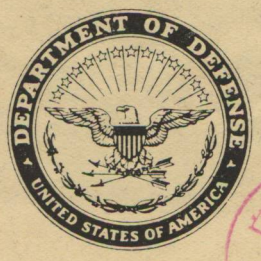
THE SHOCK AND VIBRATION BULLETIN

Part 1
Invited Papers, Submarine Shock Testing,
Shock Analysis, Shock Testing

Part 2
Structural Analysis, Design Techniques

JUNE 1973

A Publication of
THE SHOCK AND VIBRATION
INFORMATION CENTER
Naval Research Laboratory, Washington, D.C.



Office of
The Director of Defense
Research and Engineering

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The 43rd Symposium on Shock and Vibration was held at the Asilomar Conference Grounds, Pacific Grove, California, on 5-7 December 1972. The U.S. Army, Fort Ord, was host.

Office of
The Director of Defense
Research and Engineering

Design Techniques

PAPERS APPEARING IN PART 3

Skylab

Vibration Testing and Analysis

PAPERS APPEARING IN PART 4

Prediction and Experimental Techniques

Isolation and Damping

CONTENTS

PAPERS APPEARING IN PART 1

Shock Testing

PAPERS APPEARING IN PART 2

Structural Analysis

REMARKS

Elias Klein,* Ph.D.
Sarasota, Florida

(U) Prior to 1940 little consideration was given to the phenomena of Shock and Vibration in military operations. Damage caused by explosive or vibratory forces was repaired by trail and error. By the end of World War II repair shops in many parts of the world recognized and took up the problem. But there was no coordinated effort. Recognizing the need, the Navy Department early in 1946 established at the Naval Research Laboratory one unit devoted to basic research in shock and vibration and another to act as a "centralizing activity" for the collection, correlation and dissemination of all information on this subject. Later, the function came under the jurisdiction of the research and development board, and finally under the Office of the Assistant Secretary of Defense for research and engineering. All interested service agencies participated, and the function was linked with the preparedness effort. The Centralizing activity carried out its part in several ways:

1. By keeping engineers and scientists informed of developments in the field through periodic symposia on subjects which appeared urgent and timely.

2. By compiling surveys, inventories and summaries of current live research in different areas bearing upon an immediate problem. This centered the focus on whatever was being done in the Department of Defense.

3. By providing consultative services to contractors of the Department of Defense.

(U) Needless to say, the centralizing activity grew and expanded. Its prosperity attested to it as a success story.

(U) As we approach the second quarter century of operation, I would like to offer suggestions on the changes or emphasis which could be made if I had it to do again. Here are a few that come to mind.

a. Eliminate prejudice in problems as well as humans.

b. Develop motivation for interpersonal cooperation among co-workers.

c. Correct the mistake of wasting time.

This overview also points to the conclusion that in this day of problems faced by the human race, as for example in pollution, a centralizing activity can be a method for correlating the attack. Concerted effort and cooperation, exchange of information rather than competition, would bring successful solutions sooner.

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* Dr. Klein was a main driving force at the inception of the Shock and Vibration Technical Symposia in 1947. Until his retirement in 1958 he planned and directed the Shock and Vibration Symposia and the other related activities of his office. Since the 43rd Shock and Vibration Symposium in Monterey, California was held during the 25th Anniversary year of these Symposia SVIC had arranged for Dr. Klein to record these remarks. They were heard as part of the opening session chaired by Dr. W.W. Mutch, who was Head of the Shock and Vibration Center from 1958 until his retirement in 1972.

INVITED PAPERS

A QUARTER CENTURY OF PROGRESS

Dwight C. Kennard, Jr.
Consultant
Traverse City, Michigan

INTRODUCTION

(U) A quarter century, I am sure, seems like forever to the younger set. I have lived through the quarter century that followed World War II, but even to me it seems incredibly longer when reminiscing about the events of that period. Many will agree that in no other comparable period have there been more changes and perhaps more progress that seem to make time stretch like a rubber band.

(U) Twenty-five years ago we were still emerging from the devastation of World War II. The charter of the newly formed United Nations at long last raised our hopes that never again would there be another war between nations. Hardly anyone took Wernher VonBraun's crackpot ideas seriously about the feasibility of space flight and he was regarded then simply as the captured German scientist who developed the V2 Rocket. New cars were equipped with wooden planks in place of bumpers because of material shortages. There were no passenger jet airplanes. The B-50 and B-36 were our first-line bombers. Neighborhood parties were in vogue for watching TV programs in the one home on the block fortunate enough to have a set. Even the young males visited the barber shop every other week.

NEED FOR COMMUNICATION IN SHOCK AND VIBRATION TECHNOLOGY

(U) We had managed to come through the war with a shock and vibration technology that resided with only a few isolated individuals and groups primarily in the three military services but interservice coordination was practically nil. Shock and Vibration was not generally recognized as a technology or at best it was considered a kind of unimportant off-beat idiosyncrasy. The technique of the shock and vibration engineer often revolved around a kind of enlightened "cut and try" procedure.

"SOMETHING MUST BE DONE"

(U) Then into this scene came the eternally youthful and perceptive Dr. Elias Klein, a scientist at the Naval Research Laboratory. He said "something must be done" to consolidate ideas and to coordinate shock and vibration technology along more scientific lines. With characteristic vigor, foresight and determination, he became instrumental in bringing about a recognition by the Navy that no longer could it afford to deprecate the importance of this technology. In one problem alone, that of transporting World War II military equipment, it was found that more than half arrived at the scene of operations in a damaged and unusable condition due to handling and transportation-induced shock and vibration.

(U) This tremendous waste was just part of the price of neglecting the effects of shock and vibration. Facts were coming to light that showed compounding costs from malfunctions of equipment improperly designed for shock and vibration, excessive maintenance and repair, and unreliability of systems under combat and/or service conditions.

THE NAVY ACTS

(U) Yes, it was agreed that something must be done, so early in 1946 the Chief of Naval Operations through the Office of Naval Research, established a unit at the Naval Research Laboratory to conduct basic research in shock and vibration, and another unit "to act as a center for the collection, correlation, and dissemination of all available information on this subject". Thus for the first three years, the newly created Centralizing Activity for Shock and Vibration was sponsored by the Navy alone, certainly a tribute to its foresight and progressive attitude. This action, of course, was in keeping with the Naval tradition of promoting applied sciences which a quarter century earlier in 1923 led to the establishment of the Naval Research Laboratory as recommended by Thomas A. Edison.

(U) Then in 1949, the Research and Development Board of the Department of Defense

took over jurisdiction for operating the Centralizing Activity although it was destined even to this day to remain at the Naval Research Laboratory and to be operated and manned by that Laboratory.

INTERSERVICE TECHNICAL GROUP/TECHNICAL ADVISORY GROUP

(U) To involve the other services in the Centralizing Activity, a planning council composed of technical representatives from the three armed services was established, known as the Interservice Technical Group for Shock and Vibration (ITG). It was my privilege to serve as one of the Air Force members for 13 years and for the last three years of that period (1959-62) to serve as chairman. This group now is known as the Technical Advisory Group for Shock and Vibration (TAG) and is composed of four representatives each from the Air Force, Navy, Army, and the National Aeronautics and Space Administration. Also there is one representative from the Defense Nuclear Agency. Dr. Mutch served as chairman of this group from 1962 until his recent retirement as the Director of the Shock and Vibration Information Center. Mr. J. R. Sullivan, NAVSEC, is the current chairman.

DEVELOPING THE MISSION AND MODUS OPERANDI OF THE SHOCK AND VIBRATION SYMPOSIA

(U) The original mission assigned by the Chief of Naval Operations to the Centralizing Activity in 1946 still stands as the mission being performed by the Shock and Vibration Information Center today and that is: "to act as a center for the collection, correlation and dissemination of all available information on this subject". Quoting Dr. Klein concerning methods of carrying out this mission, he said in 1957: "The most fruitful method has been the periodic symposia on subjects which appeared urgent and timely in light of current defense programs". I think that statement applies as well in 1972 as it did 15 years ago.

(U) From inception there has been an underlying question about the symposia which might be paraphrased as: "What purpose can be served by the DOD-organized Shock and Vibration Symposia that could not be served better by appropriate technical societies?" Certainly this is a legitimate question but to pose it indicates a basic misconception of the functions performed over the years by the symposia. From the start, the symposia were carefully planned and conceived so as not to intrude into areas which could be served better by technical societies. At that time none of the technical societies were organized to give specific attention or recognition to shock and vibration as a field of technology. The Steering Committee (ITG) felt that one of its major goals would be to encourage the technical societies to set up their own specific programs and to change their organizations so as to give shock and vibration technologists a recognized niche on a par with other specialized areas provided by a particular technical society. This goal has been achieved during the succeeding years by several technical societies who have organized their own vibration or shock and vibration technical committees eg. ASME, SAE, IES, SESA, ASA. ASME holds biennial vibration conferences and various other technical societies hold vibration sessions at their National meetings.

(U) Aside from encouraging technical society activity in shock and vibration technology, the symposia have been organized and conceived to perform a different function than normally performed by the typical technical society. The symposia have been designed to provide up-to-the-minute information on current work in progress. Hence, papers may describe projects that are not yet completed but which are of sufficient interest to benefit others working on similar problems. Novel and innovative ideas often appear even prior to final verification. Papers sometimes evoke brainstorming sessions in the subsequent formal and informal discussion periods where the possible solution to a knotty problem may emerge.

(U) Staff members of the Shock and Vibration Information Center and sometimes the TAG members travel throughout the USA and Europe to visit organizations doing work in shock and vibration. During these visits, workers, projects, and progress in the field are noted. Where appropriate, individuals and organizations are encouraged and/or invited to present their results and describe their projects at a subsequent symposium. The net result is that papers are accepted on current work, involving short lead times for selection and review. This practice is in contrast to that of the typical technical society where papers are selected generally from completed projects or phases after long reviews with lead times possibly 18 months or more before publication. This should not be construed as a criticism of the highly selective approach typically practiced by technical societies because it is important to have their kind of refereed and reviewed papers too. The point is, there is a need for both the Shock and Vibration Symposia to summarize current work, as well as the technical societies to document the more formal, sophisticated, and conclusive work.

(U) I understand that a new policy is being adopted by the Information Center which will impose a more stringent procedure for review, referee, and selection of Symposium papers to be included in the "Bulletin" published following each symposium. Until now there has been a liberal publication policy that permitted practically all papers

presented at the Symposium to be included in the "Bulletin". It is commendable to try to raise the quality of papers included in the "Bulletin", but it must be done with great care so as not to inhibit the spontaneity of contributors which has been the hallmark of the Shock and Vibration Symposia. I would like to inject a note of caution and a warning that if the selection process dampens the motivation for presenting up-to-the-minute information on current work in progress then the "raison d'etre" for these Symposia will be gone. If this should be allowed to happen, then there would be little justification for continuing the Shock and Vibration Center since its function would be indistinguishable from that of the Technical societies.

(U) Another aspect of the Shock and Vibration Symposium which distinguishes it from the traditional function of the technical societies is the handling and publication of classified papers. With the symposia under DOD sponsorship, it is far more feasible to control presentation and publication of classified material than it would be for a technical society. Often this DOD Symposium provides the only outlet for a scientist working in classified areas to present and publish the results of his work and to exchange technical ideas concerning scientific problems.

(U) A matter closely related to the encouragement of technical society activity in shock and vibration technology, has been the development of standards in the United States Standards Institute, International Standards Organization, and the International Electrochemical Commission. It is interesting to note that many persons who have been most active in the Shock and Vibration Symposia also have been active in these standardization projects as well as in the various technical societies. This multiplicity of involvement assures an informal type of coordination and explains the absence of excessive duplication. Typically the last five chairmen of the USASI S2 Committee on "Mechanical Vibration and Shock" (Trent, Vigness, Muster, Kennard, Bouche) also served as members and/or chairmen of the "Vibration Technical Committee" of the Acoustical Society of America and have all been active participants in the Shock and Vibration Symposia. Each of these individuals have also served variously in similar capacities in the ASME, IES, SESA and international standardization.

(U) The Shock and Vibration Symposia on several occasions were planned and organized to help resolve specific technical problems. By getting workers together concerning a mutual problem area to describe their work and to discuss points of common interest, the state of the art was more clearly defined and possible approaches to a solution became more apparent. One example took place in 1950 at the start of the Korean War. Large quantities of war material were arriving at battle areas in an unusable condition due to damage in transit. This was having disastrous consequences in the conduct of the war. In Dr. Klein's words: "When this situation came to the notice of the Interservice Technical Group, a nation-wide symposium was soon organized to discuss ways and means for reducing damage to military shipments. The railroads, the trucking industry, the airlines, and maritime groups were invited to help in this emergency. Several hundred engineers, packaging designers, and operating personnel from government and commercial agencies were assembled to formulate an answer to the question: 'What can be done now to safeguard military shipments from shock and vibration damage?'

(U) "Two symposia on lading damage were held in 1950 and they served a very useful purpose. The prevailing deficiencies in the handling and transportation of cargo were promptly recognized, and definite cooperative recommendations were made with a view of immediately increasing safety in transit. To help implement the improvements discussed at these meetings, an offer was made on behalf of the government by the Centralizing Activity to provide any carrier system with the best available technical knowledge in the field of shock and vibration which would be applicable to the problem at hand. In addition, we offered guidance to any common carrier in the use of modern instrumentation for evaluating and improving the chances of an equipment's safe arrival. Certain computer facilities and data reduction procedures were made available to these organizations to expedite their results and to put them into practice. The Naval Research Laboratory processed some measurements for a railroad company which accepted our offer. This aspect of quantitive railroad technology represented a new approach to the problems of the transportation industry.

(U) "Out of these transportation symposia also came some long-range projects to benefit both civilian and military shipments."

PROFILES OF PROGRESS

(U) We often hear such statements as, "the production of scientific information doubles every ten years." It is interesting to note that this is happening in the output of the Shock and Vibration Symposia if one considers each published technical paper as a unit of production. By referring to Table I it can be seen that during the first decade (Symposia 1 through 24, 1947-1957) 412 papers were produced. During the second decade (Symposia 25 through 36, 1957-1967) 789 papers were produced with a 1.9 factor of increase. We now are half way through the third decade and the number of papers produced, including the 43rd Symposium, amounts to 744 with a 0.94

factor of increase relative to the entire second decade. So if we continue the same production rate for the next five years, the number of papers produced during the third decade will be about double that produced during the second decade.

(U) Table I also shows significant data concerning participation in the Symposia. During the twenty-five year period a total of 2181 individual authors have participated in preparing 1945 papers for the forty-three Symposia. In contemplating the audiences who have listened to these 1945 papers and the readers who have studied the subsequent published versions, one gains some idea of the immense dimension taken on by this means of communication among scientific workers.

(U) There have been many trend-setting papers which represent milestones of progress. It would be foolhardy for any one person to ennumerate these because each individual would have his own opinion based upon particular interests and problem areas. However, in consultation with the Shock and Vibration Information Center staff, it is apparent that a few memorable papers stand out as typical of the many milestones which are too numerous to mention individually:

"Vibration Problems in the V2 and Similar Guided Missiles" presented in 1949 at the 14th Symposium by Wernher VonBraun. This paper was a preview of the forthcoming challenge that would be faced by shock and vibration technologists in developing rockets for the space program.

"Shortcomings of Present Methods of Measuring and Simulating Vibration" presented in 1953 at the 21st Symposium by C.T. Morrow and R.B. Muchmore. This paper "shook up" constituents of the Shock and Vibration Symposia and set off a controversy over sinusoidal and random vibration concepts that was to continue for many years.

"A Novel High-and Low-Temperature Horizontal-Vibration Test Fixture" presented in 1957 at the 25th Symposium by W.O. Hansen. This paper introduced the "slip table". Many variations since have been developed based on this first published data.

"A Method for Predicting Environmental Vibration Levels in Jet-Powered Vehicles" presented in 1960 at the 28th Symposium by P.T. Mahaffey and K.W. Smith. This paper set forth a prediction technique that has been used widely and modified to fit other situations.

"Simulating Flight Environment Shock on an Electrodynamic Shaker" presented in 1963 at the 33rd Symposium by G.W. Painter and H.J. Parry. This paper presented the first of several methods of synthesizing shock motion on a shaker from a given spectrum and helped solve missile shock testing problems involving pyrotechnic separation devices used for staging and other actuations.

"Elementary Considerations of Shock Spectra" presented in 1964 at the 34th Symposium by Irwin Vigness. This was a tutorial paper which clarified widely misunderstood concepts of shock spectra.

"Transient Waveform Control of Electromagnetic Vibration Test Equipment" presented in 1969 at the 40th Symposium by J.D. Favour, J.M. LeBrun, and J.P. Young. This paper won the Irwin Vigness memorial award of the Institute of Environmental Sciences. It represents a newer trend for using computer facilities to control a shaker in reproducing the time history of a motion parameter involving application of Fourier integral techniques.

(U) The foregoing is only a partial list to illustrate the point that there have been many papers presented at these symposia that have been of special interest and/or have been influential in setting trends in dealing with particular problem areas.

THE SHOCK AND VIBRATION INFORMATION CENTER

(U) Although this paper primarily deals with the Shock and Vibration Symposia, it must be noted that the Shock and Vibration Information Center provides many additional services. The Symposia proceedings are published in "The Shock and Vibration Bulletin"; nine state-of-the-art monographs have been published on specific aspects of shock and vibration technology; "The Shock and Vibration Digest" is published monthly; a direct information service is provided to answer inquiries for technical information.

(U) At this point I would like to pay special tribute to the people who have administered the Shock and Vibration Centralizing Activity/Information Center over the years: to Dr. Elias Klein for his perserverence, wisdom, and foresight in conceiving, establishing, and nurturing his idea to a successful status; to Dr. W.W. Mutch who with enthusiasm, dedication, and innovation caused the activity to grow to its present importance and stature; and to Dr. Robert Belsheim who recently had the courage to accept the challenge of leading the Shock and Vibration Information Center to new levels of attainment and usefulness.

(U) A great deal of credit also goes to the Shock and Vibration Information Center Technical Staff, each of whom have established

reputations for their individual contributions in specific areas: Henry C. Pusey—Packaging and Transportation; Rudolph H. Volin—Vibration and Test Equipment; and Edward H. Schell—Shock and Fragility. We can be proud of the competence of each of these individuals and grateful for their dedication in providing the outstanding service that so many have come to rely on and perhaps too often to take for granted.

(U) In conclusion, it is this fine group of people who will be bringing about new developments to assure continued growth, improvement, and increased efficiency of the services performed by the Shock and Vibration Information Center. I do not wish to steal their thunder by revealing plans for the future, but we can all be assured that the tradition of success and service that has been so firmly established will be reaching new levels of achievement as the third decade of service continues to unfold.

TABLE I

Record of Papers Produced and Authors Participating in the Shock and Vibration Symposia

SYMPOSIUM NO.	AUTHORS	NEW AUTHORS	PAPERS	TIME PERIOD
1 - 24	393	393	412	FIRST DECADE 1947-57
25 - 36	1121	1070	789	SECOND DECADE 1957-67
37 - 43	949	718	744	THIRD HALF DECADE 1967-72
TOTALS	2463	2181	1945	QUARTER CENTURY

FORMER SHOCK

Donald E. Marlowe, Ph.D
Catholic University
Washington, D. C.

(U) When Dr. Belsheim invited me to speak to the 25th anniversary meeting of the Shock and Vibration Symposium, he reminded me that I had been one of the earliest contributors to the Symposium, and that perhaps my memories of those early days would be an amusing and informative introduction to the anniversary. His instructions were "Tell it like it was." While preparing this paper, it seemed wise to cite even earlier experiences, as they too illuminated the former state of theory and experiment in the field of applied mechanics. Although it is somewhat dismaying to recognize that my engineering studies have now extended for nearly forty years, I will plagiarize Allen Toffler's famous book, and call this paper "Former Shock".

(U) I must confess that my early education was as a Civil/Structural engineer, and at that time, moving load calculation was the epitome of dynamic analysis. Iterative methods (the Hardy Cross method) were just making their appearances. Differential equations was an elective subject in all engineering curricula. My own break with this educational tradition began with my employment as a demonstration assistant in a physics department. In this job I was guided by an excellent experimental physicist (Wm. Baker), and I learned much about the difficulties of good laboratory work, something about the sources and propagation of errors, and, above all, about that marvelous journal, Physics Abstracts. From the Abstracts, I learned something about photoelasticity, and did an undergraduate thesis on "Photoelastic Analysis of a Gravity Dam," using gelatin models. The stimulation provided by this little project was worth much more than the analysis itself.

(U) My new interest in mechanics inevitably drew me to Ann Arbor, as a graduate student, where S. Timoshenko was the keeper of the flame. (His biography is must reading for every worker in Mechanics). When I arrived, there were less than a dozen Mechanics majors, Timo had fled to Stanford, though he did return to Michigan each summer, as did most of his first generation of students. Although I had elected Differential Equations as an undergraduate, my mathematical foundation needed extensive repair, and while this was underway, I turned again to laboratory work, largely as an assistant to Lawrence Maugh, whose modest research support in studies of rigid frames enabled me to keep the wolf from the door and simultaneously introduced me to the reciprocal theorem. He also introduced me to the terrors of experiments whose output consists of small differences between large numbers. These were the days when the principal tools of strain measurement were the travelling microscope, the Huggenburger and Ackerman strain gages and the Michelson interformeter.

(U) I owe to Jesse Ormondroyd the diversion of my interests to structural dynamics. He had just finished work on the Mount Palomar telescope (a very slow dynamics, indeed); my own mathematical background had been somewhat repaired, so I went into Jesse's courses on dynamics, vibrations and above all, analysis of transients. Feedback concepts had not yet reached Ann Arbor.

(U) The Michigan mechanics department was enthusiastic about research courses (probably because there were too few students for many formally organized courses), so I plunged through a series of projects which gave me additional experience in photoelasticity, mechanical strain measurement, physical optics, and error analysis. I also discovered the existence of electricity, a phenomena which my education had kept carefully hidden from me until that time. It's true that in reading about prior research on gravity dam stresses (Physics Abstracts, again), I had come across the Bureau of Reclamation practice of burying lengths of resistance wire in dams, as a way of measuring concrete shrinkage; but since the gage lengths were a foot, and I was mostly working with models, I had quickly dismissed this as a useful strain gage.

(U) But the Michigan laboratory had, shoved away in one corner, a Peter's Telemeter