

No. 2

March 1947

# SHOCK AND VIBRATION BULLETIN



Distribution Unlimited

FR-3077



Approved for  
Public Release

NAVAL RESEARCH LABORATORY

*Washington D.C.*

Distribution Unlimited

Approved for  
Public Release

30754

0003

DISTRIBUTION LIST

CNO (3)

BuShips (15)

BuOrd (7)

BuY&D (2)

ONR (3)

NMRI (4)

DTMB (9)

Naval Gun Factory (8)

NOL (6)

Nat. Bureau of Standards (3)

P. G. School, Annapolis (3)

BuAer (2)

EES (2)

Material Lab., N. Y. Naval Shipyard (2)

Commandant, Marine Corps (1)

NAES (2)

Squier Signal Lab. (1)

Coles Signal Lab. (1)

Watson Air Force Lab. (1)

IN THIS ISSUE

	Page
The Second Symposium in Brief . . . . .	1
List of Representatives in Attendance, 13 February 1947 . . . . .	2
Minutes of 13 February Symposium . . . . .	5
Talks Presented at 13 February Symposium:	
<i>Shock or Blast Injuries</i> , by Capt. R. H. Draeger . . . . .	7
<i>Vibration Studies on the Human Body</i> , by Lt. Cdr. D. E. Goldman . . . . .	9
Discussion . . . . .	11
NRL Shock and Vibration Facilities . . . . .	13
Contributed Articles:	
<i>The Askania Vibrograph</i> , by C. B. Cunningham . . . . .	19
Schedule and Agenda, 19 March Symposium . . . . .	22
SAVIBULL (Notes). . . . .	23



## THE SECOND SYMPOSIUM IN BRIEF

The morning session was devoted to a discussion of the DTMB proposed definitions. Although no general definition of shock was evolved, many illuminating points of view were contributed. The results of this discussion have been referred to a representative committee for study. It will be the responsibility of this committee to clarify and unify the ideas. They will report to the assembly such terminology, definitions, and standards as will promote uniformity, understanding, and progress in this field of science. The work of this committee should provide a common ground where theory, design, and specifications can meet and speak the same language.

In the afternoon, the assembly heard talks by Capt. Draeger and Lt. Comdr. Goldman of NMRI concerning the effects on personnel of shock, blast, and vibration. Here, again the ultimate objective of the studies is to determine the effects of these disturbances upon structures, which in this case are living organisms. Captain Draeger and Lt. Comdr. Goldman demonstrated, by their talks, that it is the purpose of such investigations to provide protection for human beings and structures involved in Fleet operations.

LIST OF REPRESENTATIVES IN ATTENDANCE

Shock and Vibration Symposium of 13 February 1947

NAME	ORGANIZATION
Capt. A. B. Leggett	CNO (Op34H)
Capt. G. W. Stott	CNO (Op34H)
Mr. E. Rassman	BuSHIPS (332)
Mr. J. V. Levy	BuSHIPS (646)
Mr. M. L. Henoch	BuSHIPS (332)
Mr. J. D. Mayer	BuSHIPS (641)
Mr. T. Soo-Hoo	BuSHIPS (442)
Mr. J. B. Lunsford	BuSHIPS (345)
Mr. R. W. Stewart	BuSHIPS (345)
Mr. L. H. Fryer	BuSHIPS (345)
Mr. E. J. Hough	BuSHIPS (633)
Mr. V. N. Stankoff	BuSHIPS (643)
Mr. Lester W. Buechler	BuSHIPS
Mr. R. H. Oliver	BuSHIPS
Mr. R. Michel	BuSHIPS (436)
Mr. E. S. Henning	BuSHIPS (665)
Mr. J. C. Schmelzeiser	BuORD
Mr. D. H. Sellman	BuORD
Mr. Michael Goldberg	BuORD
Mr. A. J. Sussman	BuORD
Mr. J. A. S. Roy	BuORD
Mr. L. R. Evans	BuORD
Dr. H. Marcus	BuY&D
Mr. J. M. Crowley	ONR
Mr. H. W. Boehly	ONR
Capt. R. H. Draeger	NMRI
Lt. Cdr. D. E. Goldman	NMRI
Lt. (j.g.) Myles Maxfield	NMRI
Capt. R. A. Hinnens	DTMB
Comdr. J. O. Baker	DTMB
Comdr. A. O. Doritz	DTMB
Mr. N. H. Jasper	DTMB
Mr. R. T. McGoldrick	DTMB
Mr. Francis F. Vane	DTNB
Mr. H. L. Rich	DTMB
Mr. W. J. Sette	DTMB

NAME	ORGANIZATION
Mr. S. O. Carpenter	Naval Gun Factory (Design)
Mr. C. M. Ryerson	Naval Gun Factory
Mr. J. P. Strong	Naval Gun Factory (Aviation)
Mr. J. J. Peirano	Naval Gun Factory
Mr. A. Leventhal	Naval Gun Factory (Ordnance)
Mr. Ewing J. Ballou	Naval Gun Factory (Metallurgy)
Mr. F. A. Ross	Naval Gun Factory
Mr. C. C. Vogt	NOL
Mr. D. E. Marlowe	NOL
Dr. Leslie W. Ball	NOL
Mr. J. H. Armstrong	NOL
Mr. W. G. McAdams	NOL
Dr. C. D. Romborg	National Bureau of Standards
Mr. A. McPherson	National Bureau of Standards
Mr. George H. Lee	P. G. School, Annapolis
Mr. Roy W. Prowell	P. G. School, Annapolis
Mr. B. A. Wiener	BuAER (Structures)
Lt. Cdr. J. M. Vallilo	EES
Mr. Geo. J. Doshefsky	Material Lab., N. Y. Naval Shipyards
Lt. Cdr. J. B. J. Glanzman	NRL
Lt. Stephenson	NRL
Dr. Elias Klein	NRL
Dr. Irwin Vigness	NRL
Dr. H. M. Trent	NRL
Dr. H. L. Saxton	NRL
Mr. Carl J. Bastien	NRL
Mr. A. N. Ciaffardini	NRL
Mr. W. B. Wastfield	NRL
Mr. J. M. Taylor	NRL
Mr. Louis H. Feher	NRL
Mr. C. B. Cunningham	NRL
Mr. L. M. Trietel	NRL
Prof. C. F. Garland	NRL (Visitor)



MINUTES  
OF  
SHOCK AND VIBRATION SYMPOSIUM  
13 February 1947

Dr. Elias Klein, NRL, opened the morning session by reviewing the reasons for the establishment of this series of symposia. He then introduced Commander Baker of the David Taylor Model Basin, who presented the Model Basin's proposals concerning definitions (see January issue of the *Shock and Vibration Bulletin*).

The discussion which ensued touched on all the proposed definitions, but was concerned more with the definition of *shock* than with *vibration* and the several types of vibrations.

Mr. Marlowe of NOL preferred to consider *shock* as a cause rather than as an effect. He said that classical physics had provided the terms (rate of change of velocity, acceleration, momentum, etc.) for completely describing *shock* long before the term *shock* came into use. He found it difficult to differentiate between *shock* and a *damped vibration* when *shock* was considered as an effect. He thought it would be possible to define *shock* as distinct from *vibration* only if the definition were formed in terms of a cause, which need not be oscillatory. The result of a *shock*, or the "shock effect", is always oscillatory, he said. He thought the record from any pendulum-type shock machine would fall under the definition of *vibration* which had been proposed by the DTMB.

Mr. Jasper, DTMB, agreed that a "shock effect" is some kind of *vibration*, but said that it is not vibration about an equilibrium position. He felt that this property was sufficient to differentiate between the "shock effect" and a *vibration*.

Mr. Michael of BuShips preferred the definition of *shock* as an effect, as did other representatives present who were concerned with specification writing. Mr. Goldberg of BuOrd pointed out that some word for *shock* is needed, and said he did not believe there was any confusion in industry about the meaning of the term. He was very much concerned about the necessity for re-educating industry if the meaning should be changed. Mr. Leventhal of the Naval Gun Factory felt the need for some general term for *shock*, but thought that each agency which prepares specifications should determine exactly the test to be given a particular equipment--exactly what impulse or *shock* that equipment should withstand.

Those whose interests were purely scientific were inclined to agree with Mr. Marlowe's statement that *shock* could be completely described by terms from classical physics, and that a specific definition of the term *shock* was not necessary, or even desirable. They preferred, however, to think of *shock* as an effect. Dr. Trent of NRL said that most people, in thinking of *shock* and *vibration* problems, think of linear systems. The general properties of such a system, he said, require that whenever the system is disturbed from one condition of equilibrium, a new equilibrium condition is called for, and that the transient vibration which results from a *shock* is the adjustment of the system to the new condition. If *shock* is, then, just a special kind of a transient, he thought it might be better to use the term in a qualitative sense only. Dr. Ball of NOL proposed that the terms *applied shock*, *shock effect*, and *receiving structure* be defined, and

that the general term *shock* not be defined. A committee was appointed to study the problem and to form the definitions, using this discussion as a background for their action.

Comdr. Baker of DTMB was concerned that definitions were being confused with units of measurement in the discussion, and that a definition of *shock* in terms of *force* and *time*, for example, constituted the definition of a unit instead of the phenomenon of *shock*. He thought *shock* should be defined more broadly. He said that the DTMB definition of *vibration* was probably the one set up in the field of sound originally, and that nothing in the definition refers to frequency or the amplitude of the wave. The definition of *shock* should, in his opinion, parallel that of *vibration*, and be just as broad.

Mr. Wiener, of BuAer, objected to the proposed definition of *vibration* on the grounds that it was too restrictive. He said that free rigid bodies sometimes vibrate as a whole. As an example, he cited an aircraft engine, which is not elastic, but which vibrates as a whole on elastic supports. In this case the body is not restrained except by its mass reactance. Specifically, he objected to the use of "elastic body" in the definition of *vibration*.

Lt. (j.g.) Maxfield of the Naval Medical Research Institute favored a mathematical definition which would not be subject to change with the point of view of the observer. Such a definition could be formed, he thought, by determining the components of a *shock* (force, time, displacement, etc.), and combining them into some mathematical function which describes the event. One would then have, he felt, a definition which was exact and definite, understandable by all, and universally applicable.

Nominated for the committee to write the definitions were Dr. Ball of NOL, Comdr. Baker of DTMB, and Dr. Trent of NRL. BuShips is to make its nomination later. NMRI representatives were told by Dr. Klein that medical representation on the committee would be welcome. The committee is to confer frequently with the group, and to write their definitions on the basis of full discussion.

During the afternoon session, Capt. Draeger of NMRI spoke on "Shock or Blast Injuries", and Lt. Cdr. Goldman, also of NMRI, spoke on "Vibration Studies on the Human Body." These talks and the discussion which followed are printed in this issue of the Bulletin.

## SHOCK OR BLAST INJURIES

Capt. R. H. Draeger, NMRI

The problem of *shock* or *blast* may logically be divided into two categories, namely, the effects upon material and the effects upon personnel. The damage to material, including ships, planes, guns, instruments, and equipment of all kinds, is familiar to all of you, and the methods of study have been, at least partially, worked out. Damage or injuries to personnel which result from shock or blast are less well understood, and very little has been done regarding methods of study.

Considered from a causative or etiological standpoint, the extent and type of damage resulting from shock depends upon both the amount of energy transmitted to the material or personnel and the mode of transmission of this energy. All of the three states of matter--solid, liquid, and gaseous--are capable of harmfully transmitting energy to the human body. The density and elasticity of the medium involved determine to a large extent the character of the transmitted pressure wave resulting from an explosion. Thus, an explosion in air, water, or in contact with a solid structure, such as a ship, results in the formation of a pressure wave in these respective media. Let us now briefly review the injuries caused by pressure waves in these various media.

### AIR BLAST INJURIES

When an explosion occurs in air, a pressure wave is generated which travels outward at a speed initially greater than that of sound. Such an air compression wave subjects objects in its path first to an outward thrust as the wave front strikes the object, then to a compression as the object is enveloped by the wave, and finally to a phase of negative pressure as the wave passes. Since the body is

subjected to compression by an air pressure wave, the greatest amount of injury is done to the air-containing portions of the body. Thus, pulmonary or abdominal injury is the most important clinical finding.

Secondary injuries, however, caused by flying missiles or debris set in motion by the air pressure wave, or by personnel being thrown against objects in the environment, account for the majority of the injuries. When an individual is subjected to an air pressure wave of about 30 psi, the result is apt to be fatal.

### WATER BLAST INJURIES

An underwater explosion results in the formation of a water pressure wave which may be harmful to submerged or partially submerged individuals. The body is traversed by such a water pressure wave and subjected to forces of compression which, if around 500 psi, are apt to cause intestinal perforation or rupture of pulmonary vessels. It will be seen that it is also the air-containing portions of the body which are injured by a water pressure wave.

Secondary injuries are apt to be few in the case of underwater explosions, since the water exerts a retarding effect upon the movement of objects in the environment.

### SOLID BLAST INJURIES

The detonation of a high explosive in the proximity of a semi-rigid body, such as a ship or a tank, results in the transmission of energy through the solid structure as a flexion wave, which results in a sudden acceleration of deck or bulkhead surfaces. These sudden accelerations

are capable of causing serious injuries to personnel. Since this type of injury is caused by a sudden impact, the damage is greatest at a point of contact. Injuries to the lower extremities, particularly the ankles, are therefore most common. "Sudden" velocity changes of around 20 feet per second involving appreciable displacements are apt to result in lower extremity fractures.

Secondary injuries due to the displacement of personnel, such as their being thrown against the overhead or overboard, are frequent.

This type of injury was first noted at the end of the first world war, and became known as "deck slap" or "destroyer heel". In the recent war, hundreds of these injuries, particularly on the Normandy Beaches, resulted from nearby underwater or below-deck explosions.

#### CLASSIFICATION OF INJURIES

The medical classification of injuries caused by shock or blast was attempted about one year ago. Any attempt at classification must correlate a wide variety of lesions such as burns, fractures, intestinal perforation, and rupture of pulmonary vessels. It is apparent that the mere cataloging of lesions on an anatomic basis gives no clue to etiology, and takes no cognizance of the forces which, acting through a variety of media, produce so wide a range of injuries.

This classification was based on the means of transmission of energy, whether through air, through water, or through solid structures. The term *blast* has been used to designate the sudden explosive release of energy, and hence is particularly suited for the designation of the sudden release of energy from bombs, shells, depth charges, and the like. By combining these terms in *air blast*, *water blast*, and *solid blast*, it is possible to convey a precise picture of the

rapid transmission of explosive energy through a given medium.

It is realized that a uniform terminology for both physics and medicine would have been desirable, and this point was long debated. The term *shock* is in extensive use in medical literature, and much confusion already exists. A further use of this term is entirely unacceptable. The solution to the problem appeared to be the choice of a term other than *shock*, but one having the same meaning, for medical nomenclature.

The term chosen was *blast*, and it is gratifying to note that it is synonymous with *shock* as defined in the DTMB proposal. No confusion will result if these terms are used in their specialized senses by those following the respective disciplines of physics and medicine. If the physicists will merely keep in mind that the doctor means *shock* when he says *blast*, all will be well, and vice versa.

*Blast injury* appears to be a satisfactory generic term to designate the three types of injuries above described. Among the confusion of names now in the medical literature, three of the terms chosen in the above classification have already been used, i.e. *blast injuries*, *air blast*, and *water blast*. Only *solid blast* requires a stretch of the imagination.

This terminology has recently been extended to include the atomic bomb. It will be noted that the atomic bomb is capable of causing any of the injuries produced by a high-explosive bomb, and, in addition, produces injuries due to thermal and ionizing radiations. Here we might follow a parallel terminology except that the physicists have let us down by not providing a term for the medium which transmits this radiant energy. We would like to use the term *ether blast*, but we understand that the ether has been eliminated by the theory of relativity;

therefore, we have had to compromise on *radiation blast*.

A further investigation of blast injuries is definitely indicated, particularly since the time is rapidly approaching when the human body will be required to survive under conditions of still greater stress. The limit of these stresses, and the conditions under which the human body can function efficiently must be known. Since the human body can-

not be made to withstand stress beyond this limit, it is essential that the machines and equipment of the future be designed around the human body.

In closing, I would like to point out that the accomplishment of the above objectives will require a close cooperation of both physicists and biologists, and that each must acquire, to a certain extent, the point of view of the other in order to function efficiently.

---

#### VIBRATION STUDIES ON THE HUMAN BODY

*Lt. Cdr. D. E. Goldman, NMRI*

As I understand it, the reasons why shock and vibration studies are made on equipment and material are: to find out their capacity to serve, under stress, the purposes for which they are built; to obtain an understanding of structural and operating factors; and to develop protective measures, or to show how better equipment can be made. From the overall point of view, studies on the human body are, so far as possible, the same in intent and in method. There is, however, one exception of the greatest importance: it is not possible (as yet, anyway) to produce an improved type of personnel which shall be able to stand greater shocks or more intense vibration. Regardless of the type of machinery used by man, machinery is always operated by men, who, from the material point of view, thus constitute a permanent, unchangeable element of a machine.

In the past, most machinery has been of a low enough power that the question of human tolerances to the stress applied by the machinery has rarely arisen. As

greater and greater concentrations of power are used, it is evident that the time is coming when tolerance limits may be exceeded, and thus the original purpose of the machine defeated. The answer to such difficulties may consist in making the machine completely automatic, or in protecting the man. The purpose of this discussion is to cover the question of protection and safety.

Very little has been done on experiment or field observation of human performance under stress. Equipment can be stressed to the point of failure; personnel cannot. Hence the direct approach to the problem is prohibited. Of the indirect methods, a combination of the following must be used: animal experimentation, studies on cadavers, studies on the effects of stresses gradually increased to the point of *apparent risk*, and an analysis of accidents.

The characteristics of the human body are such that one can hardly bolt down an accelerometer, or otherwise treat

it as a piece of steel. Not only is the body a highly complicated mechanism, but it contains many non-linear elements as well as automatic protective devices, or servo mechanisms, which respond in a way rarely subject to control.

The ultimate practical purpose of these studies is, of course, to set up safety limits at various levels, and to find out the requirements for protective devices. It is to be expected that results will also be of some value to basic biology and medicine. For purposes of studying vibration, it is convenient to make a classification based on the frequency and upon the energy-carrying medium. For example, there are the infrasonic, the sonic and the ultrasonic ranges. The vibrations may be airborne, waterborne, or transmitted through solids by direct contact. Evidently a table of tolerance limits should be constructed, from which machine designers can determine in advance the necessary safety proceedings.

The present status of the problem is that a joint project has been set up, in which the Naval Research Laboratory is responsible for the engineering and physical aspects, and the Naval Medical Research Institute for the biological and medical aspects. The scientific literature reveals only scattered bits of information, which are quite incapable of providing answers of practical use. The program, accordingly, has been designed partly to try to fill in the gaps in our knowledge, and partly to provide a broad enough coverage of the field that, as practical problems arise in the future, it will not be necessary to go back to the beginning each time. A brief discussion of the various projects appears to be in order.

(a) It is planned to build a vibration table on which human subjects can be subjected to vibrations in the frequency range from 2 to 30 or 40 cycles per second, at accelerations up to 10 g,

if such is ever indicated. Since high accelerations at low frequency require tremendous amplitudes, a compromise has been made at a single amplitude of two inches. This equipment is now being constructed at the Naval Research Laboratory.

Further, accelerometers are being obtained which are small enough and light enough to be attached to various parts of the body without interfering seriously with the mechanical properties of the body. Glenn L. Martin Company is making some variable-reluctance bridge-type accelerometers which are about  $3/8 \times 3/8 \times 5/8$  inches, and which weigh less than 5 grams. With this apparatus, we hope to be able to investigate the body as a mechanical linkage system, and to get some information as to the effective masses and damping of the various parts.

(b) Experiments are nearly completed on some effects of vibration in the 50 to 500 cycle range on some reflexes in experimental animals. For example, it is known that the knee jerk which is partly responsible for the maintenance of posture may be reduced or abolished by vibration of sufficient amplitude.

(c) The effects of loud sounds were studied at the Psycho-Acoustic Laboratory at Harvard during the war, within, however, the somewhat limited range of 50 to 5,000 cycles, and at levels up to about 125 db. A sound chamber and generating equipment are being made available here to extend these studies both to higher sound levels and higher frequencies.

(d) High-frequency generating equipment is also being made here for basic studies on the absorption and velocity of ultrasonic vibration in human and animal tissues.

(e) Arrangements have been made to develop equipment for a study of vibration thresholds of human bodies.

Finally, it is evident that although this program is quite extensive, it leaves much to be done in the future.

From the type of work planned, it is obvious that only close co-operation between engineers and biologists can lead to the information desired. In general, what has been said about the studies in vibration applies to work on shock effects. The problem of protection of aviation personnel against crash forces (which seem to be shocks, within the meaning of the word as used at this conference) is quite analogous.

The forces applied to an aircraft pilot in a crash differ from the solid

blast forces described by Captain Draeger only in that their durations are greater (1/20 to 1/5 second), and their peak values somewhat lower. Considerable preliminary work has already been done by a Medical Department group on the protection offered by various types of crash harness under laboratory conditions. Here, again, we meet the primary difficulty of not being able to destroy the subject of study.

It is hoped that this sketchy outline has served the purpose of indicating the essential similarities and differences encountered in the biological field as against the engineering field.

---

DISCUSSION

MR. MARLOWE, NOL, asked if there were any known explanation for the difference between figures quoted for the limits of tolerance for air blasts and for water blasts.

CAPT. DRAEGER said that he knew of no satisfactory explanation, but that he was certain, from personal experience during the war, that these figures represent at least a good guess. Large animals withstood larger pressures than small animals, he said. Injuries were suffered at lower levels, but the animals usually recovered from them. Death usually occurred in a few minutes above these limits. A very slight difference in pressure meant the difference between life and death, he added.

MR. SETTE, BUSHIPS, asked if surface reflections would not possibly lower the

duration of the application time in the case of water blasts. He asked about the effects of different depths of immersion.

CAPT. DRAEGER replied that he had no figures on the effect of depth, since all their studies were on partly submerged bodies.

LT. CDR. GOLDMAN said that one general principle might be stated: when the duration is short, a larger peak value of pressure is required to produce the same damage. There are reports, he said, that a German scientist found the product of duration and peak pressure to be equal for equal damage from air blasts and water blasts.

PROF. GARLAND said that Dr. Goldman's last statement had also been found true in engineering.

DR. BALL, NOL, asked if the NMRI representatives had any reports on the effectiveness of cushioning materials.

CAPT. DRAEGER replied that one of their goals is, of course, to develop protective devices. Cushioning material, when made into vests covering the chest and abdomen, help considerably, he said. Guinea pigs protected by half an inch of such material survived seven times the lethal dose. The difficulty with such protection is that persons so protected are severely hampered in the performance of their duties. In the case of injury from solid blasts, however, the situation is much more hopeful. Some work on the effects of solid blasts on cadavers was done at the Engineering Experiment Station in Annapolis, but the work had to stop when the supply of cadavers was exhausted. In these studies, however, fractures to the lower extremities were produced by "sudden" velocity changes of about 12 ft/sec, involving displacements slightly greater than an inch. Human subjects on the shock machine suffered no ill effects when cushioned by two inches of polystyrene foam. The limit of the equipment at the EES has been completely exploited with the material available, and a plate

has now been acquired for mounting over an explosion pit, to provide higher order accelerations. He said there was little doubt that protective material can be provided, at least for key personnel. Even small thicknesses are greatly effective.

MR. MARLOWE told Capt. Draeger of the results of some tests made at NOL on large tin cans protected by a covering of foam rubber. They found that the covered cans were, in all cases, more badly damaged than the unprotected cans.

LT. (j.g.) MAXFIELD, NMRI, told of experiments made on protective material for ejection seats for pilots. They found that rubber offered no protection, but that certain hard, uncomfortable materials were protective. The accelerations imparted to the subjects were lower in the case of the hard materials.

MR. MARLOWE said their studies indicate that if the application of the shock is of sufficiently long duration to permit the cushion to bottom, the acceleration produced can not be less than twice the applied acceleration.

IMPRESSIONS OF THE SHOCK AND VIBRATION TOUR  
NAVAL RESEARCH LABORATORY  
7 JANUARY 1947

UNCLASSIFIED

The following account of the tour of NRL's shock and vibration facilities conducted during the 7 January Symposium is a composite of informal reports given by several persons who made the tour.

\* \* \*

The experimental shock and vibration facilities viewed at NRL were both impressive and encouraging. The extent and variety of the devices seen undoubtedly reflect the broad and thorough approach which NRL is planning to bring to shock and vibration problems. The statement made by Admiral Solberg that, when completed, these facilities will be unequaled elsewhere, appears to be well founded.

The Sonigage and Reflectoscope were demonstrated as material thickness-measuring devices and flaw detectors which are especially useful when only one side of a piece of material is accessible. The instruments performed very creditably in the function for which they were designed, and it appears that their use could be extended to many other physical problems, for example, that of determining the high-frequency (100 kc to 50 mc) characteristics of materials. They showed immediately the qualitative  $Q$ , or absorption, of materials, and appear to the observer to be already-developed methods for determining the applicability of various materials to such uses as high-frequency delay lines.

It appeared that considerable progress has been made in the study of the properties of solids, that the effects of air-loading sling design and other factors have been determined with reasonable accuracy, and that an optimum testing method has been developed which makes use of hysteresis driving methods in vacuum.

The facilities of the Aircraft Electrical Division were of interest because of the unique types of vibration which can be developed by their sources. One instrument can simulate motions of the "fixed" portions of aircraft engines; that is, circular or elliptical motions over a range of low audio frequencies can be provided. This type of motion is to be contrasted to the more-or-less-linear accelerations provided by most other machines encountered.

Another instrument shown in this Section was a torsional accelerator which utilizes the whip of a universal joint to give predetermined torsional shock to the rotational portion of machines--a type of facility not seen elsewhere in the tour. The projected use of the device is the testing of such equipments as motors and generators. It seems reasonable that torsional accelerations can be used to advantage in the testing of other devices.

The Vacuum Tube Section displayed several shock-testing methods and steady-state vibration methods for use in the development of ruggedized vacuum tubes. The work which they are doing shows promise of providing the Navy with tubes of greater dependability than the five-and-dime variety which the Navy has been forced to use in the past. The shock machine is a miniature hammer and table arrangement. A steady-state vibrator used to search out resonances of tube structures is a Westinghouse unit similar in construction to the conventional loud-speaker, but considerably larger.

The Transmitter Section demonstrated the largest shock and vibration table in the NRL collection. It consists of a table, probably six feet by six feet, which

can be shocked by a pneumatic hammer system, vibrated steady-state by means of motor drive, or rolled through large angles to simulate the roll of a ship, according to the desire of the operator. The table seems quite flexible in application.

The new Shock and Vibration building was very impressive. It seemed that "no stone was left unturned" to provide the optimum mounting for the large variety of shock and vibration machines which will be installed within the structure. The focal point of the building was a shielded, vibration-insulated room which has windows opening on all sides to permit the operators to use sensitive instruments in a vibration-free area while watching the progress of a test on any one of the machines. The size of several of the machines to comprise a part of the equipment of this building was a surprise to the spectators. The mounting springs for some of these machines are much larger than the springs commonly used for locomotives. The spectators were puzzled by open squares in the paved floor which were gravel filled, and questions were asked as to whether the gravel offers vibration-insulating properties. The answer was that the gravel had been placed in the openings in the deck to guard against injury of workmen during the construction of the building. At the end of construction, the gravel will be removed, leaving pits in which machines will be mounted. Only the smaller pits were treated this way; the larger ones were protected by guard rails.

Several shock and vibration equipments were already in operation in the vicinity of the shock and vibration building. Shock hammers are in use to give sharp,

nerve-wracking blows in any one of three directions to whatever equipment that can be bolted to the shock tables. Steady-state vibrating machines working on the eccentric-weight principle are in use to shake large cabinets of electronic equipment. It was demonstrated how, by adjusting the vibration frequency to a resonance, a seemingly rigid cabinet can be vibrated at a warping mode with considerable amplitude.

An interesting study in steady-state vibrations and in shock excitation of natural modes was demonstrated by means of a ship propeller. Instead of tackling the relatively impossible task of computing the normal modes of a large propeller structure, a shock device, consisting of a magnetostriction tube and a pulsing thyratron, was used in conjunction with a thyratron pulser and a spectrum analyzer. The resulting data was a paper tape record which indicated clearly the natural modes of the complicated propeller casting. After the normal modes had been determined, the propeller was vibrated steady-state from a sinusoidal source, the vibration patterns traced out, and the nodes marked in chalk on the surface of the propeller. It was pointed out that serious ship-vibration problems have been solved by a procedure similar to this. The determination of nodal lines provided the key to the source of troublesome vibrations and thereby indicated the method of correction to be employed.

This equipment, together with the huge pile of crated machinery in the new building, gave indication of the experience of this organization, and a promise of significant research on shock and vibration in the future.

\* \* \*

NRL SHOCK AND VIBRATION EQUIPMENT

No. of Machines	Type of Drive	Freq. Range (cps)	Accel. (Max. at Capacity)	Capacity (pounds)	Table Dimen.	Excursion (inches)	Direction of Motion	Manufacturer
Shock Machines								
1	swinging hammer 3000 lb.			3000	5' x 5'		vertical	Westinghouse Electric Co.
2	swinging hammer, falling wt. 400 lb.			400	24" x 27"		horiz. or vertical	General Electric Co.
1	Gravity drop table		390 g	<5 lb	4" x 4"		vertical	American Standards Assn.
1	swinging hammer 75 lb.		1000 g	25	15" x 18"		horiz. from one direction	Taft-Pierce Co.
1	swinging hammer 75 lb.		1000 g	25	15" x 18"		horiz. from one direction	Naval Research Laboratory
1	swinging hammer 83.3 lb.			100	24" x 29"		horiz. from one direction	Naval Research Laboratory
Vibration Machines								
1	reaction	5-35	3 g	1000	5' x 5'	0-0.06	horiz. or vertical	Naval Research Laboratory

No. of Machines	Type of Drive	Freq. Range (cps)	Accel. (Max. at Capacity)	Capacity (pounds)	Table Dimen.	Excursion (inches)	Direction of Motion	Manufacturer
Vibration Machines (contd.)								
1	direct	5-60	10 g	500	4' x 4'	0-0.214	horiz. or vertical	Western Electric Company
1	reaction	10-60	10 g	300	2' x 4'		horiz.	LAB Corporation
1	direct	50-200	30 g	150	24" diam.	0.009-0.50	elliptical	MB Mfg. Company
1	direct	10-60	10 g	100	30" x 30"	0-0.214	horiz. or vertical	Western Electric Company
1	direct	10-60	32 g	100	18" x 18"	0-0.125	horiz.	Waugh-Johnston Labs.
1	direct	10-60	12 g	100	18" x 24"	0-0.125	vertical	Waugh-Johnston Labs.
2	direct	10-55	23 g	100	15" x 18"	0-0.125	horiz.	All American Tool & Mfg. Co.
3	direct	10-55	23 g	100	15" x 18"	0-0.125	vertical	All American Tool & Mfg. Co.
1	direct	17-100	32 g	100	18" x 18½"	0-0.0625	horiz.	Waugh-Johnston Labs.
1	direct	10-60	10 g	100	24" x 30"	0-0.5	3 dir. circular in 2	LAB Corporation
1	reaction	10-60	20 g	100	24" x 40"	0-0.125	Circ. or lin. in hor. plane	LAB Corporation

No. of Machines	Type of Drive	Freq. Range (cps)	Accel. (Max. at Capacity)	Capacity (pounds)	Table Dimen.	Excursion (inches)	Direction of Motion	Manufacturer
Vibration Machines (contd.)								
1	direct	10-60	10 g	100	24" x 30"	0-0.5	vert. or hor.	LAB Corporation.
2	direct	10-55	23 g	25	12" x 15"	0-0.125	horiz.	All American Tool & Mfg. Co.
1	direct	3.3-50	10.9 g	25	9" x 16"	0-0.062	Circ. in 45° plane	Waugh-Johnston Labs.
1	direct	7.5-60	36.8 g	25	8" x 10"	0.04 and 0.1	horiz.	Naval Research Lab.
1	voice coil	0-10,000	350 g	25	18" x 18"	0-0.0625	vert. or hor.	Westinghouse Electric Co.
2	direct	10-55	37 g	10	8" x 8"	0-0.125	vertical	All American Tool & Mfg. Co.
1	direct	10-60	37 g	10	8" x 8"	0-0.2	vertical	" " "
1	direct	10-60	37 g	10	7" x 12"	0-0.2	horiz.	" " "
2	direct	10-60	28 g	10	7" x 7"	0-0.25	vertical	" " "
2	direct	10-60	37 g	10	7" x 7"	0-0.2	vertical	" " "

Type of Machine	No. of Machines	Type of Drive	Frequency Range (cps)	Accel. (max.)	Capacity (pounds)	Table Dimen.	Excursion (inches)	Direction of Motion	Manufacturer
Vibration	1	direct motors (magnetic coil)	20-1600 HI 20-10,000GS	50 g	250 lb force (HI) 25 lb force (GS)		0-0.375	any	Westinghouse Electric Co.
Vibration Inclination	1	reaction	6.6-60 7 cpm		400	50" x 50"	0.0096	3 planes, primarily vertical pitch or roll 45°	Naval Research Laboratory
Inclination	1		Roll: 3-3 ¼ 5, 6 2/3 cpm Pitch: ¼-13¼ at 5°; ½ - 22.2 at 3° (cpm)		24,000	308 ft <sup>2</sup>		roll: 0-15° pitch: 3° or 5°	Naval Ordnance Plant
Inclination	1		Roll: 1½ - 6 Pitch: 10 (cpm)		3,000	49 ft <sup>2</sup>		roll: 5°, 10 - 15° pitch: 5°	Bartlett-Hayward Div., Koppers Company
Shock		pneumatic ram		1000 g				hor., 4 dir.	
Vibration	1	direct	5.4 - 35.4	10 g	2,000	6' x 6'		vertical	Ordnance Shop, Brooklyn Navy Yard
Inclination		direct	5 - 10 cpm					pitch or roll: 45° 37.5°, 22.5°	
Blast	1	3" gun (50 cal.)							

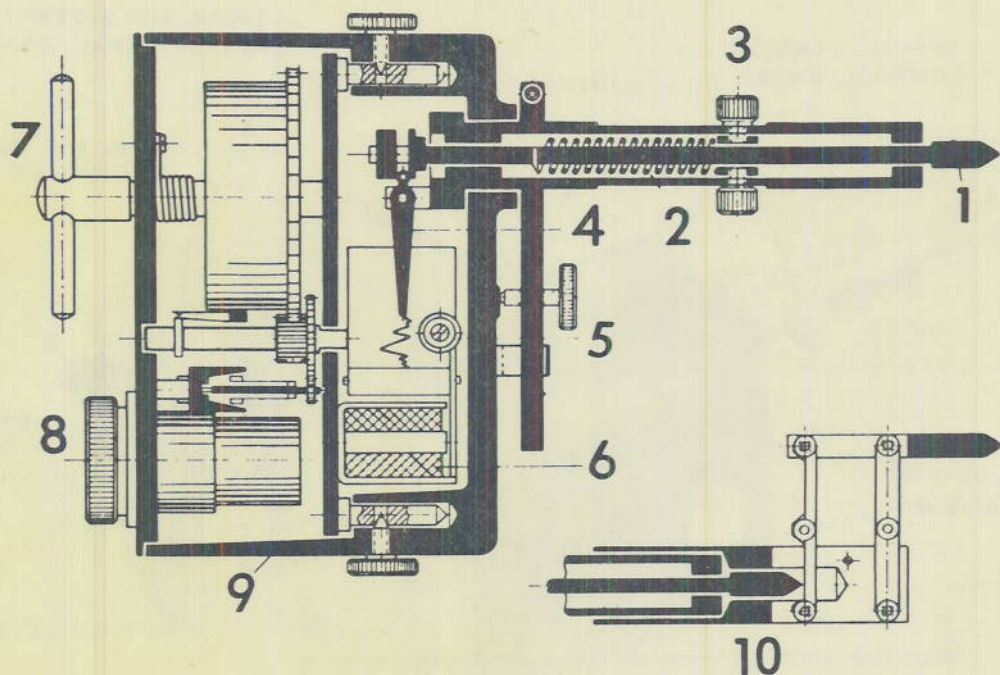


Fig. 1. Schematic drawing of Askania Vibrograph. (1) probe, (2) compression spring, (3) spring tension control knob, (4) recording scribe, (5) timing indicator, (6) timing indicator magnet, (7) winding handle, (8) battery case, (9) housing, (10) amplitude-reducing attachment.

THE ASKANIA VIBROGRAPH  
 Chester B. Cunningham, NRL

At the close of the war with Germany, an enemy cargo submarine, carrying numerous scientific instruments obviously destined for Japan, voluntarily surrendered at an east coast port. Among the instruments were several mechanical vibration recorders made by the Askania Werke, A.G., in Berlin. These vibrographs have been used at the Naval Research Laboratory in connection with many vibration problems, and, since they are soon to be manufactured in this country, it is believed that a description of the instrument will be of general interest.

The motion of a probe is mechanically amplified by a lever which scribes on a

moving strip of waxed paper. The paper is pulled from a roll by a spring-wound governor-controlled motor, and is stored in a compartment until removed. Timing marks at one-second intervals are made on the waxed paper by the armature of a magnet energized by a flashlight cell and controlled by cam contacts in the governor mechanism. The instrument also contains another timing marker actuated either by an external battery or by contacts. A selector switch provides four combinations of internal or external batteries, with internal or external timing contacts.

Figure 1 is a schematic diagram of the unit; Figure 2 is a photograph of the in-

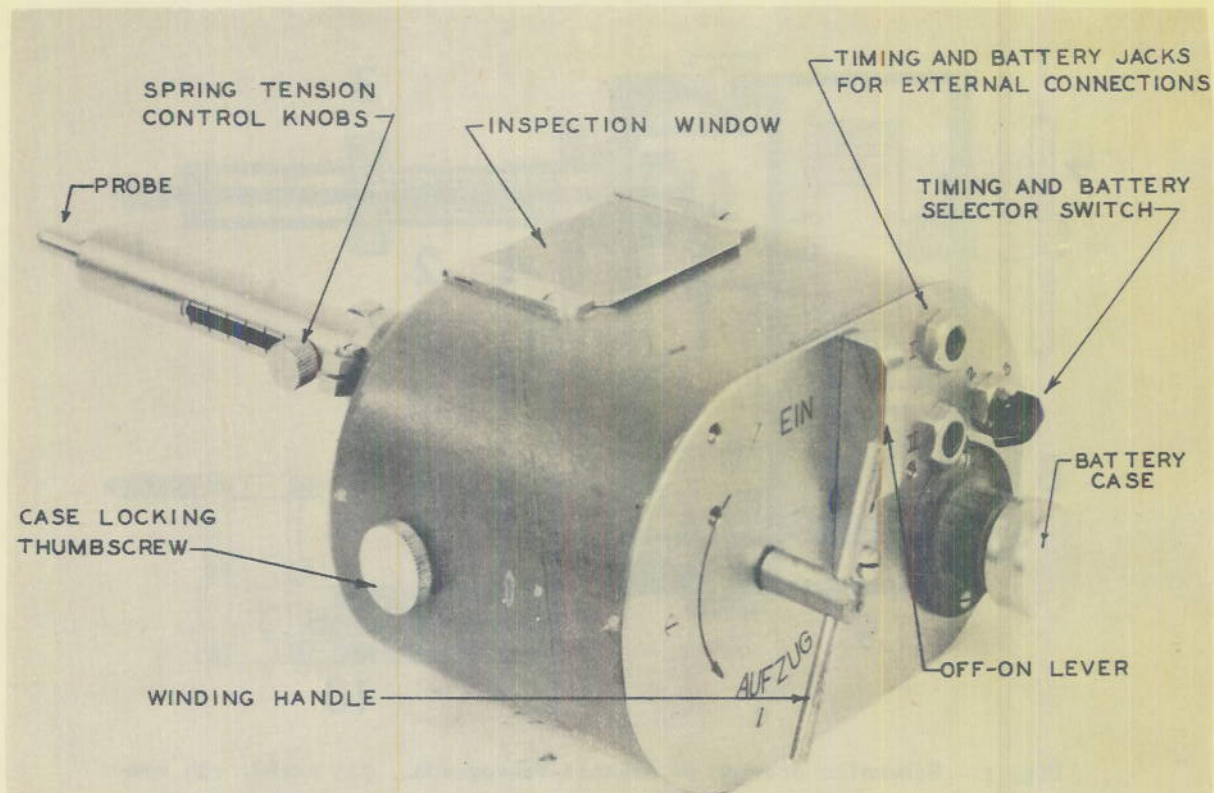


Fig. 2. Photograph of Askania Vibrograph

strument; and Figure 3 is a photograph of the unit disassembled.

A lucite inspection window is located on the top of the instrument and is covered by a piece of polished chrome-plated metal, hinged at one end so that it can be used as a mirror in difficult positions. A second lucite dust cover, located at the bottom of the instrument, can be pulled out for removal of the waxed paper record.

Accessories furnished with the unit include a carrying case, external timing cables, spare paper rolls, spare battery, and a mechanical reducing attachment. The vibrograph weighs 3.75 pounds. The instrument in the carrying case with attachments weighs 6.5 pounds.

The waxed paper is supplied in a roll nine meters long. Paper travel in the

instrument is approximately 40 millimeters per second. The paper-drive motor runs for one minute without rewinding.

The instrument was designed to be hand held, and is essentially seismic for all frequencies above five cycles per second. The upper frequency limit is determined by the tension on the compression spring. Maximum tension permits frequencies of 150 cps at 20 g acceleration to be recorded.

The mechanical magnification of the vibration amplitude is six. The maximum excursion that can be recorded is four millimeters, or approximately 0.15 inch. Excursions as low as 0.002 inch can be recorded.

The mechanical reducer produces, when attached, a total mechanical magni-

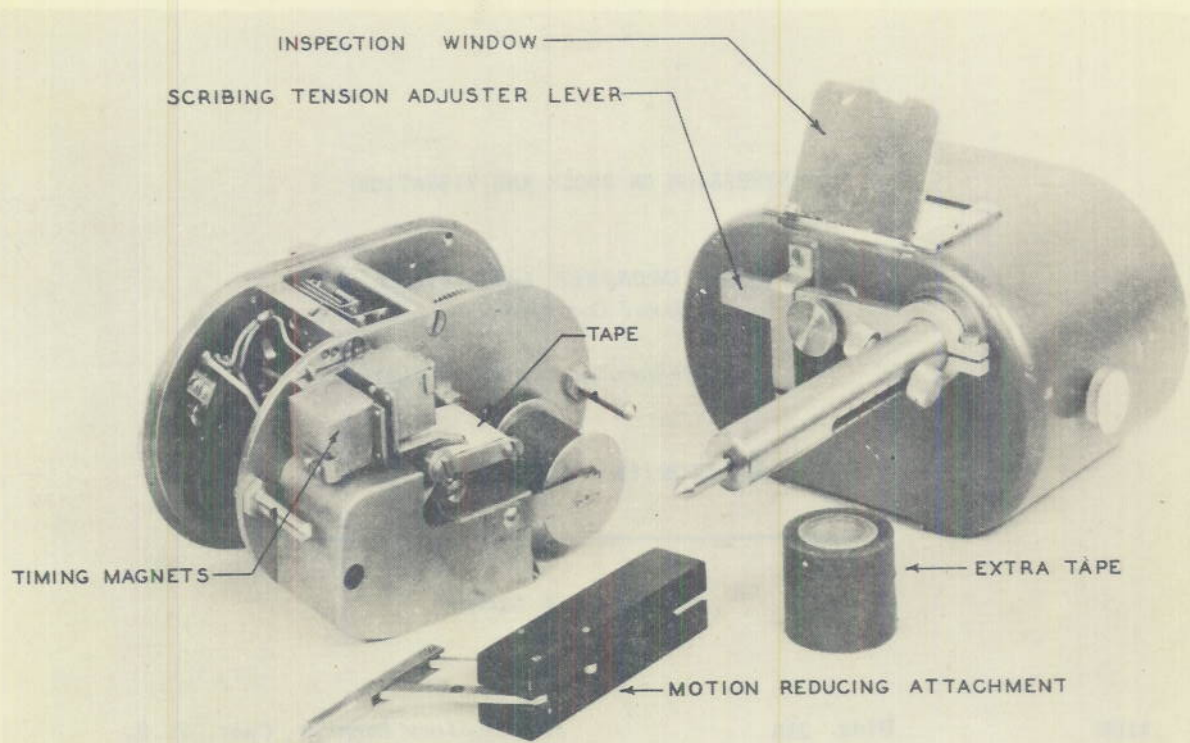


Fig. 3. Askania Vibrograph disassembled

fication of two or one, depending upon the adjustment of the attachment. Vibrational displacements of almost one inch can be recorded with the aid of the mechanical reducer.

The Askania Vibrograph record is immediately visible and can be analyzed without the use of a microscope or special projection equipment. This is of great value during field measurements when data must be studied on the spot. The mechanical reducing attachment is of value where large vibration amplitudes are encountered. The reducer is slipped over the end of the probe arm and the record obtained immediately.

The instrument scribe arm describes an arc instead of a straight line on the

record for a linear movement of the probe, so that a detailed analysis of the vibrational waveform is not practical. For quick, on-the-spot, field measurement of vibration amplitudes and frequencies, the instrument is very satisfactory.

The American model will be different from the German model in only a few respects. The width of the waxed paper will be one inch instead of 25 millimeters. The timing and battery jacks and cables for external connections are to be eliminated. The internal timing mechanism, actuated by the governor and enclosed flashlight cell, will be retained.

\* \* \*

SYMPOSIUM ON SHOCK AND VIBRATION

NAVAL ORDNANCE LABORATORY  
Naval Gun Factory

1100, Wednesday, 19 March 1947

AUDITORIUM, BUILDING 218

---

Schedule and Agenda

1100	Bldg. 218	<i>Introductory Remarks</i> , Capt. F. S. Withington, Officer-in-Charge, Naval Ordnance Laboratory
1115		Discussion of NOL Shock and Vibration Equipment
1145	Bldg. 184	Tour of NOL Shock and Vibration Facilities
1245	Bldg. 101	Lunch
1345	Bldg. 218	Talk: <i>Evaluation of Inertia-Operated Devices</i>
1430		Talk: <i>History and Development of the Lightweight Shock Machine</i> , by R. H. Oliver, BuShips
		Discussion: <i>Applications of Lightweight Shock Machine</i> , led by W. H. Hoppmann, New York Naval Shipyard
1530		Discussion: <i>Topics for next Symposium</i>

---

1545 Transportation available to NRL and Navy Department

SAVIBULL  
(Notes)

UNCLASSIFIED

Agenda Committee

In accordance with the expressed desires of the group assembled at the 7 January Symposium, a representative Agenda Committee has been formed to arrange future symposium programs, their subjects, and the time and place of meeting. The members of the Committee are: Mr. J. H. Armstrong, NOL; Mr. M. L. Henoch, BuShips (332); Mr. R. T. McGoldrick, DTMB; Dr. Irwin Vigness, NRL; and, as recording secretary, Mr. J. M. Taylor, NRL.

Suggestions and criticisms concerning the symposia agenda should be referred to to the Secretary of the Committee, for the Committee's action. The address is

S&V Agenda Committee (402)  
Naval Research Laboratory  
Washington 20, D. C.

\* \* \*

Definitions Committee

The personnel of the new Committee on Terminology; Definitions, and Standards are: Comdr. J. O. Baker, DTMB; Dr. L. W. Ball, NOL; Mr. L. H. Fryer, BuShips (345); Dr. H. M. Trent, NRL; and Mr. B. A. Wiener, BuAer.

\* \* \*

SAES Meeting

The Society for Experimental Stress Analysis has invited papers on subjects related to shock and vibration to be presented at its Chicago meeting in May 1947. Dr. Irwin Vigness of NRL will talk on "Some Characteristics of the Navy Type HI Shock Machine." A representative of the David Taylor Model Basin will discuss "The Effect of Impact on Simple Elastic Structures."

Next Meeting, S. & V. Symposium

The next Shock and Vibration Symposium will be held on 19 March 1947 at the Naval Ordnance Laboratory, Naval Gun Factory, at 1100. The Schedule and Agenda of this meeting appears on page 22 of this issue of the *Bulletin*.

Visitors are requested to enter the Gun Factory grounds through the Administration Building on Eleventh Street.

\* \* \*

Contributed Articles

Readers of the *Bulletin* are invited to submit articles for publication in the *Bulletin*. The *Bulletin* will not attempt to compete with the established journals, and articles published here should be limited to those of general interest to the Navy. In addition to papers describing new or unusual equipment, the *Bulletin* will welcome discussion-provoking treatments of more fundamental matters of interest to workers in this specialized field. Gadgeteering notes and experimental hints will be welcomed. Persons who speak extemporaneously during informal discussions at the Symposia may wish to prepare a short summary of their remarks for inclusion in the published proceedings of the Symposium. A "Letters to the Editor" column is contemplated, in which continuing discussions may be carried on.

The address for contributions of any of these types is:

Shock and Vibration Bulletin  
Code 402  
Naval Research Laboratory  
Washington 20, D. C.

\* \* \*

Editorial Committee

At the 13 February Symposium, the Agenda Committee was given additional duties as an Editorial Committee for the *Bulletin*. The Committee recognizes, as its editorial responsibilities, the following:

1. To review contributed papers for technical competence and accuracy, or to

submit them to a referee for such a review.

2. To review invited papers (those read at symposia).

3. To review the transcript of informal discussions at symposia, and to abstract or summarize the more important points for inclusion in the printed minutes.

