

UNCLASSIFIED

AD NUMBER

AD473912

CLASSIFICATION CHANGES

TO: unclassified

FROM: confidential

LIMITATION CHANGES

TO:

Approved for public release, distribution unlimited

FROM:

No public or foreign release.

AUTHORITY

DSWA ltr., 10 Apr 97; DSWA ltr., 10 Apr 97

THIS PAGE IS UNCLASSIFIED

X-10
113

(14) XRI-173

OPERATION CROSSROADS

REPORT OF

BUREAU OF SHIPS INSTRUMENTATION GROUP

CLASSIFICATION (Cancelled) referred to **UNCLASSIFIED**
By Authority of *Memorandum* Date *3/2/65*
By *Shassa*

SECTION II,

Accelerometers, Reed Gages,
and
Seismic Instruments

QUALIFIED REQUESTERS MAY OBTAIN COPIES OF THIS REPORT FROM DDC.
NOT FOR PUBLIC RELEASE.

NOV 19 1965

UNCLASSIFIED

COPY NO. 000121

AU NO. 473912
DDC FILE COPY

(12) 7/4

TOP SECRET

ef

Report On
ACCELEROMETERS, REED GAGES,
and
SEISMIC INSTRUMENTS

TESTS ABLE AND BAKER

**QUALIFIED REQUESTERS MAY OBTAIN COPIES OF THIS REPORT FROM DDC,
NOT FOR PUBLIC RELEASE.**

The installation of these instruments and the analysis of the data were performed by R. T. McGOLDRICK and S. DAVIDSON of the David Taylor Model Basin. This report was prepared by R. T. McGOLDRICK.

~~TABLE OF~~ CONTENTS!

	Page No.
General	1
Instrument Locations;	2
Description and General Theory of the Instruments;	2
Data and Results for Test Able;	14
Remarks on Test Able;	34
Data and Results for Test Baker;	35
Remarks on Test Baker;	63
Discussion of Instrument Behavior; and	64
Shock Intensity as a Function of Distance	72
List of Figures other than Photographs	ii
List of Photographs	iii
Bibliography	77

List of Figures other than Photographs

<u>Figure Number</u>	<u>Title</u>	<u>Page No.</u>
1	Attack Transport Type of Target Vessel (APA) - Outboard Profile Showing General Locations of Compartments in which Instruments were Located.	4
2	Theoretical Response of One Degree System to Impressed Motion $x = \sin wt$.	13
3	Reproductions of Pallograph Records Obtained on Test Able, APA-64, E gages 1 & 2.	78
4	Reproductions of Pallograph Records Obtained on Test Baker, APA-64, E gages 1 & 2.	79

List of Photographs

<u>Photo. No.</u>	<u>Title</u>	<u>Crossroads Negative No.</u>
100	A gage: Mass plug accelerometer	AV 14-618-5
101	E-1 gage: Pallograph Type C	AV 14-618-2
102	E-2 gage: Pallograph Type B	AV 14-618-3
103	J gage: Jacklin accelerometer	AV 14-618-1
104	K gage: Shock displacement gage	AV 14-618-6
105	R gage: Multi-frequency reed gage	AV 14-618-7
106	S gage: Seismic displacement gage	AV 14-618-4
107	A-1,3 - APA-64, Wardroom, port side plating	54-609-4
108	A-2,4 - APA-64, Wardroom, stbd side plating	95-394-3
109	A-5,7 - APA-64, Dry provisions, port shell frame	95-394-10
110	A-6,8 - APA-64, Dry provisions, stbd shell frame	54-609-5
111	A-9,10,11,12 - APA-64, Ammunition Stowage, over keel	54-406-9
112	E-1 - APA-64, Ammunition Stowage, over keel	54-406-3
113	E-2 - APA-64, Ammunition Stowage, over keel	54-406-2
114	J-1 - APA-64, Ammunition Stowage, over keel	54-797-5
115	K-1 - APA-64, Ammunition Stowage, over keel	54-797-2
116	R-1 - APA-64, Wardroom, port side plating	95-394-5

TOP SECRET

List of Photographs (continued)

Photo. No.	Title	Crossroads Negative No.
117	R-2 - APA-64, Wardroom, stbd side plating	95-394-2
118	R-3 - APA-64, Garbage disposal, underside Weather deck	54-610-1
119	R-4 - APA-64, Dry provisions, port shell frame	95-394-7
120	R-5 - APA-64, Dry provisions, stbd shell frame	95-394-8
121	R-6 - APA-64, Ammunition stowage, port shell frame	95-393-11
122	R-7 - APA-64, Ammunition stowage, stbd shell frame	95-393-10
123	R-8 - APA-64, Ammunition stowage, over keel	54-406-8
124	R-9 - APA-64, Ammunition stowage, over keel	54-406-7
125	R-10 - APA-64, Underside weather deck, frame 113	95-394-12
126	R-11 - APA-64, Gasoline stowage, over keel	95-601-2
127	R-12 - APA-64, Gasoline stowage, over keel	95-601-3
128	S-1 - APA-64, Wardroom, port side plating	54-610-8
129	S-2 - APA-64, Wardroom, stbd side plating	95-393-12
130	S-3 - APA-64, Garbage disposal, underside weather deck	54-799-12
131	S-4 - APA-64, Dry provisions, port shell frame	54-609-10
132	S-5 - APA-64, Dry provisions, stbd shell frame	54-609-11
133	S-6, 7 - APA-64, Ammunition stowage, over keel	54-406-6
134	S-8 - APA-64, Gasoline stowage, over keel	54-610-5
135	S-9 - APA-64, Gasoline stowage, over keel	54-610-3
136	Sample S gage Record	AV 14-601-6



General

When the problem of instrumentation for the Crossroads Project was first considered by the Bureau of Ships Instrumentation Group, it was appreciated that shock instrumentation was still in an early stage of development in spite of the work that had been done in this field during World War II. Although the primary aim was to collect as much information as possible as to the behavior of the target vessels that survived the bombs the opportunity to test various instruments under actual shipboard conditions was not overlooked. It was felt, however, that the improvising of new gages of types that had never been tried before was somewhat risky and undesirable.

The instruments coming under the heading of accelerometers, reed gages, and seismic instruments were for the most part rather simple in construction and had proven useful both on board ship and in the laboratory during World War II. As anticipated much was learned about the good and bad features of their design from their performance at Bikini and suggestions for their improvement are included in the discussion of the results obtained.

The target vessels on which these instruments were installed were expected to suffer various degrees of shock damage according to their distances from the bombs. The principal vessels selected for this purpose comprised chiefly the southern string of attack transports (APA's). In addition an APA and a submarine not in this formation carried some of these same instruments. The vessels in question were APA's 57, 63, 64, 65, and 85, and SS 308.

In the case of the submarine the instruments were located on the shell frames in the forward and after torpedo rooms. In the case of the attack transports the instruments were dispersed throughout the vessel as far as the number available would permit. It was hoped by so doing to obtain the pattern of shock for the vessel as a whole as well as to reveal the shock sustained by the principal structural members such as main frame members and typical sections of shell and deck plating.

Instrument Locations

With few exceptions the instruments of this group occupied the same positions in the target vessels for both the air and underwater shots. These locations are tabulated in detail in the sections on Tests Able and Baker. The names and numbers of the vessels involved were as follows: U.S.S. APOGON (SS-308), U.S.S. GILLIAM (APA-57), U.S.S. BLADEN (APA-63), U.S.S. BRACKEN (APA-64), U.S.S. BRISCOE (APA-65), and U.S.S. GASCONADE (APA-85). The U.S.S. NIAGARA (APA-87) was also equipped with fittings for receiving the same instruments as APA-65, but the transfer of instruments from APA-65 to APA-87 after Test Able was found unnecessary.

As the tests were planned on the basis of an assumed wind direction, the side of the vessel to be hit by the shock was considered to be known. With few exceptions, however, the instrumentation was duplicated on each side of the vessel in order to indicate the contrast in the shocks on two sides. The preferred members for instrument locations were the main structural members such as the keel, transverse frames, panels of side plating, and deck panels. Locations were selected both above and below the waterline including the locations at which both the maximum underwater shock and the maximum air blast were anticipated. Figure 1 shows an outboard profile of an attack transport (APA). The general locations of the compartments selected for instrumentation are shown by the dotted lines on this profile view.

Description and General Theory of the Instruments

A detailed report of the instruments included in this group may be found in a TMB report entitled: 'Instruments for Measuring Vibration and Shock on Ship Structures and Machinery' (see bibliography at end of this section). Only a brief description of each instrument is given here for convenience in reading this report. Photographs of instruments of each type are included in a separate volume.

The mass plug accelerometer (A gage) which is shown in Photo. No. 100 is designed to indicate whether or not the structure to which it is attached reaches a certain acceleration. Inside of a cylindrical case which fits a stud welded to the structure is a small tensile specimen of bakelite. One end of the specimen threads into a nut which

forms part of the case while the other end threads into a small steel weight which is otherwise free to move axially inside the case. While a detailed investigation of the behavior of this instrument has shown its action to be more complicated (see Reference (2) in bibliography), the simple theory is that if the product of mass and acceleration exceeds the tensile or compressive strength of the bakelite specimen, fracture will result. The acceleration setting of the instrument depends on the diameter of the tensile specimen. These gages are usually installed in groups, each having a plug of a different diameter. The settings used were 200, 500, 1000, and 1500 g (g standing for the acceleration of gravity).

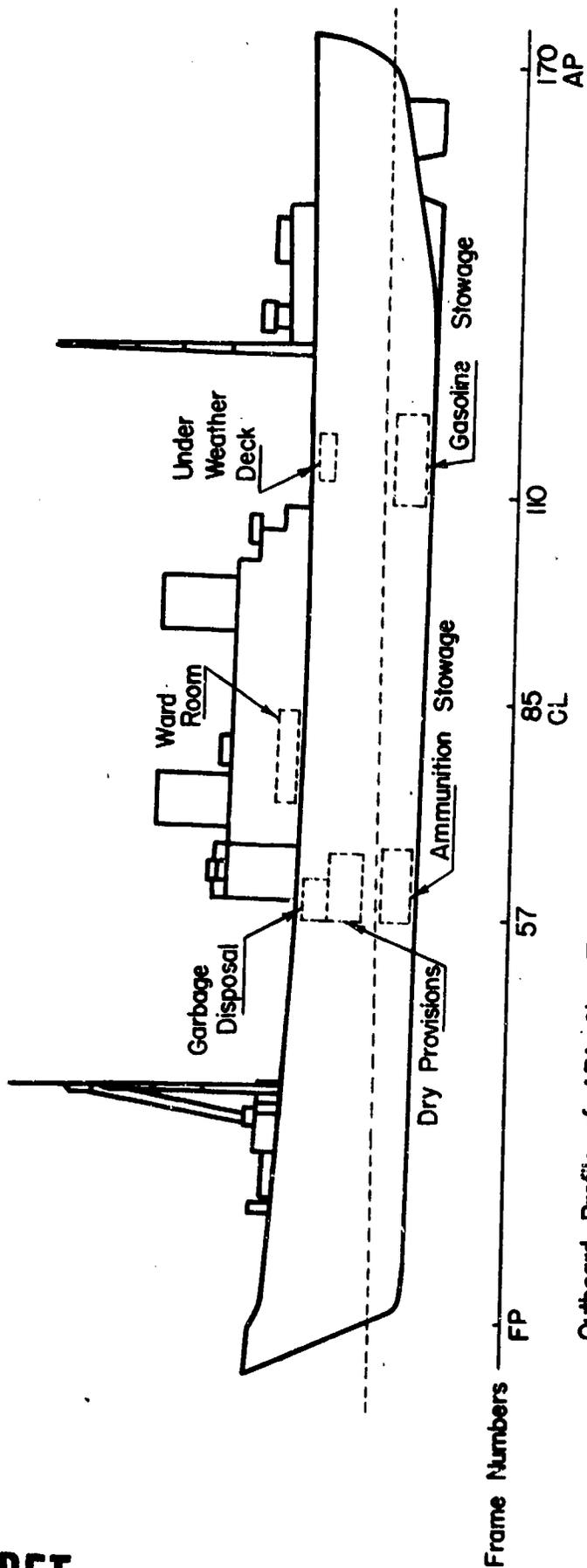
The pallographs (E gage) are seismic instruments designed specifically for recording ship vibration (Photos. Nos. 101 and 102). The seismic arm is suspended from the frame of the instrument by means of flexure springs. Balance is obtained by the use of adjustable helical springs. An air dashpot with adjustable orifice is provided for damping out the free vibrations of the arm. The motion of the arm relative to the frame is transmitted through a multiplying linkage to a stylus which makes a trace on a moving strip of waxed paper. A timing magnet connected to an external contractor makes an additional trace on the paper having a jog every second. Photo. No. 101 shows the Type C pallograph for horizontal vibration and Photo. No. 102 shows the Type B pallograph for vertical vibration.

While intended for recording steady vibrations, the pallographs can be used for recording shock or transient motions provided the displacements are small and the accelerations low enough so that the instrument remains undamaged. They cannot be considered high shock instruments. Obviously such an instrument cannot be shock mounted but must be rigidly attached to the structure whose motion is to be recorded. The principal characteristics of these pallographs are as follows:

Pallograph Type C: direction of recorded vibration - horizontal
frequency range: 150 to 1,000 CPM.
amplitude range: 2 to 150 mils single
magnification: 3x

Pallograph Type B: direction of recorded vibration - vertical
frequency range: 50 to 1,000 CPM.
amplitude range: 3 to 225 mils single
magnification: 2x

TOP SECRET



Outboard Profile of APA Class Target Vessel Showing Location of Compartments in Which Gages Were Installed.

FIGURE 1

The Jacklin accelerometer (J gage), of which only one was available, is a 3-component, photographic recording instrument of high sensitivity. This instrument was acquired by the TMB for recording steady state vibrations and other motions involving very low accelerations such as the rolling, heaving, and pitching motions of ships. The element for each component of acceleration consists of a hollow metal cylinder supported by flexure springs and mounted concentrically with a stationary plastic core. The axes of the cylinders of the three elements are oriented in each of the three principal directions. When the instrument is accelerated in the direction of the axis of one of the elements, the motion of the cylinder deflects a small mirror causing a narrow beam of light to move up or down on a slit in front of the photographic paper. The paper drive is furnished by a separate power unit which also provides a timing signal. The power unit is designed for 12 volt, d-c operation. The instrument is illustrated in Photo. No. 103.

The natural frequency of each element is about 100 CPS and the sensitivity is such that a 1-inch deflection of the trace on the record represents an acceleration of 1g. The instrument is considered reliable up to frequencies of 60 CPS and acceleration single amplitude of 1.5g. On the Crossroads tests the vertical acceleration, transverse acceleration, and timing signals were used.

The shock displacement (K gage), which is illustrated in Photo. No. 104, is a one directional seismic instrument designed for recording displacement due to moderate shocks such as are encountered during structural gun firing tests. The relatively heavy seismic element consists of a hollow steel cylinder moving on roller guides and attached to helical restoring springs. The element carries a steel scribe by means of which its movement is recorded on a rotating chromium plated brass disk. In order to make the instrument independent of electric power for the Crossroads tests, the motor drive was eliminated and instead an eccentric weight was attached to the shaft carrying the disk so that under the shock the disk would rotate enough to spread out the record thus indicating the number of oscillations occurring. The principal characteristics of the shock displacement gage are the following:

frequency range: 800 to 10,000 CPM
amplitude range: 0.01 inch to 1.0 inch single
magnification: direct reading
natural frequency: 520 CPM

The multi-frequency reed gage (R gage) contains a series of reeds

of different natural frequencies. As may be seen from Photo. No. 105 the reeds are clamped at one end and each carries a double pointed stylus at the free end. Under shock perpendicular to the longitudinal axis of the reeds, their movement relative to the gage frame causes a series of lines to be scribed on the waxed paper. No paper drive is provided in the gage as dealt with in this section of the report other than two spools which may be turned by hand for winding off the record after the shock is recorded. Accordingly, the maximum deflection of each reed is the quantity to be observed, and wherever deflection is referred to, it is understood as maximum deflection.

The advantage in field work of a gage requiring no power supply is obvious. It is therefore important to compare the information that can be derived from such a gage with that obtained from various time recording instruments. Past experience has shown that in general the shock motions encountered on board ship are fairly complex whereas the response of a group of reeds can be theoretically computed only for relatively simple types of impressed motions. Before the question of the adequacy of the reed gage for shock measurement can be answered, it is therefore necessary to consider the question of a criterion of shock intensity. The following axioms have been generally accepted for some time by the various groups working in shock measurement.

(1) A high instantaneous acceleration does not necessarily indicate a high shock. High accelerations lasting for very short times can have very little shock effect.

(2) A high velocity does not necessarily indicate a high shock. The high velocity must be acquired in a relatively short time to produce a shock effect.

(3) Large displacements do not necessarily indicate high shock. The displacement also must take place in a relatively short time to have a shock effect.

It has been agreed that if shock motions were all of the impulsive type - that is, such that the velocity-time relation was represented by a step function - the velocity would be the true shock criterion. For other types of shock motion the velocity appears to be the best criterion so far proposed, but it is also necessary to append to it some statement as to the type of motion.

In the case of time recording instruments the information as to shock intensity contained on the record is not in a form in which it can be readily utilized. The data must eventually be reduced to numbers before the designer can interpret them. The reed gage in a sense

performs part of this analysis. While the reed gage cannot possibly reveal all the components of a complicated shock motion, it appears that at least for the type of shocks encountered on board ship, the reed gage demonstrates what simple type of motion would come nearest to producing a shock effect similar to that produced by the actual motion, and that when a statement defining this motion is added to the maximum velocity the shock motion is adequately described for most practical purposes.

In analyzing the reed gage record by comparing the pattern of reed gage deflections (i.e. the relative deflections of the different reeds) with the theoretical patterns produced by certain standard types of motion, it is clear that only the determination of the predominant motion can be hoped for in cases where a succession of shocks is encountered. In general, the shock effects are determined chiefly by the initial motion, but this cannot always be assumed. The response of the reed to various motions impressed on the gage can be readily computed if the reed is considered as a system of one degree of freedom and if damping is considered to have a negligible effect. These assumptions require justification. The second mode of a uniform reed supported as a cantilever has a frequency over six times that of the fundamental. The addition of the stylus will lower this ratio somewhat, but it is clear that even if the reed did execute a second mode vibration, its amplitude would in general be small compared to the fundamental. Moreover if a second mode vibration were predominant, it would be apparent from the reduced radius of the arc scribed by the stylus due to the appearance of the nodal point in the reed. Estimates of damping have been made both by recording free vibrations while moving the paper by hand, and measuring the magnification of a steady state vibration at resonance by tests on a vibration table. These indicate the damping to be quite variable and not to follow the viscous law which is ordinarily assumed in theoretical treatments. Evidently the damping is due to a combination of coulomb and viscous friction. The effective damping was in no case found to exceed 20% of critical damping and in cases it was as low as 5% of critical damping. In each case where the theoretical response to an assumed motion is considered, the response of the undamped reed is given and the effect of damping of this order of magnitude is pointed out. The presence of coulomb friction means that regardless of the type of shock motion impressed there will be a lower limit beneath which the reed will show no deflection; in other words the reed cannot overcome the static friction. This condition is not dealt with in the analysis as shock motions of this low order would seldom be under investigation. Once the reed starts to move the friction is greatly reduced and conforms more nearly to viscous friction.

The following notation is adopted in the analysis of the reed gage:

- t represents time
- x represents the instantaneous displacement of the structure with an arbitrary convention as to sign; for instance x may be considered positive to the right
- x_1 represents instantaneous displacement of the reed relative to the gage; the same convention as to sign is adopted for x_1 as for x
- x_0 is the amplitude of a simple harmonic vibration of the structure.
- v represents velocity of the structure
- a represents acceleration of the structure
- w or ω represents circular frequency of a simple harmonic motion
- p represents the natural circular frequency of the reed without damping
- c/c_c represents the ratio of the viscous damping constant of the reed to its critical viscous damping constant

The dot notation represents differentiation with respect to time - thus \dot{x} is velocity and \ddot{x} is acceleration

Case I: The structure acquires an impulsive velocity v_i which is maintained during the time interval under consideration; that is, the velocity-time relation is a step function. The following conditions apply to the motion of the structure:

$$\begin{aligned}\ddot{x} &= 0 \quad \text{for } t > 0 \\ \dot{x} &= 0 \quad \text{for } t < 0 \\ \dot{x} &= v_i \quad \text{for } t \geq 0 \\ x &= 0 \quad \text{for } t < 0 \\ x &= v_i t \quad \text{for } t > 0\end{aligned}$$

If the reed is undamped its motion relative to the gage is given by the equation

$$x_1 = \frac{-v_0}{p} \sin pt$$

which shows that the reed will deflect the same distance either side of its rest position and this deflection will be numerically equal to v_0/p .

If damping is considered, the expression for the motion of the reed relative to the gage becomes

$$x_1 = \frac{-v_0}{p \sqrt{1-(\frac{c}{c_c})^2}} \sin \sqrt{1-(\frac{c}{c_c})^2} pt e^{-\frac{c}{2m} pt}$$

which represents a damped sine function. If a value of 0.1 for c/c_c (corresponding to 10% of critical damping) is substituted in this equation, it is found that the initial deflection of the reed is reduced by about 15%; for smaller values of damping the reduction would be correspondingly less, but the reed deflections would still be inversely proportional to their natural frequencies provided all the reeds had the same percentage of critical damping. Hence the pattern of reed deflections would not be altered by the damping.

Case II: The structure is subject to a constant or step acceleration, a , during the time interval under consideration. The conditions applying to the motion of the structure are:

$$\begin{aligned} \ddot{x} &= 0 \quad \text{for } t < 0 \\ \ddot{x} &= a \quad \text{for } t \geq 0 \\ \dot{x} &= at \quad \text{for } t = 0 \\ x &= \frac{at^2}{2} \quad \text{for } t > 0 \end{aligned}$$

and the motion of the undamped reed relative to the gage is given by the equation:

$$x_1 = \frac{-a}{p^2} (1 - \cos pt)$$

This shows that the reed oscillates about a position displaced $-a/p^2$ from its rest position. Its oscillation has a single amplitude of a/p^2 so that its maximum deflection from its rest position will be $-2a/p^2$ and the record shows a trace on one side only of the zero line.

If damping is considered, the expression for the motion of the reed relative to the gage becomes

$$x_1 = \frac{-c}{p^2} \left[1 - e^{-\frac{c}{2m}pt} \left(\frac{q_{02}}{\sqrt{1-(\frac{c}{2m})^2}} \cos \sqrt{1-(\frac{c}{2m})^2} t + \cos p \sqrt{1-(\frac{c}{2m})^2} t \right) \right]$$

For a value of damping represented by the relation $c/c_c=0.1$ this gives a peak deflection about 14% lower than for the undamped condition.

Case III: The structure suddenly starts to execute a simple harmonic vibration having a circular frequency w . Here the conditions applicable to the motion of the structure are:

$$\begin{aligned} x &= x_0 \sin \omega t \text{ for } t \geq 0 \\ \dot{x} &= x_0 \omega \cos \omega t \text{ for } t \geq 0 \\ \ddot{x} &= -x_0 \omega^2 \sin \omega t \text{ for } t \geq 0. \end{aligned}$$

and the motion of the undamped reed relative to the gage is given by the equation

$$x_1 = \frac{x_0}{\left(\frac{p}{w}\right)^2 - 1} \sin \omega t + \frac{x_0}{\frac{p}{w} - \frac{p}{w}} \sin pt.$$

This equation is not applicable in the special case arising when $p=w$, that is, the case of resonance. For this special case the expression for x_1 is

$$x_1 = \frac{x_0}{2} [pt \cos pt - \sin pt]$$

It is seen that in the non-resonant condition x_1 contains two sinusoidal terms whose relative magnitudes depend on the ratio p/w . In the resonant condition x_1 increases indefinitely which shows that the treatment without damping is not a realistic one for this special case.

The equation for the relative motion of the damped reed under the condition in which the structure suddenly starts to execute a simple harmonic motion is a cumbersome one.

Theoretical calculations have been made of the responses of both damped and undamped reeds to the impressed motion $x=\sin wt$ for various values of p/w . These show that the transient term has a predominant effect on the response of the reed for values of p/w greater than 1, the peak deflections being many times the steady state amplitude which the reed will assume if the vibration of the structure is maintained. The calculations also show that the pattern of peak deflections,

that is, the ratios between peak deflections of the different reeds, will not differ appreciably from the pattern for the same reeds with no damping, even though the actual values of the deflections are lowered in proportion to the damping, except for the case where one of the reeds happen to be in resonance. In the latter case it is necessary to assume a resonance magnification factor for the particular reed in resonance. The theoretical resonance magnification factor is equal to $\frac{1}{2\zeta}$. It appears from the theoretical calculations that the precision of the gage is not such as to indicate the difference in the peak deflections in both directions under this type of impressed motion. While the first two half swings of the reed may be very different under the impressed motion $x = \sin \omega t$, successive swings frequently equalize the traces made by the reed on either side of the zero. However, this type of motion can be identified from the pattern of maximum reed deflections even though equal in both directions.

Figure 2 shows the theoretical response of a reed for which $p/w = 2.5$ to the motion $x = \sin \omega t$ for no damping and also for a damping value equal to 10% of critical damping ($c/c_c = 0.1$).

Case IV: The structure acquires an impulsive velocity which is maintained only for a time comparable with the natural period of the reed when it is suddenly reduced to zero. Here the conditions applicable to the motion of the structure are

$$\begin{aligned} \ddot{x} &= 0 \text{ for } t > 0 \text{ to } t < t_1, \\ \ddot{x} &= 0 \text{ for } t < 0 \text{ and } t > t_1, \\ \dot{x} &= v_i \text{ for } t \geq 0 \text{ to } t = t_1, \end{aligned}$$

In this case the motion of the reed from the time $t=0$ to $t=t_1$ is the same as for Case I. For the undamped reed the motion is given by the equation

$$x_1 = -\frac{v_i}{p} \sin pt$$

After t_1 the equation of motion becomes

$$x_1 = \frac{v_i}{p} (1 - \cos pt_1) \sin p(t-t_1) - \frac{v_i}{p} \sin pt_1 \cos p(t-t_1)$$

In which it will be observed that the terms $\cos pt_1$ and $\sin pt_1$ are constants. If $t_1 = \frac{\pi}{p}$, that is, if the time interval from 0 to t_1 is a half period of the free vibration of the reed, then

$$x_1 = \frac{2g}{p} \sin p(t-t_1)$$

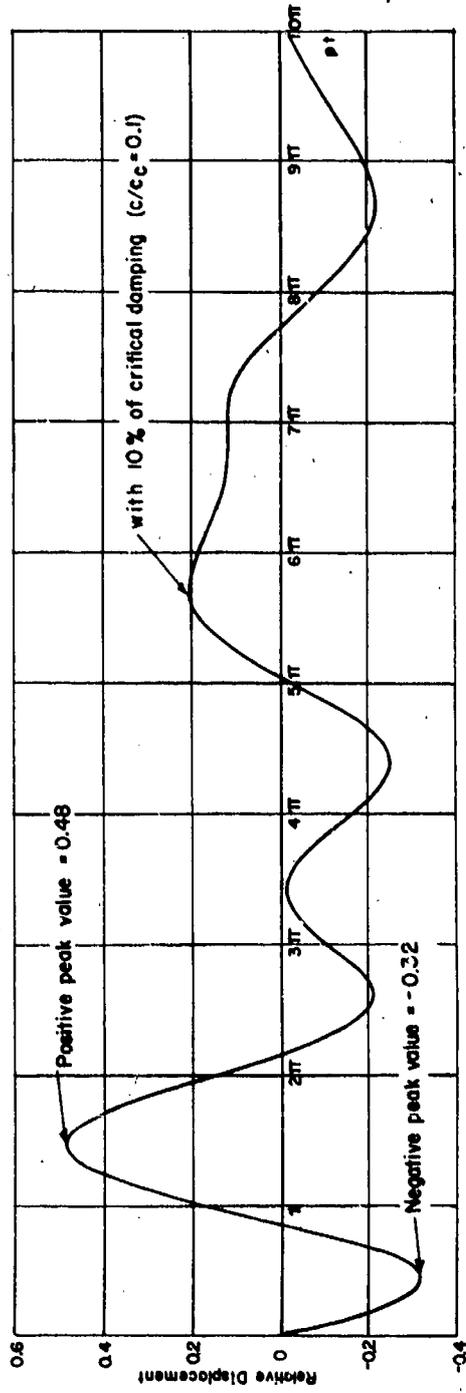
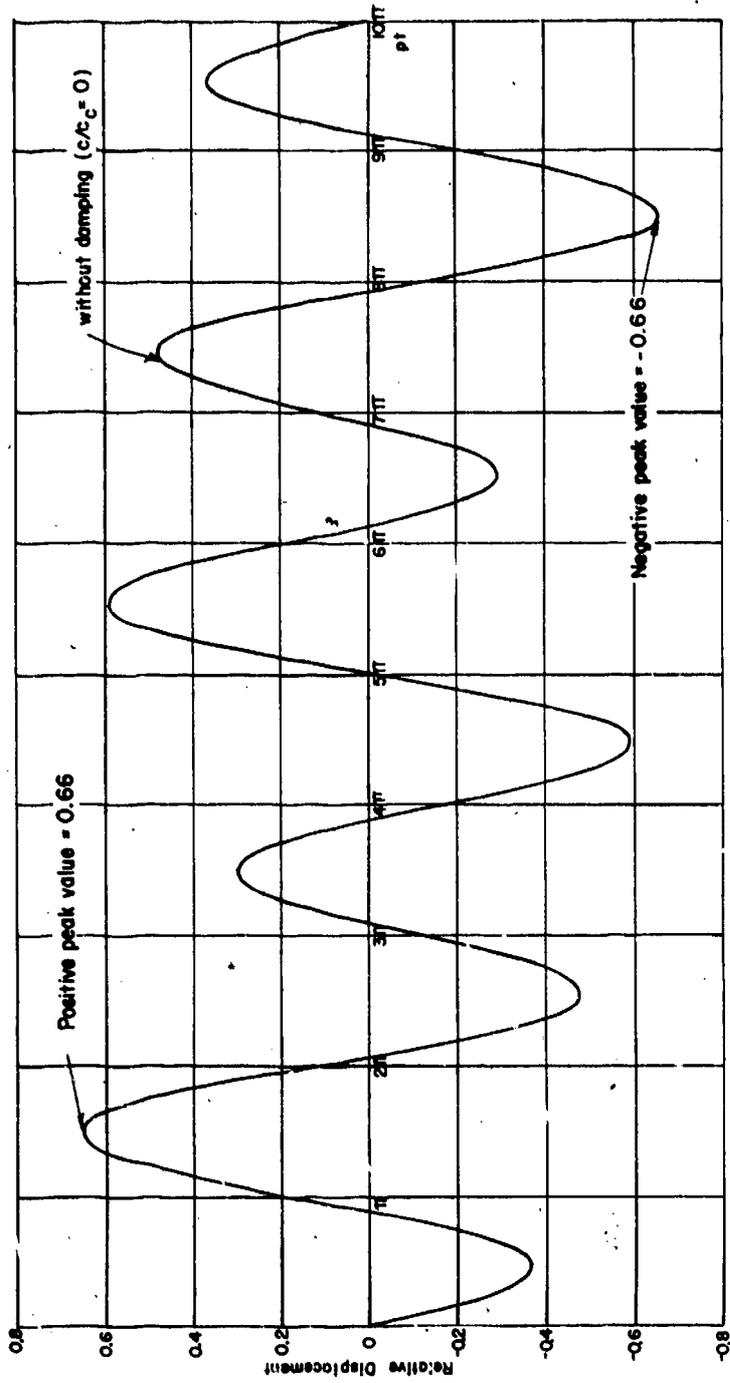
which shows that the amplitude of the reed doubles after its first half swing, emphasizing the fact that it cannot be assumed that the largest deflection of the reed will always be in the direction opposite to that in which the structure starts to move. If the time interval from 0 to t_1 is equal to a whole period of the free vibrations of the reed ($t_1 = \frac{2\pi}{p}$) the motion of the reed relative to the gage stops after the reed executes one complete cycle.

The effect of damping in Case of IV is similar to that for Case I.

Of the above cases the oscillatory case is the easiest to identify if the range of natural frequencies of the reeds is sufficient to cover the frequency of the vibration of the structure. Hence the reed whose frequency is nearest to this frequency will have a very large deflection.

The procedure followed in analyzing the reed gage records obtained from the target vessels after Tests Able and Baker was first to tabulate the reed natural frequencies, next to tabulate the maximum deflection of each reed but noting whether there was any appreciable difference in the deflections of the reed on both sides of the zero line, next to tabulate the step velocities that would correspond to such deflections, and last the step accelerations that would correspond to the reed deflections. If the step velocities tabulated for all reeds giving a measurable deflection on the gage in question were substantially the same, it was assumed that a step function of velocity characterized the shock motion at that gage location. If the tabulated accelerations were found to be substantially the same, it was assumed that the shock motion at the location in question was characterized by a constant acceleration maintained for a time equal at least to half the natural period of the reed of lowest natural frequency. If the tabulation of reed deflections indicated a resonance, the values were compared with the theoretical values obtained from the equations for Case III. In the summary of test results, after each tabulation of reed gage deflections and equivalent step velocities and accelerations, a brief description of the shock motion deduced is given. Further details of this procedure are given in the comparison of the reed gage with the velocity meter in the general analysis of test data.

The seismic displacement gage (S gage) illustrated in Photo. No.



Theoretical Response of One Degree System of Natural Frequency $p/2\pi$ to the Driving Motion $X = \sin \omega t$ for the Case $p/\omega = 2.5$

FIGURE 2

TOP SECRET

105 consists of a cylindrical steel weight which is free to slide on a steel rod ordinarily welded to the ship structure. The cylinder carries a scribe which makes a scratch on the rod whenever there is relative motion between it and the cylinder. To improve the visibility of the record the part of the rod over which the scribe moves is usually coated with Prussian blue. In order to spread out the record so that the oscillatory character of the shock motion may be discerned, the cylinder is unbalanced by the addition of steel washers. This in general will cause the cylinder to rotate as well as move axially under the shock, leaving a continuous trace on the rod. When used to record horizontal motion, the gage has no springs but when it is used for vertical motion, it is necessary to support the cylinder by means of a coil spring. The spring is such as to give the system a natural frequency of about 2 CPS.

As the spring used in the vertical gage is relatively soft, the behavior of the two types is substantially the same except where very low frequency vibrations caused resonance in the vertical type. If the spring force is neglected, the only force that can act on the cylinder in the direction of its axis is the frictional force which includes both the friction between the cylinder and the rod, and the friction due to the scribe. This friction, which must be high enough to prevent the cylinder from moving under normal rolling and pitching of the ship, varies considerably as the cylinder starts to move. It will also vary considerably according to the pressure applied by the scribe. Because of the predominant role of friction in determining the behavior of this gage, it appears that a mathematical analysis would have to be based on unwarranted assumptions. However, it can be seen without such an analysis that if the motion of the structure is oscillatory and of a moderately high frequency the absolute motion of the cylinder, due to its inertia, must be quite small. Hence in such cases, the recorded displacement cannot be very far from the true displacement. It is for recording relatively large oscillatory displacements that this gage is considered most useful. Although a crude instrument, it is easily produced and installed, and can record much larger shock displacements than most instruments now available for shipboard use.

Data and Results for Test Able

The instruments included in this group were designated as follows:

- A mass plug accelerometer
- E pallograph
- J Jacklin accelerometer
- K shock displacement gage
- R multi-frequency reed gage
- S seismic displacement gage

These instruments were used for recording shock and vibratory motions on certain of the target vessels located in zones beyond the range of severe damage. The vessels equipped with such instruments during Test Able were APA's 57, 63, 64, 65, and SS 308. The instrument locations and data obtained are given by ships.

U.S.S. GILLIAM (APA-57)

R gage (multi-frequency reed gage)

Three instruments were installed on this vessel for Test Able at the following locations:

Gage No.	Compart.	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Dry Provisions	Fr. 57	55" below Main Dk.	Sb.Shell Frame	Frame	Athwartshp.
2	Ammun. Stowage	12" fwd Fr. 58	Tank Top	Ctrline.	Over Keel	"
3	"	24" aft Fr. 58	"	"	"	Vertical

None of these instruments was recovered after the sinking of the GILLIAM.

U.S.S. BLADEN (APA-63)

R gage (multi-frequency reed gage)

One R gage was installed on this vessel at the same location for both Tests Able and Baker.

Gage No.	Long. Compartment	Vertical Location	Athwart. Location	Struc.	Direction
2	Aramun. Stowage	Fr. 57	32' below 2nd Pltm.	Pt. Shell	Shell Frame Athwartshp.

All reed deflections were zero on this gage after Test Able.

U.S.S. BRACKEN (APA-64)

A gage (mass plug accelerometer)

Gage No.	Long. Compt.	Vert. Loca.	AthShp. Location	Struc.	Direction	Set-ting	Test A Result
1	Wrdrm.	Fr. 80 1/2	37" above Wthr. deck	Pt. Shell	Panel	Athshp 200g	Unbroken
2	"	"	"	Sb. Shell	"	"	"
3	"	"	40" above Wthr. Deck	Pt. Shell	"	1500g	"
4	"	"	"	Sb. Shell	"	"	"

A gage (continued)

Gage No.	Compt.	Long. Loca.	Vert. Loca.	AthShp. Location	Struc. tion	Direc- tion	Set- ting	Test A Result
5	Dry Prov.	Fr.58	41" below Main deck	Pt.Shell	Frame	AthShp	200g	Broken
6	"	"	"	Sb.Shell	"	"	"	Unbroken
7	"	"	38" below Main deck	Pt.Shell	"	"	1500g	"
8	"	"	"	Sb.Shell	"	"	"	"
9	Amm. Stowage	20" fwd Fr.58	Tank Top	Ctrline.	Over Keel	Vert.	200g	"
10	"	23" fwd Fr.58	"	"	"	"	1500g	"
11	"	32" fwd Fr.58	"	"	"	Athshp	200g	"
12	"	35" fwd Fr.58	"	"	"	"	1500g	"

E gage (pallograph)

Two of these instruments were installed on this vessel at the same locations for Tests Able and Baker.

Gage No.	Compartment	Long. Location	Vertical Location	Athwart Location	Struc.	Direction
1	Ammun. Stowage	42" fwd Fr. 60	Tank Top	Ctrline.	Over Keel	Athwartship
2	"	58" fwd Fr. 61	"	"	"	Vertical

Reproductions of records obtained on Shot Able with E gages 1 and 2 are given in Figure 3 at the end of the text. For convenience in reproduction only the first few seconds of record have been reproduced.

The record obtained from E-1 shows 5 cycles of athwartship vibration with a double amplitude of 7 mils and a frequency of 15 CPS starting to starboard followed 2.1 seconds later by 3 cycles of vibration of a frequency of 7.3 CPS and a double amplitude of 170 mils starting to port. Following this a larger motion to port caused the seismic element to hit the stop. The continuation of the record shows all disturbance to have subsided within 7 seconds.

The record obtained from E-2 shows 10 cycles of vertical vibration reaching a maximum double amplitude of 60 mils and having a frequency of 15 CPS starting upward followed 2.3 seconds later by a series of larger vibrations of complex form having a fundamental frequency of 5 CPS and a maximum double amplitude of 125 mils, starting upward. The record shows all disturbance to have subsided within 7 seconds.

J gage (Jacklin accelerometer)

This instrument, J-1, was installed in the ammunition stowage compartment, on the tank top at the centerline, frame 62, directly over the keel. The athwartship and vertical elements were used. The instrument apparently started too late for illumination and paper speed to reach a steady state before the shock occurred. The athwartship record shows a very slight shock followed in about 2 seconds by a train of vibrations of complex form of which the initial acceleration could not be estimated. The average acceleration during the subsequent vibrations was 0.1g. The vertical trace shows a vibration at a frequency of 8 CPS after the initial shock and an average vibration acceleration of 0.09g. Both traces show the vibration to have subsided

within 7 seconds.

K gage (snock displacement gage)

This instrument was installed in the ammunition stowage compartment at frame 59, on the tank top, directly over the keel and set so as to record athwartship displacement. No displacement was recorded for Test Able on this gage.

R gage (multi-frequency reed gage)

Twelve of these gages were installed in the same locations for both Tests Able and Baker as follows:

Gage No.	Compart.	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Wardroom	Fr. 81 1/2	30" above Wthr.Dk.	Pt.Side Plating	Panel	Athwartshp
2	"	"	;;	Sb.Side Plating	"	"
3	Garbage Disposal	Fr.58	Underside Wthr.Dk.	30" from Pt.Shell	Frame	Vertical.
4	Dry Provisions	Fr.57	56" below Main Dk.	Pt.Shell Frame	Frame	Athwartshp
5	"	"	"	Sb.Shell Frame	"	"
6	Ammun. Stowage	"	52" below 2ndPltfm	Pt.Shell Frame	"	"
7	"	"	"	Sb.Shell Frame	"	"

R gage (continued)

Gage No.	Compart.	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
8	Ammun. Stowage	12" fwd Fr. 58	Tank Top	Ctrline.	Over Keel	Athwartshp
9	"	"	"	"	"	Vertical
10	Near Aft Hatch	Fr. 113	Underside Wthr.Dk.	47"from Pt.Shell	Frame	"
11	Gasoline Stowage	12" fwd Fr. 110	Tank Top	Ctrline.	Over Keel	Athwa rtshp
12	"	60" aft Fr. 110	"	"	"	Vertical

The R gage results for Test Able were as follows (reeds having no measurable deflections are omitted from the tables):

R-1

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.61	6.4	12.5
4	40	1.14	23.8	89.
8	100	0.24	12.6	120.
11	210	0.035	3.8	80.
13	345	0.015	2.7	75.

In this case neither the assumption of an impulsive velocity nor of a step acceleration gives consistent values. The record corresponds most nearly to the condition in which the structure in the vicinity of the gage vibrates sinusoidally with a single amplitude of 0.29 inches

at a frequency in the neighborhood of 40 CPS. Such a motion would give a maximum velocity of 6.1 ft/sec and a maximum acceleration of 46g.

R-2

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.22	2.3	4.6
4	40	.51	10.6	41.
8	100	.075	3.9	40.

This record corresponds most nearly to the condition in which the structure vibrates sinusoidally with a single amplitude of 0.14 inch at a frequency in the neighborhood of 40 CPS. Such a motion would give a maximum velocity of 2.9 ft/sec and a maximum acceleration of 22g.

R-3

Record fouled by moisture, unreadable.

R-4

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.07	0.7	1.5
4	40	.05	1.0	3.9
8	100	.125	6.5	65.

This record corresponds most nearly to the condition in which the structure vibrates sinusoidally with a single amplitude of 0.05 inch at a frequency in the neighborhood of 100 CPS, which would give

a maximum velocity of 2.6 ft/sec and a maximum acceleration of 50g.

R-5

Only one reed on this gage, namely the 20 CPS one, gave a measurable deflection. This deflection was 0.03 inch. The only conclusions that can be drawn from this information are that if the structure acquired an impulsive velocity its value was 0.3 ft/sec or if it had a step acceleration, the latter had a value of 0.5g.

R-6

Only one reed on this gage, namely the 20 CPS one, gave a measurable deflection. This was 0.01 inch. The only conclusions that can be drawn from this information are that if the structure acquired an impulsive velocity, its value was 0.1 ft/sec or if it had a step acceleration, its value was 0.16g.

R-7, 8, 9

These gages showed no reed deflections.

R-10

Reed No.	Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
4	40	0.18	3.9	14.
8	100	.075	3.8	39.

This record corresponds most nearly to the condition where the structure acquired an impulsive velocity of 3.8 ft/sec.

R-11, 12

These gages showed no reed deflections.

S gage (seismic displacement gage)

Nine of these gages were installed on this vessel at the same locations for both Tests Able and Baker as follows:

Gage No.	Compartment	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Wardrm.	Fr. 80 1/2	22" above Wthr.Dk.	Pt.Side Plating	Panel	Athwartshp
2	"	"	"	Sb.Side Plating	"	"
3	Garbage Disposal	Fr. 58	Underside Wthr.Dk.	60" from Pt.Shell	Frame	Vertical
4	Dry Provisions	"	66" below Main Dk.	Pt.Shell	"	Athwartshp
5	"	"	"	Sb.Shell	"	"
6	Ammun. Stowage	29" aft Fr. 58	Tank Top	Ctrline.	Over Keel	"
7	"	"	"	"	"	Vertical
8	Gasoline Stowage	21" aft Fr. 110	"	"	"	Athwartshp
9	"	29" aft Fr. 110	"	"	"	Vertical

The data obtained from the S gages for Test Able are tabulated below:

T C P S E C R E T PAGE 23 OF 79 PAGES

Gage No.	Displacement Indicated (inches)	Direction of Displacement	Notes
S-1	0.31	Starboard	High frequency oscillations of 0.05" double amplitude superimposed.
S-2	0.56	Starboard	High frequency oscillations of 0.02" double amplitude superimposed.
S-3	None		
S-4	0.16	Port	
S-5	None		
S-6	None		
S-7	None		
S-8	None		
S-9	None		

A sample S gage record is given in Photo. No. 107.

U.S.S. BRISCOE (APA-65)

A gage (mass plug accelerometer)

Twenty gages were installed at the same locations for Tests Able and Baker as follows:

Gage No.	Long. Compt.	Vert. Loca.	AthShp. Loca.	Struc.	Direction	Set-ting	Test A Result
1	Wrdrm. Fr.	37" above Wthr. Deck	Pt.Side Plating	Panel	AthShp	200g	Unbrok.
2	"	"	Sb.Side Plating	"	"	"	"
3	"	40" above Wthr. Deck	Pt.Side Plating	"	"	500g	"

A gage (continued)

Gage No.	Compt.	Long. Loca.	Vert. Loca.	AthShp. Loca.	Struc. tion	Direc- tion	Set- ting	Test A Result
4	Wrdrm.	Fr. 80 1/2	40" above Wthr. Deck	Sb.Side Plating	Panel	AthShp	500g	Unbrok.
5	"	"	43" above Wthr. Deck	Pt.Side Plating	"	"	1000g	"
6	"	"	"	Sb.Side Plating	"	"	"	"
7	"	"	46" above Wthr. Deck	Pt.Side Plating	"	"	1500g	"
8	"	"	"	Sb.Side Plating	"	"	"	"
9	Dry Prov.	Fr.58	41" below Main Deck	Pt.Shell	Frame	"	200g	"
10	"	"	"	Sb.Shell	"	"	"	"
11	"	"	38" below Main Deck	Pt.Shell	"	"	1500g	"
12	"	"	"	Sb.Shell	"	"	"	"
13	Ammun Stowage	20" fwd Fr.58	Tank Top	Ctrline.	Over Keel	Vert.	200g	"
14	"	23" fwd Fr.58	"	"	"	"	500g	"

A gage (continued)

Gage No.	Compt.	Long. Loca.	Vert. Loca.	AthShp. Loca.	Struc.	Direction	Set-ting	Test A Result
15	Ammun. Stowage	26" fwd Fr.58	Tank Top	Ctrline.	Over Keel	Vert.	1000g	Unbrok.
16	"	29" fwd Fr.58	"	"	"	"	1500g	"
17	"	32" fwd Fr.58	"	"	"	AthShp	200g	"
18	"	35" fwd Fr.58	"	"	"	"	500g	"
19	"	38" fwd Fr.58	"	"	"	"	1000g	"
20	"	41" fwd Fr.58	"	"	"	"	1500g	"

R gages (multi-frequency reed gage)

Twelve of these gages were installed on this vessel for Test Able. For Test Baker gages R-11 and R-12 were transferred to APA-85.

Gage No.	Compart.	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Wardroom	Fr. 81 1/2	30" above Wthr.Dk.	Pt.Side Plating	Panel	Athwartshp
2	"	"	"	Sb.Side Plating	"	"
3	Garbage Disposal	Fr. 58	Underside Wthr.Dk.	30" from Pt.Shell	Frame	Vertical
4	Dry Provisions	Fr. 57	49" below Main Dk.	Pt.Shell	"	Athwartshp

R gage (continued)

Gage No.	Compart.	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
5	Dry Provisions	Fr. 57	49" below Main Dk.	Sb.Shell	Frame	Athwartshp
6	Ammun. Stowage	"	36" below 2ndPltfm.	Pt.Shell	"	"
7	"	"	"	Sb.Shell	"	"
8	"	12" fwd Fr. 58	Tank Top	Ctrline.	Over Keel	"
9	"	12" aft Fr. 60	"	"	"	Vertical
10	Near Aft Hatch	Fr. 113	Underside Wthr.Dk.	47" from Pt.Shell	Frame	"
11	Gasoline Stowage	12" fwd Fr. 110	Tank Top	Ctrline.	Over Keel	Athwartshp
12	"	58" aft Fr. 110	"	"	"	Vertical

The R gage results for Test Able were as follows:

R-1				
No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.57	6.0	11.9
4	40	1.19	24.8	93.
8	100	0.14	7.5	73.
11	210	.03	3.3	68.

This record corresponds most nearly to the condition in which

the structure vibrates sinusoidally at a frequency in the neighborhood of 40 CPS with a single amplitude of 0.28 inch. This gives a maximum velocity of 5.9 ft/sec and a maximum acceleration of 45g.

R-2

Reed No.	Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.47	4.9	9.7
4	40	1.15	24.0	90.
8	100	0.25	13.2	131.
11	210	.04	4.4	91.

This record corresponds most nearly to the condition in which the structure vibrates sinusoidally at a frequency in the neighborhood of 40 CPS with a single amplitude of 0.32 inch. This gives a maximum velocity of 6.7 ft/sec and a maximum acceleration of 51g.

R-3

Reed No.	Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.055	0.6	1.1
4	40	.06	1.3	4.7
8	100	.11	5.8	57.

In the analysis of this record neither the assumption of an impulsive velocity nor of a step acceleration gives consistent values. There is an indication of resonance in the neighborhood of 100 CPS, the amplitude being 0.043 inch. Such a motion would give a maximum velocity of 2.3 ft/sec and a maximum acceleration of 43g.

R-4

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.04	0.4	0.8
4	40	.055	1.1	4.3
8	100	.065	3.4	34.

In this case the reed deflections are nearly the same which probably indicates a sinusoidal vibration at a frequency higher than 100 CPS at an amplitude of about 0.05 inch. As far as velocity is concerned, it can only be concluded that a velocity of at least 3.4 ft/sec was attained.

R-5

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.06	0.6	1.3
4	40	.065	1.4	5.1
8	100	.045	2.4	23.
11	210	.01	1.1	23.
14	430	.01	2.3	94.
15	570	.01	2.9	160.

This record seems to indicate that the structure received an impulsive velocity which was maintained for only a short fraction of the period of the 20 cycle reed so that the deflections of the first two reeds were lower than they would have been if the velocity had persisted longer. This impulsive velocity as shown by the reeds of higher frequencies was about 2.2 ft/sec.

R-6

Only one reed deflection was measurable on this record, namely that of the 20 cycle reed. This deflection was 0.025 inch. All that can be deduced from this data is that if the velocity was impulsive, its value was 0.3 ft/sec or if the motion corresponded to a step acceleration, the value of the latter was 0.5g.

R-7, 8

These gages showed no reed deflections.

R-9

Only the 40 cycle reed showed a deflection on this gage, the deflection being 0.09 inch. The fact that no deflection was shown for the 20 cycle reed which normally would have a larger deflection than the 40 is taken as an indication that the structure vibrated at a frequency in the neighborhood of 40 CPS at a single amplitude of 0.03 inch. This would give a maximum velocity of 0.6 ft/sec and a maximum acceleration of 5g.

R-10

Reed No.	Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.10	1.1	2.1
4	40	.11	2.3	8.6
8	100	.03	1.5	15.6
11	210	.01	1.1	22.7

This record corresponds most nearly to the condition in which an impulsive velocity of 1.5 ft/sec is imparted to the structure and sustained for at least 0.05 second.

R-11, 12

The gasoline stowage compartment was flooded by fire fighting. There appeared to be no deflections of any of the reeds of either gage.

S gage (seismic displacement gage)

Nine of these gages were installed on this vessel at the same locations for both Tests Able and Baker as follows:

Gage No.	Compartment	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Wardroom	Fr. 80 1/2	22" above Wthr.Dk.	Pt.Side Plating	Panel	Athwartshp
2	"	"	"	Sb.Side Plating	"	"
3	Garbage Disposal	Fr. 58	Underside Wthr.Dk.	70" from Pt.Shell	Frame	Vertical
4	Dry Provisions	"	61" below Main Dk.	Pt.Shell	"	Athwartshp
5	"	"	"	Sb.Shell	"	"
6	Ammun. Stowage	35" aft Fr. 58	Tank Top	Ctrline.	Over Keel	"
7	"	43" aft Fr. 58	"	"	"	Vertical
8	Gasoline Stowage	42" aft Fr. 110	"	"	"	Athwartshp
9	"	50" aft Fr. 110	"	"	"	Vertical

The S gage data obtained were as follows:

Gage No.	Displacement Indicated (inches)	Direction of Displacement	Notes
1	0.45	Starboard	Record indicates many oscillations.
	0.42	Port	
2	0.875	Starboard	
	0.31	Port	
3	None		
4	0.06	Starboard	
5	0.13	Port	
6	None		
7	None		
8	None		
9	None		

U.S.S. APOGON (SS-308)

A gage (mass plug accelerometer)

Four A gages were installed on this vessel at the same locations for both Tests Able and Baker as follows:

Gage No.	Long. Compt.	Vert. Loca.	AthShp. Loca.	Struc.	Direction	Set-ting	Test A Result
1	Fwd Torp. Room	Fr.23	23" above Pltfm.	Pt.Side Frame	Frame Athshp	200g	Unbrok.
2	"	"	27" above Pltfm.	"	"	500g	"

A gage (continued)

Gage No.	Compt.	Long. Loca.	Vert. Loca.	AthShp. Loca.	Struc.	Direction	Set-ting	Test A Result
3	Fwd Torp. Room	Fr.23	36" above Pltfm.	Pt.Side Frame	Frame	AthShp	1000g	Unbrok.
4	"	"	40" above Pltfm.	"	"	"	1500g	"

R gage (multi-frequency reed gage)

Two R gages were installed on this vessel at the same locations for both Tests Able and Baker as follows:

Gage No.	Compart.	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Fwd Torp Room	Fr. 20	14" above Platform	Pt.Side Frame	Frame	Athwartshp
2	"	Fr. 19	12" above Platform	"	"	Vertical

No reed deflections were shown on either gages R-1 or R-2 after Test Able.

S gage (seismic displacement gage)

Four S gages were installed on this vessel at the same locations for Tests Able and Baker as follows:

Gage No.	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Fwd Torp. Fr. 23 Room	31" above Platform	Pt. Side Frame	Frame	Athwartshp
2	" Fr. 19	18" above Platform	"	"	Vertical
3	Aft Torp. Fr. 116 Room	38" above Platform	"	"	"
4	" "	21" above Platform	"	"	Athwartshp

The following results were obtained from the S gages for Test Able:

Gage No.	Displacement Indicated (inches)	Direction of Displacement	Notes
1	None		
2	0.125	Down	
	0.13	Up	
3	None		
4	None		

Remarks on Test Able

The shock indicated by this group of instruments on APA's 63, 64, 65 and SS 308 was in all cases less than anticipated. Had the bomb exploded nearer to the aiming point, a good deal more data would have been obtained. The mass plug accelerometers in particular had been designed for a higher range of shock than encountered on the vessels on which they were installed.

The time recording instruments on APA-64 show a weak shock followed in about two seconds by a much stronger shock. The most obvious explanation is that the first came through the water and the

second through the air. The reed gage records show that the shock due to the air blast was concentrated in the superstructure and did not produce much effect below the waterline.

The oscillatory nature of the shock as indicated by the time recording instruments was undoubtedly a general characteristic throughout the ships and is to be expected in an elastic structure. When such vibrations occur at frequencies within the range covered by the reed gages (20 to 920 CPS), it will usually be found that one of the reeds shows an exceptionally high deflection.

A shock impulsive velocity of ten feet per second, while representing a substantial shock, is generally considered of a magnitude which equipment installed on board ship should be designed to withstand. The low order of shock sustained by APA's 63, 64 and 65 on Test Able is indicated by the fact that a shock velocity of 10 ft/sec was not reached at any station at which instruments of this group were located.

It is not possible to deduce from the data obtained on APA-64 the modes of vibration which the ship assumed, but it is probable that both vertical and horizontal flexural modes of the entire hull were set up as well as local vibrations of sections of deck and side plating subject to the direct impact of the blast.

While the time recording instruments in this group were not intended to record rolling and pitching motions specifically, the records lasted for over five minutes and would have indicated such motions if they had exceeded a few degrees. The indication is that on APA-64 the rolling and pitching motions were negligible even within the first half minute.

Data and Results for Test Baker

The instruments included in this group were designated as follows:

- A mass plug accelerometer
- E pallograph
- J Jacklin accelerometer

- K shock displacement gage
- R multi-frequency reed gage
- S seismic displacement gage

These instruments were used for recording shock and vibratory motions on certain of the target vessels located in zones beyond the range of severe damage. The vessels equipped with such instruments during Test Baker were APA's 63, 64, 65, and 85, and SS-308. Instrumentation for Test Baker was identical with that for Test Able with the exception that gages R-11 and R-12 were removed from APA-65 and installed as R-2 and R-3 on APA-85. R-1 was omitted from APA-85. The original plan of transferring the three reed gages from APA-57 to APA-85 after Test Able could not be carried out because of the sinking of APA-57.

The instrument locations and data obtained are given in the following.

U.S.S. BLADEN (APA-63)

R gage (multi-frequency reed gage)

One R gage was installed on this vessel at the time of Test Baker at the following location:

Gage No.	Long. Compartment	Vertical Location	Athwart. Location	Struc.	Direction	
2	Ammun. Stowage	Fr. 57	32" below 2nd Pltfm.	Pt. Shell	Shell Frame	Athwartshp

Only one reed gave a measurable deflection on this gage, namely the 20 cycle reed which deflected 0.02 inch. The only conclusions that can be drawn from this record are that if the structure acquired an impulsive velocity its value was 0.2 ft/sec, and if the structure responded to a constant acceleration, the latter had a value of 0.4g.

U.S.S. BRACKEN (APA-64)

A gage (mass plug accelerometer)

Twelve A gages were installed on this vessel for Test Baker. The locations and results were as follows:

Gage No.	Compt.	Long. Loca.	Vert. Loca.	AthShp. Loca.	Struc. tion	Direc- tion	Set- ting	Test B Result
1	Wrdrm.	Fr.	37" 80 1/2 above Wthr. Deck.	Pt.Shell	Panel	Athshp	200g	Unbrok.
2	"	"	"	Sb.Shell	"	"	"	"
3	"	"	40" above Wthr. Deck	Pt.Shell	"	"	1500g	"
4	"	"	"	Sb.Shell	"	"	"	"
5	Dry Prov.	Fr.58	41" below Main Deck	Pt.Shell	Frame	"	200g	"
6	"	"	"	Sb.Shell	"	"	"	"
7	"	"	38" below Main Deck	Pt.Shell	"	"	1500g	"
8	"	"	"	Sb.Shell	"	"	"	"
9	Ammun. Stowage	20" fwd Fr.58	Tank Top	Ctrline.	Over Keel	Vert.	200g	"

A gage (continued)

Gage No.	Compt.	Long. Loca.	Vert. Loca.	AthShp. Loca.	Struc.	Direction	Setting	Test B Result
10	Ammun. Stowage	23" fwd Fr.58	Tank Top	Ctrline.	Over Keel	Vert.	1500g	Unbrok.
11	"	32" fwd Fr.58	"	"	"	Athshp	200g	"
12	"	35" fwd Fr.58	"	"	"	"	"	"

As no plug was found broken after Test Baker, and as the minimum acceleration setting was 200g, this indicates that the acceleration was less than 200g at any of the locations at which these gages were installed.

E gage (pallograph)

Two of these instruments were installed on this vessel for Test Baker at the following locations:

Gage No.	Compart.	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Ammun. Stowage	42" fwd Fr. 60	Tank Top	Ctrline.	Over Keel	Athwartshp
2	"	58" fwd Fr. 61	"	"	"	Vertical

Reproductions of the pallograph records obtained on this vessel for Test Baker are shown in Figure 4 at the end of the test. For convenience in reproduction only the first few seconds of record have been reproduced. A summary of the results follows:

E-1

This record shows a very irregular athwartship vibration having a maximum double amplitude of 30 mils and an average frequency of about 20 CPS lasting for about 1.25 seconds. A second and larger vibration began 2.4 seconds after the first disturbance. Starting with a small amplitude this built up to a double amplitude in excess of 210 mils causing the seismic element to hit the stop. The frequency of this vibration was 6.2 CPS. The disturbance diminished to a negligible value 4 seconds after the first shock and nothing further appeared on the record for the next 117 seconds when the start of a slow periodic motion, apparently a rolling of the ship, was indicated. This motion had a period of ten seconds and the record indicated only one cycle of such motion.

E-2

This record shows an initial half sine displacement pulse in the upward direction of 90 mils single amplitude and 0.22 second half period followed by a downward pulse exceeding 100 mils causing the seismic element to hit the stop. The motion after this shows vibrations of a double amplitude exceeding 500 mils at a frequency of about 4 CPS lasting for about 1.25 seconds with vibrations of a frequency of 15 CPS and a double amplitude of 60 mils superimposed. About 2.4 seconds after the first disturbance the vibration again started to build up reaching a double amplitude of 250 mils and settled into a gradually decaying vibration having a frequency of 3.3 CPS with a 6 CPS component superimposed which became imperceptible 12 seconds after the beginning of the first disturbance. At 60 seconds after the first disturbance the record indicated the start of slow vertical movements having a period in excess of ten seconds. These motions were observable for the next 140 seconds or up to 200 seconds after the start of the initial disturbance.

J gage (Jacklin accelerometer)

This instrument, J-1, was installed in the ammunition stowage compartment, on the tank top at the centerline, frame 62, directly over

TOP SECRET PAGE 39 OF 79 PAGES

the keel and was set for recording vertical and athwartship accelerations. The vertical trace showed an initial acceleration pulse having a single amplitude of 0.06g and a half period of 0.07 second, the acceleration being in the upward direction. The trace then became indistinguishable until 5.8 seconds after the start of the disturbance when it showed a decaying sinusoidal acceleration having a double amplitude of 0.06g and a frequency of 6.0 CPS. The acceleration became negligible 8 seconds after the initiation of the shock.

The athwartships trace showed a shock starting 0.29 second after the start of the vertical shock but the trace became indistinguishable until 2.3 seconds later. Starting at this point, which seemed to indicate the initiation of a second shock, the record showed a vibration with an acceleration double amplitude of 0.3g and a frequency of 6 CPS with higher frequency components superimposed, settling in about 2 seconds into a gradually damped sinusoidal vibration having a frequency of 3.1 CPS. This vibration became negligible 10 seconds after the initiation of the shock.

Neither trace indicated any measurable acceleration due to rolling or pitching motions of the ship.

K gage (shock displacement gage)

This instrument was installed in the ammunition stowage compartment at frame 59, on the tank top, directly over the keel, and set so as to record athwartship displacement.

The record indicated a displacement of 0.13 inch to starboard and 0.12 inch to port. The shock failed to produce a rotary motion of the disk so that there was no indication of the number of oscillations.

R gage (multi-frequency reed gage)

Twelve of these gages were installed on this vessel for Test Baker at the following locations:

Gage No.	Compartment	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Wardroom	Fr. 81 1/2	30" above Wthr.Dk.	Pt.Side Plating	Panel	Athwartshp
2	"	"	"	Sb.Side Plating	"	"
3	Garbage Disposal	Fr. 58	Underside Wthr.Dk.	30" from Pt.Shell	Frame	Vertical
4	Dry Provisions	Fr. 57	56" below Main Dk.	Pt.Shell Frame	"	Athwartshp
5	"	"	"	Sb.Shell Frame	"	"
6	Ammun. Stowage	"	52" below 2ndPltfm.	Pt.Shell Frame	"	"
7	"	"	"	Sb.Shell Frame	"	"
8	"	12" fwd Fr. 58	Tank Top	Ctrline.	Over Keel	"
9	"	12" aft Fr. 58	"	"	"	Vertical
10	Near Aft Hatch	Fr. 113	Underside Wthr.Dk.	47" from Pt.Shell	Frame	"
11	Gasoline Stowage	12" fwd Fr. 110	Tank Top	Ctrline.	Over Keel	Athwartshp
12	"	60" aft Fr. 110	"	"	"	Vertical

The R gage results on APA-64 for Test Baker were as follows (reeds having no measurable deflection are omitted from the tables):

R-1

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1		0.34	3.6	7.0
4	40	.49	10.2	40.
8	100	.11	5.8	56.
11	210	.02	2.2	44.
13	345	.015	2.7	92.
14	430	.01	2.3	94.
15	570	.005	1.5	83.
17	920	.005	2.4	220.

This record corresponds most nearly to the condition in which the structure suddenly starts to execute a simple harmonic vibration at a frequency in the vicinity of 40 CPS at a single amplitude of 0.20 inch. Such a motion would give a maximum velocity of 4.2 ft/sec and an acceleration single amplitude of 32g.

R-2

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.54	5.7	11.
4	40	.96	20.0	78.
8	100	.33	17.2	170.
11	210	.015	1.7	34.
13	345	.01	1.8	61.

R-2 (continued)

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
14	430	.005	1.1	47.
15	570	.005	1.5	83.
17	920	.005	2.4	220.

This record corresponds most nearly to the condition in which the structure suddenly executes a simple harmonic vibration at a frequency in the vicinity of 40 CPS at a single amplitude of 0.30 inch. Such a motion would give a maximum velocity of 6.3 ft/sec and an acceleration single amplitude of 48g.

R-3

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.06	0.63	1.2
4	40	.03	.63	2.5
8	100	.02	1.0	10.

This record corresponds most nearly to the condition in which the structure acquires an impulsive velocity of 1.0 ft/sec which is maintained for about 0.005 second.

R-4

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.04	0.42	0.83
4	40	.025	.52	2.0
8	100	.015	.78	7.6

This record indicates that the structure acquired an impulsive velocity of 1.0 ft/sec which was maintained for about 0.005 second.

R-5

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.055	0.58	1.1
4	40	.075	1.6	6.1
8	100	.065	3.4	33.

This record indicates a sinusoidal vibration of a single amplitude of 0.026 inch and a frequency in the vicinity of 100 CPS, giving a maximum velocity of 1.4 ft/sec and a maximum acceleration of 26g.

R-6

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.06	0.63	1.2
4	40	.03	.63	2.7
8	100	.015	.78	7.7

This record indicates an impulsive velocity of 0.7 ft/sec maintained for about 0.005 second.

R-7

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.08	0.84	1.7
4	40	.05	1.0	4.1
8	100	.02	1.1	10.
11	210	.01	1.1	22.
13	345	.015	2.7	92.
14	430	.01	2.3	94.
15	570	.01	2.9	170.

This record indicates an impulsive velocity of 1.7 ft/sec maintained for about 0.006 second.

R-8

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.015	0.16	0.31
4	40	.005	.10	.41

This record indicates a constant acceleration of 0.36g maintained for 0.02 second during which time a velocity of 0.2 ft/sec was attained.

R-9

Reed Natural Reed Frequency No. (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1 20	0.27	2.8	5.6

This record was fouled in the decontamination of the ship and only one reed deflection could be read. The 20 cycle reed showed a deflection of 0.27 inch corresponding to an impulsive velocity of 2.8 ft/sec or a steady acceleration of 5.6g.

R-10

Reed Natural Reed Frequency No. (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1 20	0.20	2.1	4.1
4 40	.22	4.6	18.
8 100	.03	1.6	15.

This record indicates a suddenly acquired sinusoidal vibration having a single amplitude of 0.09 inch and a frequency in the vicinity of 40 CPS. Such a motion would have a velocity of 1.9 ft/sec and an acceleration single amplitude of 14g.

R-11

Reed Natural Reed Frequency No. (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1 20	0.025	0.26	0.51
4 40	.015	.31	1.2
8 100	.01	.52	5.1

R-11 (continued)

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
11	210	.01	1.1	22.
13	345	.015	2.7	91.

This record indicates an impulsive velocity of 0.33 ft/sec with a vibration having a frequency in the vicinity of 345 CPS superimposed.

R-12

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.085	0.89	1.8
4	40	.005	.10	.41
8	100	.01	.52	5.1

This record indicates a vibration in the vicinity of 20 CPS with a single amplitude of 0.03 inch involving a velocity of 0.3 ft/sec and an acceleration of 1.2g. A superimposed vibration having a frequency around 100 CPS is also indicated.

S gage (seismic displacement gage)

Nine of these gages were installed on APA-64 for Test Baker at the following locations:

Gage No.	Compart.	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Wardroom	Fr. 80 1/2	22" above Wthr.Dk.	Pt.Side Plating	Panel	Athwartshp
2	"	"	"	Sb.Side Plating	"	"
3	Garbage Disposal	Fr. 58	Underside Wthr.Dk.	60" from Pt.Shell	Frame	Vertical
4	Dry Provisions	"	66" below Main Dk.	Pt.Shell	"	Athwartshp
5	"	"	"	Sb.Shell	"	"
6	Ammun. Stowage	29" aft Fr. 58	Tank Top	Ctrline.	Over Keel	"
7	"	"	"	"	"	Vertical
8	Gasoline Stowage	21" aft Fr. 110	"	"	"	Athwartshp
9	"	29" aft Fr. 110	"	"	"	Vertical

The S gage results on APA-64 for Test Baker were as follows:

Gage No.	Recorded Displacement	Notes
1	2.62" to Port	Weight hit stop or gage was disturbed by boarding party.
2	.06" to Port .13" to Starboard	
3	None	
4	.06" to Starboard .08" to Port	
5	.09" to Starboard .09" to Port	
6	None	
7	None	
8	None	
9	.025" Upward .13" Downward	

U.S.S. BRISCOE (APA-65)

A gage (mass plug accelerometer)

Twenty A gages were installed on APA-65 for Test Baker. Locations and results were as follows:

Gage No.	Compt.	Long. Loca.	Vert. Loca.	AthShp. Location	Struc.	Direction	Set-ting	Test B Result
1	Wrdrm.	Fr.	37" 80 1/2	Pt.Side above Wthr. Deck Plating	Panel	Athshp	200g	Unbrok.
2	"	"	"	Sb.Side Plating	"	"	"	"
3	"	"	40" above Wthr. Deck	Pt.Side Plating	"	"	500g	"
4	"	"	"	Sb.Side Plating	"	"	"	"
5	"	"	43" above Wthr. Deck	Pt.Side Plating	"	"	1000g	"
6	"	"	"	Sb.Side Plating	"	"	"	"
7	"	"	46" above Wthr. Deck	Pt.Side Plating	"	"	1500g	"
8	"	"	"	Sb.Side Plating	"	"	"	"

A gage (continued)

Gage No.	Compt.	Long. Loca.	Vert. Loca.	AthShp. Location	Struc.	Direction	Setting	Test B Result
9	Dry Prov.	Fr.58	41" below Main Deck	Pt.Shell	Frame	Athshp	200g	Unbrok.
10	"	"	"	Sb.Shell	"	"	"	"
11	"	"	38" below Main Deck	Pt.Shell	"	"	1500g	"
12	"	"	"	Sb.Shell	"	"	"	"
13	Ammun. Stowage	20" fwd Fr.58	Tank Top	Ctrline.	Over Keel	Vert.	200g	Unbrok.
14	"	23" fwd Fr. 58	"	"	"	"	500g	"
15	"	26" fwd Fr. 58	"	"	"	"	1000g	"
16	"	29" fwd Fr. 58	"	"	"	"	1500g	"
17	"	32" fwd Fr. 58	"	"	"	Athshp	200g	"
18	"	35" fwd Fr. 58	"	"	"	"	500g	"
19	"	38" fwd Fr. 58	"	"	"	"	1000g	"
20	"	41" fwd Fr. 58	"	"	"	"	1500g	"

It will be noted that of the twenty A gages installed on APA-65 none was found to have the plug broken after Test Baker. As the

minimum acceleration setting was 200g it is indicated that the acceleration was less than 200g at any of the locations at which these gages were installed.

R gage (multi-frequency reed gage)

Ten of these gages were installed on APA-65 for Test Baker at the following locations:

Gage No.	Compartment	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Wardroom	Fr. 81 1/2	30" above Wthr.Dk.	Pt.Side Plating	Panel	Athwartshp
2	"	"	"	Sb.Side Plating	"	"
3	Garbage Disposal	Fr. 58	Underside Wthr.Dk.	30" from Pt.Shell	Frame	Vertical
4	Dry Provisions	Fr. 57	49" below Main Dk.	Pt.Shell	"	Athwartshp
5	"	"	"	Sb.Shell	"	"
6	Ammun. Stowage	"	36" below 2ndPltfm.	Pt.Shell	"	"
7	"	"	"	Sb.Shell	"	"
8	"	12" fwd Fr. 58	Tank Top	Ctrline	Over Keel	"
9	"	12" aft Fr. 60	"	"	"	Vertical
10	Near Aft Hatch	Fr. 113	Underside Wthr.Dk.	47" from Pt.Shell	Frame	"

R gage (continued)

Gage No.	Compartment	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
11	Gasoline Stowage	12" fwd Fr. 110	Tank Top	Ctrline.	Over Keel	Athwartshp
12	"	58" aft Fr. 110	"	"	"	Vertical

The R gage results on APA-65 for Test Baker were as follows:

R-1

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	1.20	12.6	25.
4	40	1.51	31.6	120.
8	100	.66	34.5	340.
11	210	.08	8.8	180.
13	345	.04	7.2	240.
14	430	.015	3.4	140.
15	570	.02	5.8	330.
17	920	.005	2.4	215.

This record indicates that the structure suddenly started to execute a simple harmonic motion having a single amplitude of 0.6 inch and a frequency in the vicinity of 40 CPS. Such a motion would have a maximum velocity of 12.6 ft/sec and an acceleration single amplitude of 90g.

R-2

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.51	5.4	10.5
4	40	.51	10.6	44.
8	100	.07	3.6	36.

This record indicates that the structure suddenly started to execute a simple harmonic vibration having a single amplitude of 0.25 inch and a frequency in the vicinity of 40 CPS. Such a motion would have a maximum velocity of 5.2 ft/sec and an acceleration single amplitude of 40g.

R-3

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.46	4.8	9.5
4	40	.23	4.8	20.
8	100	.30	15.7	150.
11	210	.015	1.7	33.
13	345	.025	4.5	150.
14	430	.015	3.4	140.
15	570	.01	2.9	170.
17	920	.005	2.4	230.

This record corresponds most nearly to the condition in which the structure acquired an impulsive velocity of 4 ft/sec which was

maintained for 0.012 second and was followed by a vibration at a frequency in the vicinity of 100 CPS.

R-4

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.20	2.1	4.1
4	40	.16	3.3	14.
8	100	.26	13.6	140.
11	210	.035	3.8	78.
13	345	.015	2.7	91.
14	430	.01	2.3	94.
15	570	.01	2.9	170.
17	920	.005	2.4	220.

This record indicates that the structure acquired an impulsive velocity of 2.6 ft/sec which was maintained for about 0.01 second and followed by a vibration at a frequency in the vicinity of 100 CPS.

R-5

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.07	0.73	1.4
4	40	.04	.84	3.4
8	100	.015	.78	7.6
13	345	.005	.91	30.
14	430	.005	1.0	47.

This record indicates that the structure acquired an impulsive velocity of 0.85 ft/sec which was maintained for about 0.01 second.

R-6

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.25	2.6	5.2
4	40	.35	7.3	30.
8	100	.12	6.3	61.
11	210	.13	14.	290.
13	345	.08	14.5	490.
14	430	.04	9.0	380.
15	570	.07	20.	1200.
17	920	.02	9.6	860.

This record indicates that the structure suddenly started to execute a simple harmonic motion with a single amplitude of 0.14 inch at a frequency in the vicinity of 40 CPS. Such a motion would have a maximum velocity of 2.9 ft/sec and an acceleration single amplitude of 22g. Superimposed vibrations at frequencies in the vicinity of 210 and 570 CPS are also indicated.

R-7

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.24	2.5	5.0
4	40	.25	5.2	21.
8	100	.03	1.6	15.

R-7 (continued)

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
11	210	0.025	2.8	56.
13	345	.035	6.3	210.
14	430	.02	4.5	190.
15	570	.015	4.3	250.
17	920	.005	2.4	220.

This record indicates that the structure suddenly started to execute a simple harmonic motion having a single amplitude of 0.12 inch at a frequency in the vicinity of 40 CPS. This motion would have a maximum velocity of 2.5 ft/sec and an acceleration single amplitude of 22g.

R-8

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.10	1.1	2.1
4	40	.07	1.5	6.0
8	100	.035	1.8	18.
11	210	.01	1.1	22.

This record indicates that the structure acquired an impulsive velocity of 1.4 ft/sec which was maintained for about 0.01 second.

R-9

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.77	8.1	16.
4	40	.18	3.8	15.
8	100	.06	3.1	30.
11	210	.025	2.7	56.
13	345	.025	4.5	150.
14	430	.02	4.5	190.
15	570	.02	5.8	330.
17	920	.01	4.8	480.

This record indicates that the structure suddenly started to execute a simple harmonic motion having a single amplitude of 0.3 inch at a frequency in the vicinity of 20 CPS. Such a motion would have a maximum velocity of 3 ft/sec and an acceleration single amplitude of 12g.

R-10

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.75	7.9	15.
4	40	.88	18.4	72.
8	100	.22	11.5	110.
11	210	.025	2.7	56.
13	345	.015	2.7	91.

R-10 (continued)

Reed No.	Reed Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
14	480	.025	5.6	230.
15	570	.040	11.6	660.
17	920	.005	2.4	220.

This record indicates that the structure suddenly started to execute a simple harmonic vibration having a single amplitude of 0.35 inch and a frequency in the vicinity of 40 CPS. Such a motion would have a maximum velocity of 7.3 ft/sec and an acceleration single amplitude of 56g. A superimposed vibration having a frequency in the vicinity of 570 CPS is also indicated.

S gage (seismic displacement gage)

Nine of these gages were installed on APA-65 for Test Baker at the following locations:

Gage No.	Compartment	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Wardroom	Fr. 80 1/2	22" above Wthr.Dk.	Pt.Side Plating	Panel	Athwartshp
2	"	"	"	Sb.Side Plating	"	"
3	Garbage Disposal	"	Underside Wthr.Dk.	70" from Pt.Shell	Frame	Vertical
4	Dry Provisions	Fr. 58	61" below Main Dk.	Pt.Shell	"	Athwartshp
5	"	"	"	Sb.Shell	"	"

S gage (continued)

Gage No.	Compart.	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
6	Ammun. Stowage	35" aft Fr. 58	Tank Top	Ctrline.	Over Keel	Athwartshp
7	"	43" aft Fr. 58	"	"	"	Vertical
8	Gasoline Stowage	42" aft Fr. 110	"	"	"	Athwartshp
9	"	50" aft Fr. 110	"	"	"	Vertical

The S gage data obtained on APA-65 for Test Baker were as follows:

Gage No.	Recorded Displacement	Notes
S-1	2.89" to Starboard .38" to Port	
S-2	1.75" to Starboard 1.50" to Port	
S-3	1.05" Upward .90" Downward	3 Oscillations
S-4	• .56" To Starboard .09" to Port	
S-5	1.22" to Starboard .10" to Port	
S-6	.58" to Starboard .60" to Port	
S-7	• 1.70" Upward 2.60" Downward	3 Oscillations
S-8	1.00" to Starboard .85" to Port	
S-9	.90" Upward .75" Downward	

U.S.S. GASCONADE (APA-85)

R gage (multi-frequency reed gage)

Two of these gages were installed on APA-85 for Test Baker at the following locations:

Gage No.	Compartment	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
2	Ammun. Stowage	12" fwd Fr. 58	Tank Top	Ctrline.	Over Keel	Athwartshp
3	"	12" aft Fr. 58	"	"	"	Vertical

The R gage results on APA-85 for Test Baker were as follows:

R-2				
Reed No.	Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	0.25	2.6	5.1
4	40	.13	2.8	11.

This record indicates that the structure acquired an impulsive velocity of 2.7 Ft-Sec which was maintained for at least 0.012 second.

R-3

Reed No.	Natural Frequency (CPS)	Maximum Reed Deflection (inches)	Step Velocity Corresponding to Reed Deflection (ft/sec)	Step Acceleration Corresponding to Reed Deflection (g)
1	20	1.41	14.8	29.
4	40	.41	8.6	34.
8	100	.165	8.6	84.
11	210	.09	9.9	200.
13	345	.06	11.	370.
15	570	.01	2.9	170.

This record indicates that the structure suddenly started to execute a simple harmonic motion having a single amplitude of 0.06 inch and a frequency in the vicinity of 20 CPS. Such a motion would have a maximum velocity of 6 ft/sec and an acceleration single amplitude of 24g.

U.S.S. APOGON (SS-308)

This vessel was not refloated after Test Baker nor were any of the instruments recovered. The instruments installed are listed here as a matter of record.

A gage (mass plug accelerometer)

Four of these gages were installed on SS-308 for Test Baker at the following locations:

Gage No.	Long. Compartment	Long. Loca.	Vert. Loca.	AthShp. Location	Struc.	Direction	Setting
1	Fwd.Torp. Room	Fr.23	23" above Pltfm.	Pt.Side Frame	Frame	Athshp	200g
2	"	"	27" above Pltfm.	"	"	"	500g
3	"	"	36" above Pltfm.	"	"	"	1000g
4	"	"	40" above Pltfm.	"	"	"	1500g

R gage (multi-frequency reed gage)

Two R gages were installed on SS-308 for Test Baker at the following locations:

Gage No.	Long. Compartment	Long. Location	Vertical Location	Athwart. Location	Struc.	Direction
1	Fwd.Torp. Room	Fr. 20	14" above Platform	Pt.Side Frame	Frame	Athwartshp
2	"	Fr. 19	12" above Platform	"	"	Vertical

S gage (seismic displacement gage)

Four S gages were installed on SS-308 for Test Baker at the following locations:

Gage No.	Long. Compartment	Vertical Location	Athwart. Location	Struc.	Direction
1	Fwd Torp. Fr. 23 Room	31" above Platform	Pt. Side Frame	Frame	Athwartshp
2	" Fr. 19	18" above Platform	"	"	Vertical
3	Aft Torp. Fr. 116 Room	38" above Platform	"	"	"
4	" Fr. 116	21" above Platform	"	"	Athwartshp

Remarks on Test Baker

In general the shock on APA's 64 and 65, the principal ships carrying instruments of this group, was higher for Test Baker than for Test Able, and considerably more data were obtained for Test Baker, particularly from the reed gages. As in the case of Test Able the pallographs installed on APA-64 indicated the arrival of two shocks about 2.4 seconds apart and the same interpretation is accepted, namely that the first shock came through the water and the second through the air. There is one striking difference in the two cases however. In the case of Test Able both the vertical and the athwartships records showed the second or air shock to be the greater of the two, whereas in the case of the Test Baker the athwartships record obtained in the ammunition stowage compartment shows the air shock to be the greater than the water shock while the vertical record shows the water shock to be greater than the air shock. This is also corroborated by the reed gage data.

If the records obtained from the reed gages in the superstructure are assumed to be due to the air shock, it is indicated that APA-65 encountered a greater air shock on Test Baker than on Test Able.

On both Tests Able and Baker flexural vibrations of the entire hulls appear to have been set up involving frequencies in the range from 1 to 15 CPS as well as local vibrations of sections of deck and side plating involving frequencies in the range of 20 to 600 CPS.

The large displacements indicated by the seismic displacement (S) gages on APA-65 for Test Baker in general cannot be corroborated by the reed gage data. If such large motions actually occurred, they may have been due to the lowest modes of flexural vibration of the entire hull involving frequencies of the order of 1 to 3 CPS. In the case of the two vertical gages, S-3 and S-7, which had springs, there is a good possibility of a resonance with a hull vibration at a frequency of 2 CPS. Vibrations at such low frequencies would have little effect on the reed gages and unless accompanied by components of higher frequencies would scarcely be considered as a shock.

The one reed gage installed on APA-63 showed the shock on this vessel to be negligible. The two reed gages installed on APA-85, when compared with the corresponding gages on APA-65, showed the underwater shock due to Test Baker to have been twice as great on APA-85 as on APA-65.

Although greater shocks were encountered on Test Baker than on Test Able, when the criterion of shock impulsive velocity of 10 ft/sec is considered, none of the shocks measured by this group of instruments in either test could be classified as high shock. This is further emphasized by the fact that none of the mass plug accelerometers whose lowest setting was 200g was found to have the plug broken after Test Baker and only one after Test Able.

Discussion of Instrument Behavior

The measurement of shock motions, a relatively new field in research, received a considerable impetus during World War II and in the bibliography at the end of this section of the Crossroads Report will be found a number of references on this subject. Most of the instruments used for shock recording at Bikini were of recent origin, some being still only in the development stage. The test data have been studied, therefore, not only with a view to obtaining information as to the motions of the ship structures but also with a view to obtaining information as to the merits of the various shock instruments themselves. While a number of investigations of shock due to gun fire, air blast, and underwater explosions had been made during the war and are described in references in the bibliography, the number of instruments available on those occasions was generally too small to permit a fair appraisal of their relative merits. In the case of the Crossroads tests, all available apparatus for shock measurement was

mustered and there were few stations chosen for shock measurement on the target ships where two or more instruments were not installed.

From the instrumentation point of view the chief question to be answered is: What instruments are the most suitable for establishing indices of the intensity of shock produced at various locations on naval vessels under attack? There is much more to be taken into account in answering this question than the amount of information derivable from the instrument records. There is the problem of installation, the size, weight, vulnerability, and power requirements of the instruments, as well as the time required for installation. There is the question of the ease with which the records may be retrieved after the shock and whether or not they can be destroyed by radioactivity, heat, or moisture. There is the question of the time required for analysis, the man hours per record, the complexity of any calculations that may have to be made in order to put the information in terms that are readily understood. Comments are given on the instruments of this group in the order in which they are described in the introduction.

Mass plug accelerometers: The mass plug accelerometers used at Bikini were designed for a higher range of acceleration than was encountered on the target ships chosen. This applies to both Tests Able and Baker. While, theoretically, the breaking acceleration can be made as low as desired without changing the overall dimensions of the gage simply by reducing the diameter of the turned down portion of the bakelite specimen, particularly the specimen of lowest setting actually used (200g) is already so weak that great care has to be exercised in installing it and many breakages occurred during the installation on the target vessels. This means that larger gages would have to be used to measure accelerations less than 200g, and as these gages are usually used in sets of at least four a considerable increase in weight of material would be involved in any comprehensive ship test.

Furthermore, the information derivable from the mass plug accelerometer does not at present appear to be very great. It has been generally agreed for some time that high accelerations lasting for very short times are not significant as far as shock on board ship is concerned. While the mass plug accelerometer is less deserving of criticism on this score than the contact accelerometer, since the acceleration must be sustained at least long enough to rupture the specimen, an intensive study of the behavior of this gage (Reference (2)) has shown that the maximum acceleration at which it breaks varies considerably with the rate of application. It is therefore felt that the in-

formation which it gives in its present form is too limited to be of practical value unless the gage is used only as an auxiliary gage with other more elaborate instruments. However, because of its compactness and simplicity of installation, it may prove useful as a rough check on peak accelerations above 200g in cases where accelerations alone are under investigation.

Pallographs: The pallographs performed much better on the Crossroads tests than anticipated as these instruments were designed primarily as steady state vibration recording instruments. Had the shocks encountered on APA-64 been much more severe, these instruments would undoubtedly have been rendered inoperative. As it was they continued to operate until all the paper had run out. The indications which they gave of the vibration amplitudes and frequencies, as well as of the time interval between the arrival of the water born and air born shocks was very useful in spite of the fact that the seismic elements hit the stops in certain instances. While requiring electric power, these instruments record directly on waxed paper and hence the records are available for examination immediately after the test. Furthermore, the records may be photographed later and blueline or blackline prints made on which any desired notes may be added.

The question arises as to what role such instruments should play in future shock investigations on board ship. The two chief faults observed were: first, that these instruments have a very low range of displacement for shock work, and second, that they have very high sensitivity as accelerometers so that they respond to the slow rolling and pitching motions of the ship. As a result of the latter condition, it is frequently found that the seismic element has shifted considerably from the position to which it was adjusted before the test and as a result it may hit the stop even for a displacement which is a very small fraction of the range of the instrument. These instruments can be converted to accelerometers which obviates this difficulty, but is otherwise objectionable. Their frequencies when converted to accelerometers are of the order of 10 CPS which is in the range of natural flexural frequencies of ship hulls, hence the acceleration-time record of a shock may be considerably distorted by resonance effects within the instrument.

If it were contemplated using the pallographs for similar work in the future, it would probably be best to use them as seismic instruments but to provide some means for holding the seismic element in its mean position until just before the shock. The release mechanism could be made to operate at the instant the paper drive was started.

These instruments are not at present available in quantity. They are fragile and considerable care is required in their installation. They are best considered as a check instrument to be installed in some central position on the vessel suitable for giving an overall picture of the shock sustained by the vessel as a whole, while more portable instruments are distributed about the ship to determine the behavior of particular structural members.

Jacklin accelerometers: The Jacklin instrument was built to specifications for a low range accelerometer suitable for recording steady state vibrations and such low-order accelerations as accompany rolling, pitching, and heaving motions of a ship. Hence, as in the case of the pallographs, the instrument was pressed into a service for which it was not designed. Even so, because of the low order of the shock encountered on APA-64, good records apparently would have been obtained had there been sufficient illumination. The elements appear to have performed satisfactorily and what is required is a guarantee of sufficient exposure to insure a distinct trace on the record for high sweep velocities of the light beam.

In general this accelerometer is of too low a range for shock work. Since the original instrument acquired by Taylor Model Basin was shipped to Bikini, a set of higher frequency elements has been manufactured giving the instrument a range of plus or minus 10g. Even this, however, is of too low an order for shock investigations and it is doubtful whether the instrument itself could stand much more than this. There also apply in this case the objections of requiring electric power and photographic development both of which are to be avoided if possible.

Shock displacement gages: The shock displacement gage was designed as a rugged displacement-recording instrument capable of handling fairly large amplitudes (plus or minus 1.0 inch). A satisfactory drive for the disk, free from backlash, had not been developed up to the time of the Bikini tests and the instrument was used without the driving motor, but having an eccentric weight for the purpose of rotating the disk under the shock, thereby spreading out the record. Although the instrument did not have time recording, if it had functioned as intended, it would have indicated the number of displacement oscillations as well as their amplitudes and would have been independent of electric power supply. This is a very heavy instrument (weight 89 pounds) and only one of this type has been manufactured to date. It is a type of shock instrument worthy of further development for shipboard service.

Multi-frequency reed gages: This instrument, of which 30 were included, furnished the bulk of the shock data obtained from this group of instruments. From a study of the reed gage data obtained on Tests Able and Baker, it appeared that in practically all cases the pattern of reed deflections obtained could be fitted into a theoretical pattern derived for a relatively simple type of motion. It also seemed clear that the way in which the motion started had a decisive effect on the pattern of reed deflections. Obviously, if after the initial shock the resulting oscillatory motion of the ship structure continued to build up, the reed deflections due to the initial shock may be exceeded. The reed shock gage without paper drive can only indicate the most effective motion. In general, this will be the initial motion, but this cannot always be assumed. Where the subsequent motion produces greater shock effects than the initial motion, it might be argued that the initial motion is relatively unimportant.

On comparing the motions as deduced from the reed gage records with the oscillograms obtained from the velocity meter signals, the following points were noted:

- (1) The velocity meter records usually showed the motion to be more complicated than could be predicted from the reed gage record.
- (2) In spite of greater complexity indicated by the velocity meter record, the maximum velocities deduced from the two instruments agreed remarkably well.
- (3) Where the reed gage record indicated a sinusoidal vibration of the structure, the frequency usually agreed with the fundamental frequency shown on the velocity meter oscillogram.

The vital question is whether the multi-frequency reed gage furnishes the most essential information concerning the shock motion or whether the additional information that can be derived from the oscillograms is indispensable. The reed gage without paper drive cannot show the duration of the vibrations resulting from the shock or the number of shocks if there is a succession of them. It cannot possibly show all the frequency components in the resulting shock motion. On the other hand the principal case in which the intensity of the shock is not characterized by the initial motion is that in which the resulting vibrations persist long enough to permit resonant vibrations to build up in the equipment that must withstand the shock. The reed gage has been designed to pretty well cover the range of frequencies encountered on ship structures subject to shock and hence even though it will not show all the frequency components present, the pattern of reed

deflections is almost certain to indicate the order of frequency of any considerable vibration accompanying the shock. For clarification of this point a comparison has been made between reed gage and velocity meter data obtained from instruments located side by side at various locations on APA's 64 and 65 for Test Baker (see Tables on Pages 70 and 71).

It was not possible in all cases to mount the velocity meter and the reed gage on the same frame or the same panel of plating. Hence even though they were mounted as close together as practicable, some of the discrepancies shown in the comparison table may actually have existed in the shock motions themselves. The agreement as to the particular form of the displacement-time or velocity-time functions is not as good as the agreement in numerical values of maximum velocities, but this may be less important than originally supposed.

The ability of the reed gage itself to withstand shock is certainly limited and 20 cycle or even 40 cycle reeds would give too large deflections for shocks involving structural damage. It so happened that the reeds used were well suited to the order of shock encountered on these particular target vessels. The practical upper limit of such an instrument has not as yet been determined, but it appears to be well above the range of shock measured on these APA's at Bikini.

While the theoretical analysis of reed gage response to various impressed shock motions could be carried much further than has been done so far, it is believed that the use of the instrument on the Crossroads tests has proven it a valuable tool for shock investigation. It appears capable of yielding the most important shock quantity, the shock velocity, by means of an analysis that is not too involved. It is necessary for this purpose to compare the pattern of reed deflections with the theoretical patterns for various simple types of shock motions. These are the motions to which the shock conforms in effect even though it may actually be more complicated.

Seismic displacement gages: The seismic displacement gage appears to have a limited application in the field of shock investigation on board ship. Unless great caution is observed in evaluating the displacements indicated by this gage, very erroneous conclusions may be drawn. Nevertheless, in view of the simplicity of installation and the large range of displacements which it is capable of recording, it should not be discarded too hastily from the potential list of shock instruments. The possibility of further refinement should be considered.

TABLE

Comparisons of Estimates of Shock Motions Obtained from Multi-frequency Reed Gages and Velocity Meters Located at the Same Gage Stations on APA's 64 and 65 for Test Baker:

Ship Location	Instrument Location	Gage No. R	V	Maximum Velocity		Nature of Motion as Deduced from Reed Gage	Nature of Motion as Shown by Velocity Meter Oscillogram
				R Gage	V Gage		
APA-64	Wardroom, Fr. 81½ Port Side Plating	1	1	4.2	3.2	A suddenly started simple harmonic motion - frequency in vicinity of 40 CPS. curve.	A 40 CPS simple harmonic pulse starting as a sine wave.
APA-64	Garbage Disposal Fr. 58, Underside of Weather Deck	3	7	1.0	0.82	An Impulsive or step velocity sustained for about 0.005 second.	A half sine pulse of velocity lasting 0.006 second.
APA-64	Dry Provisions, Fr. 57, Port Shell Frame	4	3	1.0	0.57	A step velocity sustained for 0.005 second.	A velocity wave form intermediate between a half sine pulse and a rectangular pulse of duration 0.008 sec.
APA-64	Ammunition Stowage, Fr. 57, Port Shell Frame	6	5	0.7	0.64	A step velocity sustained for about 0.005 sec.	Several cycles of vibration at 40 CPS starting flat topped and later becoming sinusoidal.
APA-64	Ammunition Stowage, Fr. 57, Stbd Shell Frame	7	6	1.7	1.1	Impulsive velocity sustained for 0.006 second.	A velocity wave approximating a triangular pulse more nearly than a step function.
APA-64	Dry Provisions, Fr. 57, Stbd Shell Frame	5	4	1.4	1.2	A sinusoidal vibration with a single amplitude of 0.026" and a frequency near 100 CPS.	Sinusoidal vibration at a frequency of 70 CPS.

(continued next page)

(continued from last page)

Ship	Instrument Location	Gage No.	Maximum Velocity		Nature of Motion as Deduced from Reed Gage	Nature of Motion as Shown by Velocity Meter Oscillogram
			R - V	V Gage		
APA-65	Dry Provisions, Fr. 57, Stbd Shell Frame	4	4	2.6	3.1	An impulsive velocity sustained for 0.01 second city followed by a 100 CPS vi- vibration.
APA-65	Garbage Disposal, Fr. 58, Underside of Weather Deck	3	3	4.0	4.4	An impulsive velocity sustained for 0.012 secondcity followed by a 100 CPS vi- vibration.
APA-65	Ammunition Stowage, Fr. 57, Port Shell Frame	6	6	2.9	6.9	Shm with single amplitude of 0.14 inch and a frequency near 40 CPS with superimposed vibration at 210 CPS and 570 CPS.
APA-65	Ammunition Stowage, Fr. 57, Stbd Shell Frame	7	7	2.5	2.3	Shm with a single amplitude of 0.12 inch and a frequency in the vicinity of 40 CPS.
APA-65	Wardroom, Fr. 81 $\frac{1}{2}$, Port Side Plating	1	1	12.6	13.	Shm with a single amplitude of 0.6 inch and a frequency in the vicinity of 40 CPS.

T O P S E C R E T

PAGE 71 OF 79 PAGES

Without resorting to a theoretical analysis based on unwarranted assumptions, it can readily be seen that in cases where the structure executes low frequency oscillations the friction action on the cylinder could be so great that no motion would be recorded even though the actual amplitudes might be very large. On the other hand when the gage is used with a spring, which is necessary for vertical measurements, there is a possibility of a considerable amplification of low frequency oscillations due to resonance. If the friction were reduced by the introduction of rollers, it would be necessary to restrain the seismic element by means of springs to prevent it from shifting from one stop to the other just due to the rolling and pitching motions of the ship. Thus it is seen that the design would be taking the shape of the shock displacement gage already discussed. Perhaps a design could be worked out which would be a compromise between these two instruments in which some of the simplicity of the seismic displacement gage was sacrificed in order to obtain an instrument lighter and less bulky than the present shock displacement gage.

Shock Intensity as a Function of Distance and Orientation of the Vessel

In spite of the number of instruments used at Bikini, the data on which to base relations between shock intensity and distance are rather meager. With the exception of the submarine APOGON (SS-308) which was lost on Test Baker, the instruments of this group were all installed on target vessels of the APA Class.

On Test Able, as may be seen from the plan of the array, APA-57 and SS-308 were on the inner circle, while APA's 63, 64, and 65 were on the southern string. APA-57 was lost on this shot and ~~no~~ instruments of this group were recovered from this vessel. For Test Able, air blast test, it appears that a comparison of shock intensities at different distances must logically be based on measurements made above the waterline. Furthermore, on the basis of the discussion of the shock instruments, the shock velocities will be used as the best index of shock intensity established so far.

Among the instrument locations of this group the only ones available for this comparison for Test Able were the wardroom side plating locations, port and starboard, on APA's 64 and 65. Both vessels were hit from astern by the blast. In the case of APA-65 the blast struck practically stern on, whereas in the case of APA-64 it struck some-

what to port. In the case of APA-65 the radius vector from a point on the surface directly below the bomb to the center of the ship made an angle of about one degree with the fore and aft centerline, whereas in the case of APA-64 this angle was about eleven degrees. Comparative data are given in the following table.

Comparison of Shock Velocities of Wardroom Side Plating, Frame 80 1/2, APA's 64 and 65, Test Able:

Ship	Horizontal Distance from Bomb to Hull Amidships (yards)	Angle between Radius Vector and Fore & Aft Centerline (degrees)	Shock Velocities (ft/sec) Athwartships	
			Wardroom Stbd. Side	Wardroom Port Side
APA-65	1646	1	6.7	5.9
APA-64	2096	11	2.9	6.1

It is apparent from this table that the effect of distance is masked by the effect of orientation. It was the athwartship component of shock that was measured in each case.

In the case of these two vessels note should also be taken of the extent to which the shock resulting from the air blast diminished in passing from the superstructure down into the ship. This is shown in the following table.

APA's 64 and 65 - Test Able - Variation of Shock Velocity as Indicated by Multi-frequency Reed Gage with location in the ship:

Gage No.	Compartment	Direction of Measurement	Shock Velocity (ft/sec)	
			APA-65	APA-64
R-1	Wardroom Port Side	Athwartships	5.9	6.1
R-2	Wardroom Stbd Side	Athwartships	6.7	2.9
R-3	Garbage Disposal Port Side	Vertical	2.3	No reading
R-4	Dry Provisions Port	Athwartships	3.4	2.6
R-5	Dry Provisions Stbd	Athwartships	2.2	0.3
R-6	Ammunition Stowage Port	Athwartships	0.3	0.1

(continued next page)

(continued from last page)

Gage No.	Compartment	Direction of Measurement	Shock Velocity (ft/sec)	
			APA-65	APA-64
R-7	Ammunition Stowage Stbd	Athwartships	0.0	0.0
R-8	Ammunition Stowage Keel	Athwartships	0.0	0.0
R-9	Ammunition Stowage Keel	Vertical	0.6	0.0
R-10	Underside Weather Deck Near Aft Hatch	Vertical	1.5	3.8
R-11	Gasoline Stowage Keel	Athwartships	0.0	0.0
R-12	Gasoline Stowage Keel	Vertical	0.0	0.0

In making use of the data given in the two preceding tables a note of caution should be observed. In the first place as previously pointed out, the shock velocities listed are not all of the step or impulsive type, and although they represent the best index of shock so far selected, for many purposes it would be necessary also to take account of the type of motion involved. In the second place, the particular target ships involved, the APA Class, bear little similarity structurally to other classes of modern naval vessels. In view of the role which the vibration characteristics of the structure play in the motions resulting from shock, this point requires no further emphasis.

In the case of Test Baker, which may be referred to as the underwater test, the comparison of shocks at different distances must logically be based on measurements made below the waterline. Shock measurement in Test Baker was complicated by the occurrence of an air blast which was much greater than anticipated. As has been pointed out, the reed gage without paper drive indicates only the peak shock effect and where two shocks occur in succession a single reed gage record will not tell which shock was the greater. On APA-64 two pallographs were installed in the ammunition stowage compartment on the keel. One of these recorded vertical displacement and the other athwartship displacement. The pallograph records showed the arrival of two shocks about two seconds apart, and on the assumption that the first shock came through the water and the second through the air, they indicated that the underwater shock produced greater vertical shock motions and the air blast produced greater transverse shock motions. The comparison of underwater shock intensities at different

distances is therefore based on the readings of the vertical reed gages on the keel in the ammunition stowage compartment of APA's 85, 65, and 64. The results are shown in the following table.

Comparison of Shock Velocities as Measured in the Ammunition Stowage Compartment on the Keel on APA's 85, 65, and 64 for Test Baker (shock velocities measured in the vertical direction):

Ship	Horizontal Distance from Bomb to Hull Amidships (yards)	Angle between Radius Vector and Fore & Aft Centerline (degrees)	Vertical Shock Velocity (ft/sec)
APA-85	642	16	6.0
APA-65	908	60	3.0
APA-64	1492	16	2.8

It will be noted that as in the case of Test Able the vessels were not only at different distances, but due to the shift of the wind they had different orientations. All three vessels were hit from astern, but APA-65 was hit on the port side while APA's 64 and 85 were hit on the starboard side. Had the wind been east all three vessels would have been hit on the port side.

The next tabulations show the variation in shock velocities at different locations on APA's 64 and 65 for Test Baker.

APA's 64 and 65 - Test Baker - Variation of Shock Velocity with Location on Ship as Indicated by Multi-frequency Reed Gages:

Gage No.	Compartment	Direction of Measured Shock	Shock Velocity (ft/sec)	
			APA-65	APA-64
1	Wardroom Port Side	Athwartships	12.6	4.2
2	Wardroom Stbd Side	Athwartships	5.2	6.3
3	Garbage Disposal Port Side	Vertical	4.0	1.0
4	Dry Provisions Port Side	Athwartships	2.6	1.0

(continued next page)

(continued from last page)

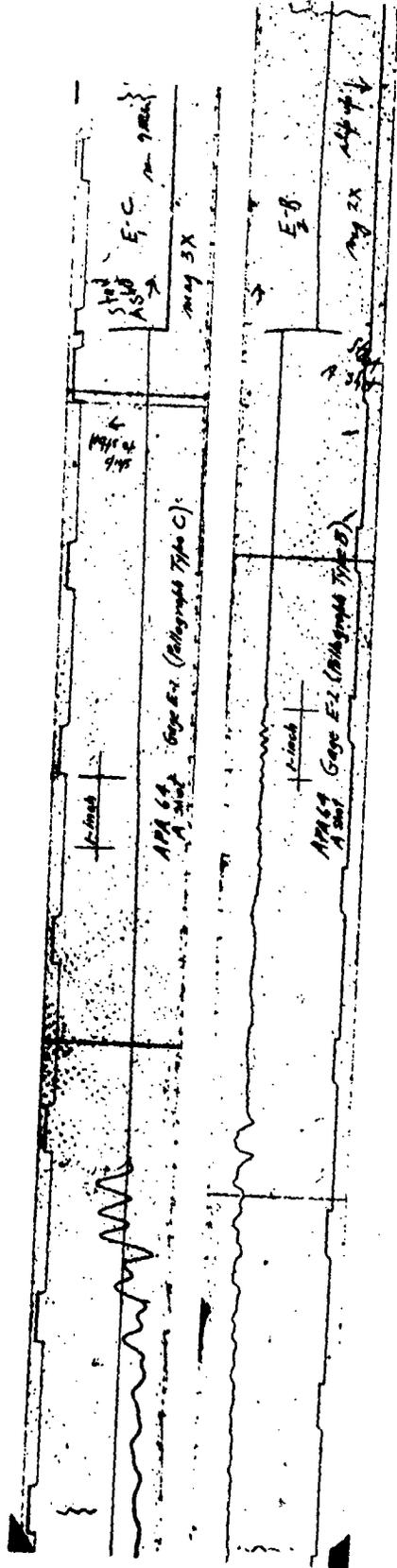
Gage No.	Compartment	Direction of Measured Shock	Shock Velocity (ft/sec)	
			APA-65	APA-64
5	Dry Provisions Stbd Side	Athwartships	0.9	1.4
6	Ammunition Stowage Port Side	Athwartships	2.9	0.7
7	Ammunition Stowage Stbd Side	Athwartships	2.5	1.7
8	Ammunition Stowage Keel	Athwartships	1.4	0.2
9	Ammunition Stowage Keel	Vertical	3.0	2.8
10	Underside Weather Deck Near Aft Hatch	Vertical	7.3	1.9
11	Gasoline Stowage Keel	Athwartships	No gage	0.3
12	Gasoline Stowage Keel	Vertical	No gage	0.3

The shock velocities tabulated in the foregoing table do not conform to the pattern to be expected from an underwater shock. On the contrary the pattern is very similar to that obtained on the air blast shot, Test Able. This, as has been pointed out, was due to the unexpected severity of the air blast accompanying the underwater shot. According to the evidence supplied by the reed gages, the air blast effect on the wardroom side plating of APA-65 was considerably greater for Test Baker than for Test Able, the distance being much less for Test Baker. This makes comparisons of the underwater shock effects difficult. Again it must be kept in mind that the shock velocities tabulated are not necessarily impulsive velocities, but the maximum velocities for the type of motion indicated by analysis of the reed deflections. It is also repeated that the APA Class of target vessel is not generally representative of a modern combat vessel from the structural point of view.

Bibliography

1. "Instruments for Measuring Vibration and Shock on Ship Structures and Machinery", by F. Mintz and R. B. Allnutt, TMB Report 563 (in preparation).
2. "Experimental and Theoretical Investigations of the Mass Plug Accelerometer", by D. M. Smith, TMB Report R-267, March 1946.
3. "Effects of Impact on Simple Elastic Structures", by J. M. Frankland, Ph.D., TMB Report 481, April 1942.
4. "Structural Firing Tests with Depth Charges on the Destroyer Escort HOPPING (DE-155)", by H. R. Thomas and Lt.Cdr. J. R. Parkinson, USNR, TMB CONF Report R-185, November 1943.
5. "Deck Loads Measured During Firing Tests of an A/S Projector, Mark 10", by H. R. Thomas, TMB CONF Report R-178, February 1944.
6. "Shock Measurements During Depth Charge Tests on the U.S.S. DRAGONET (SS-293)", by H. L. Rich, TMB CONF Report R-283, April 1945.
7. "Shock Mounts for Naval Shipboard Service", NAVSHIPS 250-600 Electrical Section, June 1944.
8. "Mechanical Shocks", NAVSHIPS 900, 052, January 1945.

UNCLASSIFIED

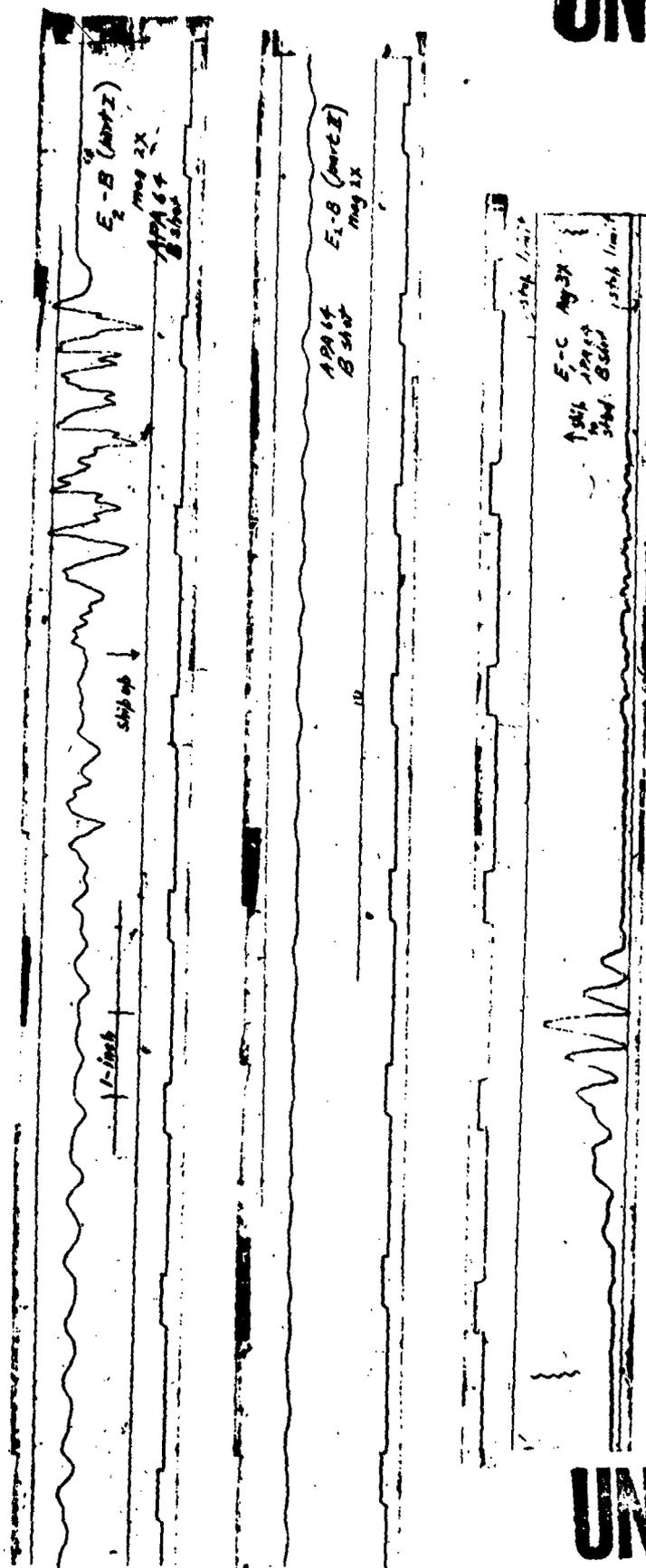


Reproductions of Pallograph Records Obtained on Shot A, APA 64, E Gages 1 and 2

FIGURE 3

UNCLASSIFIED

UNCLASSIFIED



Reproductions of Pallograph Records Obtained on Shot B, APA 64, E Gages 1 and 2

FIGURE 4

UNCLASSIFIED





TRC

Defense Special Weapons Agency
6801 Telegraph Road
Alexandria, Virginia 22310-3398

10 April 1997

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
ATTENTION: OMI/Mr. William Bush

SUBJECT: Declassification of Reports

The Defense Special Weapons Agency (formerly Defense Nuclear Agency) Security Office has reviewed and declassified the following reports:

AD-366718✓	XRD-32-Volume 3	
AD-366726✓	XRD-12-Volume 2	
AD-366703✓	XRD-16-Volume 1	
AD-366702✓	XRD-14-Volume 2	
AD-376819L✓	XRD-17-Volume 2	
AD-366704✓	XRD-18	
AD-367451✓	XRD-19-Volume 1	
AD-366700 5	XRD-20-Volume 2	AD-366705
AD-376028L✓	XRD-4	
AD-366694✓	XRD-1	
AD-473912✓	XRD-193	
AD-473891✓	XRD-171	
AD-473899✓	XRD-163	
AD-473887✓	XRD-166	
AD-473888✓	XRD-167	ST-A 28 JAN 80 made target
AD-473889✓	XRD-168	

TRC

10 April 1997

SUBJECT: Declassification of Reports

AD-B197749	XRD-174
AD-473905 ✓	XRD-182
AD-366719 ✓	XRD-33 Volume 4
AD-366700 ✓	XRD-10
AD-366712 ✓	XRD-25 Volume 1
AD-376827L ✓	XRD-75
AD-366756 ✓	XRD-73
AD-366757 ✓	XRD-74
AD-366755 ✓	XRD-72
AD-366754 ✓	XRD-71
AD-366710 ✓	XRD-23 Volume 1
AD-366711 ✓	XRD-24 Volume 2
AD-366753 ✓	XRD-70
AD-366749 ✓	XRD-66
AD-366701 ✓	XRD-11
AD-366745 ✓	XRD-62.

All of the cited reports are now **approved for public release; distribution statement "A" applies.**

Arndith Jarrett
ARDITH JARRETT
Chief, Technical Resource Center

copy furn: FC/DSWA (DASIAC)
KSC

Completed

R.W