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OPERATION CROSSROADS

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REPORT OF

BUREAU OF SHIPS INSTRUMENTATION GROUP

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SECTION XII

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Roll and Pitch Measurement

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Report Of

BUREAU OF SHIPS INSTRUMENTATION GROUP.

SECTION XII.

ROLL AND PITCH MEASUREMENT

(10) W. E. Hansen.

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ROLL AND PITCH MEASUREMENT

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(192 600)

Report On

ROLL AND PITCH MEASUREMENT

This report was prepared by Mr. W. R. JANSEN, of the Bureau of Ships. The apparatus was handled in the field by Mr. JANSEN, Mr. R. C. WINTERBOTTOM, of the Bureau of Ships, and Mr. WALTER POPIEL, of New York Naval Shipyard. This project was supeinsed by Comdr. R. M. LANGER, USNR, of the Bureau of Ships.

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Purpose of Measurement

1. To determine to what degree the target vessels roll and pitch when subjected to the atomic bomb explosions.

2. To undertake a comparative study of the shock sensitivity of inclinometer pendulum recorders and gyroscopic instruments.

Conclusions

1. The target vessels on which roll and pitch instruments were located did not roll or pitch as much as had been expected from previous predictions of wave heights and slopes. Of the thirteen vessels instrumented with roll and pitch recorders for the air burst the GILLIAM (APA - 57) sank with records lost and only the RHIND (DD - 404) registered motion in excess of normal roll and pitch. The subsurface burst sank the SARATOGA with the loss of her roll and pitch records. The BRISCOE (APA - 65) recorded a roll of plus and minus 14 degrees - the only roll in excess of plus and minus 10 degrees in all thirteen target ships on which recorders were installed.

2. With few exceptions the ships recorded normal roll and pitch amplitudes and periods.

3. Particularly true of TEST BAKER, records indicate that the wave front was of such slope as to "heave" the ships bodily rather than to cause appreciable roll and pitch. Evidence supporting that is: -

(a) For the same amplitude of motion recorded by comparable classes of vessels following the two shots, the records indicate greater acceleration of the vessels subjected to Able blast.
(b) Gyro records of ships marked "heaving" in detailed results tabulation show an envelope containing secondary minima between nulls.
(c) Both gyros and pendulums provided records of abnormally long pitch and roll periods. Test Baker records of the USS Gasconade showed a 20 second pitch period and normal roll period.

4. The rate of damping of large angles of roll and pitch on both APA's and DD's showed both classes to be relatively stable ships. The USS Rhind (DD404) damped from a 16° maximum roll to normal within two minutes after Able blast and despite the series of waves following the Baker explosion damped from 1[illegible]° maximum roll to normal

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in 2-1/3 minutes. After Baker, the Briscoe (APA 65) recovered from 14-1/2° to normal in 1-1/2 minutes while the Gasconade (APA 85) damped from 6-1/2° to normal in 1 - 2/3 minutes.

5. As had been anticipated, pendulum recorders were found to be highly susceptible to shock excitation and hence not reliable as a means of measuring ship's motion resulting from blast.

6. Either the area within which the ships transmitted high shock through their structure to the pendulum was less in the subsurface shot than in the air burst or else the ships' hulls absorbed more of the shock of the subsurface explosion than the ships' surface could absorb the air burst shock. This is indicated from the pendulum records taken from the southeast string of APA's. These vessels showed greater pendulum acceleration from Able than from Baker despite the fact that the ships were farther from Able blast than from Baker.

Description of Recording Equipment

A number of possibilities by means of which roll and pitch measurements might be made were considered. The most important of these are as follows:

(a) Brush Recorders taking synchro data from either Mark 6 or Mark 8 stable elements.
(b) Cameras photographing dials that repeated roll and pitch information from Mark 6 or Mark 8.instruments.
(c) Cameras photographing the horizon from the superstructures of target vessels.
(d) Maximum reading inclinometers.
(e) Pendulums
(f) Gyros.

Because of the various hazards of delivery of Brush Recorders, of undetermined radioactivity levels but which were expected to fog film beyond use, and of the insufficiency of only maximum readings, the first four proposals were discarded; the measurements were undertaken on the basis of schemes (e) and (f). Subsequently, scheme (c) was employed for other purposes as well, but this report is confined to the pendulum and gyro efforts.

There was available a number of gyro elements which were facsimilies of the SU Radar stabilizer. With these as the starting point, the Navigational Division, Material Laboratory, New York Naval Shipyard was given the job of adopting these to a stylus recording on a clock-driver disc. There was also developed a pendulum recorder for use where power might not be available.

Gyro Roll and Pitch Recorder

The Gyro Roll and Pitch Recorder shown in Figures 1 - 3 consists of two gyro stabilized styluses normal to one another - one parallel to the ship's roll axis and the other parallel to the ship's pitch axis. This instrument recorded both roll and pitch in the plane normal to the deck. The stylus, rigidly fastened to the outer gimbal of the gyro, produced a permanent record on an aluminum disc. This disc was driven by a clock mechanism that was modified to provide one revolution per hour.

Both the roll and pitch gyros have plus and minus 90 degrees clearance which permitted a record of 180 degrees total travel.

The gyros were powered by the 3 phase output of the frequency changer supplied with single phase alternating current. The supply to the frequency changer was provided by special power installation (batteries and motor generators) for instrumentation installations, or by power from diesel generators which remained in operation during the test.

The clocks on gyro roll and pitch recorders installed on the following target vessels were electrically triggered by the minus 20 second pulse used in the instrumentation power arrangements on those vessels: GILLIAM (APA-57), BLADEN (APA-63), BRACKEN (APA-64), BRISCOE (APA-65), GASCONADE (APA-85), NIAGARA (APA-87), RHIND (DD-404) and WILSON (DD-408).

The clocks on gyro roll and pitch recorders installed on the PENNSYLVANIA (BB-38), RALPH TALBOT (DD-390) and PARCHE (SS-384) had a combination of mechanical and electrical triggering. The recorder gyros on these ships were driven by power supplied by diesel generators tied in with the ship's power circuit.

The mechanical triggering consisted of silk threads which held four flexible contacts in an open position. The closing of any of these parallel circuits released both styluses and clocks. These parallel circuits closed when a thread strung across the path but beyond the normal roll of the razor-tipped gimbal was cut.

The gyro roll and pitch recorder had four shock mounts located as shown in the photographs. A metal cover over the recorder protected the instrument from damage.

Pendulum Roll and Pitch Recorder

The pendulum roll and pitch recorder is illustrated in Figures 4 and 5. The instrument consists of two pendulums and two clocks mounted 90 degrees apart as shown in Figure 5. The period of each pendulum was less than the normal roll or pitch period of the ship in order to prevent a resonant condition. The clocks were triggered by the razor-cut thread strung on each side of the pendulum bob. The styluses were identical to those used on the gyro recorders. The limit of displacement was plus and minus 60 degrees from the vertical for both the roll and pitch pendulums. The pendulum recorder like the gyro was shock mounted and enclosed in a metal case.

Accuracy of Instruments

The gyro accuracy with the mechanical stylus attached is approximately plus and minus 1/2 degree for all normal ship's rolls less than 20 degrees providing the instrument is located within 50 feet of the ship's metacenter. However, within this 1/2 degree circle, the instrument will hold a particular position within a few minutes of arc once it has come to speed.

The clocks loaded with the disc's inertia started the discs and kept them scanning at one revolution per hour with a tolerance of plus and minus 5 minutes at the end of one hour.

The records were read to plus and minus 15 minutes of arc in amplitude and one second time. Hence the gyro records have a tolerance of plus and minus 45 minutes amplitude with reference to vertical and an envelope error of less than plus and minus 10 minutes for any section of the recording. The gyro error of 1/2 $^{\circ}$ appears on the records visibly for the gyro will hold a fix until the impressed torque, gimbal friction, stylus, drag etc., is sufficient to cause an evident discontinuity in the smooth curve record. The periods of time recorded by the gyro instruments are within plus or minus 10 per cent.

Pendulum errors attributable to shock excitation were to all practical purposes indefinite. After the shock wave passed and ship's normal roll was recorded these measurements are of equal accuracy as gyro recordings for rolls less than plus and minus 10 degrees. Clock and reading errors are the same for both gyro and pendulum.

Location of gauges

Tables I and II indicate the installation by target vessels, the vessels being arranged in order of increasing distance from the explosion. Table III lists the detailed locations within the vessels.

Results

Tables IV - VII list the essential features of the data. Full scale photographs of representative gyro and pendulum records are shown in Figures 6 - 9. Inasmuch as the factors of roll and pitch recorded here are within the range of normal experience, no extended analysis is undertaken. The measurements, however, will support a formal study of bodily motions of ships.

TABLE I
TARGET VESSELS

TEST ABLE

• Listed in order of increasing distance from the blast.

GILLIAM	APA57	Gyro and pendulum
RHIND	DD404	Gyro and pendulum
WILSON	DD408	Gyro and pendulum
RALPH TALBOT	DD390	Gyro
PENNSYLVANIA	BB38	Gyro
BRISCOE	APA65	Gyro and pendulum
CATRON	APA71	Pendulum
BRACKEN	APA64	Gyro
SARATOGA	CV3	Pendulum
PARCHE	SS384	Gyro
FILLMORE	APA83	Pendulum
BLADEN	APA63	Gyro and pendulum
NIAGARA	APA87	Pendulum

TABLE II
TARGET VESSELS

TEST BAKER

Listed in order of increasing distance from the blast.

SARATOGA	CV3	Gyro and pendulum
GASCONADE	APA85	Gyro and pendulum
BRISCOE	APA65	Gyro and pendulum
CATRON	APA71	Pendulum
PENNSYLVANIA	BB38	Gyro
WILSON	DD408	Gyro and pendulum
PARCHE	SS384	Gyro
BRACKEN	APA64	Gyro
RALPH TALBOT	DD390	Gyro
FILLMORE	APA83	Pendulum
RHIND	DD404	Gyro and pendulum
BLADEN	APA63	Gyro and pendulum
NIAGARA	APA87	Gyro and pendulum

TABLE III

GAGE LOCATIONS

In all instances the recording instruments were located within fifty feet of the metacenter of the ship.

VESSEL	GAGE	COMPARTMENT	LONGITUDINAL LOCATION	VERTICAL LOCATION	ATHWARTSHIP LOCATION
BLADEN	Gyro	Auxiliary Machinery Space B-2-1E	Frame 85 fwd side of fresh water tank	3 ft. above 2nd platform deck.	Centerline
	Pendulum	Ship's Store Stores B-205-1A	Aft side of frame 83	2 ft above 1st platform deck	Centerline
BRACKEN	Gyro	Auxiliary Machinery Space B-2-1E	Frame 85 fwd side of fresh water tank	3 ft above 2nd platform deck	Centerline
BRISCOE	Gyro	Auxiliary Machinery Space B-2-1E	Frame 85 fwd side of fresh water tank	3 ft above 2nd platform deck	Centerline
	Pendulum	Ship's Store Stores B-205-1A	Aft side of frame 83.	2 ft.above 1st platform deck	Centerline
CATRON	Pendulum	Ship's Store Stores B-205-1A	Aft side of frame 83.	2 ft. above 1st platform deck	Centerline
FILLMORE	Pendulum	Ship's Store Stores B-205-1A	Aft side of frame 83.	2 ft.above 1st platform deck.	Centerline
GASCONADE	Gyro	No. 1 Hold	Frame 40	1st platform deck.	Centerline
	Pendulum	No. 1 Hold	Frame 40	1st platform deck	Centerline

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TABLE III (cont'd)
GAGE LOCATIONS

VESSEL	GAGE	COMPARTMENT	LONGITUDINAL LOCATION	VERTICAL LOCATION	ATHWARTSHIP LOCATION
NIAGARA	Gyro	Auxiliary Machinery Space B-2-1E	Frame 85 fwd side of fresh water tank.	3 ft.above 2nd platform deck.	Centerline
	Pendulum	Ship's Store Stores'	Aft side of frame 83.	2 ft. above 1st platform deck.	Centerline
PENNSYL-VANIA	Gyro	Central Sta. A-434 P	Frame 55	On deck	3 ft.to port of gyro comp.
SARATOGA	Gyro	Central Sta. A-449 C	Frame 67	On deck	Centerline
	Pendulum	Central Sta. A-449 C	Frame 70 1/2	28 in. above deck.	Centerline
PARCHE	Gyro	Control Room	Frame 58	On deck	4 ft.to port of centerline
RALPH-TALBOT	Gyro	Crews Mess A-203 L	Frame 33	1st platform deck.	6 in.to stbd. of centerline
RHIND	Gyro	Torpedo Work-shop-B-107E	Frame 120	6 in.above main deck.	1 ft.to stbd. of centerline.
	Pendulum	I.C.& Mas-ter Gyro Rm. A-305-3C	Frame 45	2 1/2 ft.above deck	1 ft.to port of gyro comp. centerline
WILSON	Gyro	Torpedo Work-shop B-107E	Frame 120	8 in. above main deck.	1 ft.to stbd. of centerline.
	Pendulum	I.C.& Mas-ter Gyro Rm. A-305-3C	Frame 44	10 in. above deck	1 ft. to stbd. of gyro comp. centerline.

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TABLE III (concl'd)
GAGE LOCATIONS

VESSEL	GAGE	COMPARTMENT	LONGITUDINAL LOCATION	VERTICAL LOCATION	ATHWARTSHIP LOCATION
GILLIAM	Gyro	Auxiliary Machinery Space B-2-1E	Frame 85 fwd side of fresh water tank.	3 ft. above 2nd platform deck.	Centerline
	Pendulum	Ship's Store Stores B-205-1A	Aft side of frame 83.	2 ft. above 1st platform deck.	Centerline

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TABLE IV

TEST ABLE
DETAILED RESULTS
GYRO

VESSEL	Roll	Pitch
GILLIAM**	--------	--------
RHIND	±16 degrees damped to ± 2 degrees in 20 seconds 10 second period	± 2 degrees damped to ±30 minutes
WILSON	± 2 degrees, 6 sec period	Less than ±30 minutes
RALPH TALBOT	Did not trigger	Did not trigger
PENNSYLVANIA	±2 degrees, period normal	Less than ±30 minutes
BRISCOE	± 2 degrees	±1 degree
CATRON	--------	--------
BRACKEN	± 2 degrees	±1 degree
SARATOGA	--------	--------
PARCHE	±2 degrees, 9 sec period	Less than ±5 degree
FILLMORE	--------	--------
BLADEN	±1 1/2 degrees	Less than ±30 minutes
NIAGARA	--------	--------

** SUNK - Records were not recovered.

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TABLE V

TEST ABLE
DETAILED RESULTS
PENDULUM

VESSEL	Roll	Pitch
GILLIAM**	- - - - - - - - - -	- - - - - - - - - -
RHIND	±60 degrees for 20 sec. Shock excited	±10 degrees Shock excited
WILSON	±11 degrees. Shock excited	No record
RALPH TALBOT	- - - - - - - - - -	- - - - - - - - - -
PENNSYLVANIA	- - - - - - - - - -	- - - - - - - - - -
BRISCOE	Did not trigger	Did not trigger
CATRON	Did not trigger	Did not trigger
BRACKEN	- - - - - - - - - -	- - - - - - - - - -
SARATOGA	Did not trigger	Did not trigger
PARCHE	- - - - - - - - - -	- - - - - - - - - -
FILLMORE	Did not trigger	Did not trigger
BLADEN	±5 degrees, damped to ±30 minutes	Did not trigger
NIAGARA	±8 degrees for 5 seconds then damped to ±1 degree	±3 degrees or less Did not trigger

** SUNK - Records were not recovered

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TABLE VI

TEST BAKER
DETAILED RESULTS
GYRO

VESSEL	Roll	Pitch
SARATOGA*	- - - - - - - - - -	- - - - - - - - - - -
GASCONADE	±9 degrees damped to ±2 1/2 degrees	±7 degrees - first 3 pitches took 20 sec. Normal period-5 sec.
BRISCOE	±14 degrees,10 sec.period damped to ±3 degrees	±1 1/2 degrees, normal
CATRON	- - - - - - - - - -	- - - - - - - - - - -
PENNSYLVANIA	Did not trigger Set for ±5 degrees	Did not trigger Set for ± 5 degrees
WILSON	±10 degrees maximum. 10 secs.period damped to ± 2 degrees in 3 min.	±2 1/2 degrees for 1 1/2 minutes damped to less than ±30 min.
PARCHE**	- - - - - - - - - -	- - - - - - - - - - -
BRACKEN	±3 degrees, 10 sec period	±1 1/2 degrees, 20 sec period - "heaving"
RALPH TALBOT	Did not trigger Set for ± 10 degrees.	
FILLMORE	- - - - - - - - - -	- - - - - - - - - - -
RHIND***	±7 degrees, several pulses from ±2 degrees to ±7 degrees. Period 10 sec.	Normal-built up to ±1 1/2 degrees then dropped.
BLADEN	±3 degrees, 10 sec period	±2 1/2 degrees, 18 sec period "heaving"
NIAGARA	No record-power failure	±2 degrees - gyro became pendulous.

* SUNK - Records were not recovered.
** Records not recovered until Oct.1946(did not trigger).
*** Pendulum location inaccesible due to gas fumes.

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TABLE VII

TEST BAKER
DETAILED RESULTS
PENDULUM

VESSEL	Roll	Pitch
SARATOGA*	- - - - - - - - - -	- - - - - - - - - -
GASCONADE	±60 degrees. Shock excited.	No record - clock failed.
BRISCOE	±42 degrees, 4 cycles in 4 seconds - shock excited.	±12 degrees Shock excited.
CATRON	±15 degrees at blast- recovered and rolled ±3 degrees in next few minutes.	Did not trigger.
PENNSYLVANIA	- - - - - - - - - -	- - - - - - - - - -
WILSON	Did not trigger Set for ± 10 degrees.	Did not trigger
PARCHE**	- - - - - - - - - - -	- - - - - - - - - - -
BRACKEN	- - - - - - - - - - -	- - - - - - - - - - -
RALPH TALBOT		
FILLMORE	Did not trigger	Did not trigger
RHIND***		
BLADEN	Did not trigger	Did not trigger.
NIAGARA	±2 degrees	±2 degrees -18 second period-"heaving"

* SUNK - Records were not recovered.
** Records not recovered until Oct. 1946 (did not trigger).
*** Pendulum location inaccessible due to gas fumes.

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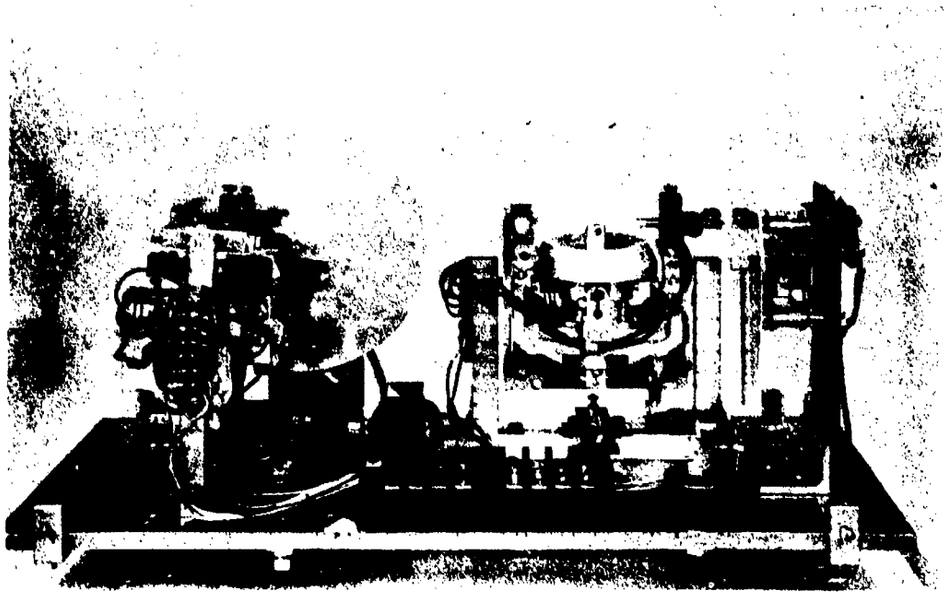

SPECIAL SELF [illegible]ERING GYRO ROLL [illegible]
FRONT VIEW

Figure 1

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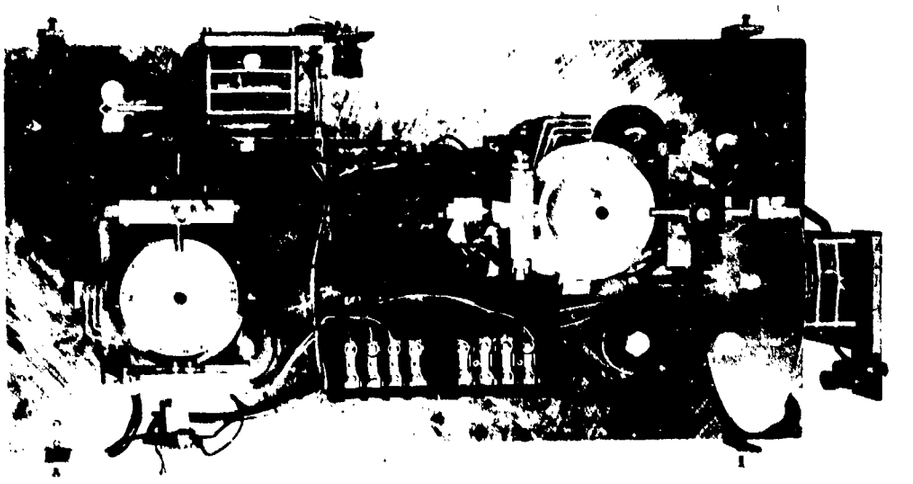

SPECIAL SELF TRIGGERING GYRO ROLL & PITCH RECORDER
TOP VIEW

MAT'L LAB.
NYNAVSHIPYD

MAR 1946
TEST 4920

Figure 2

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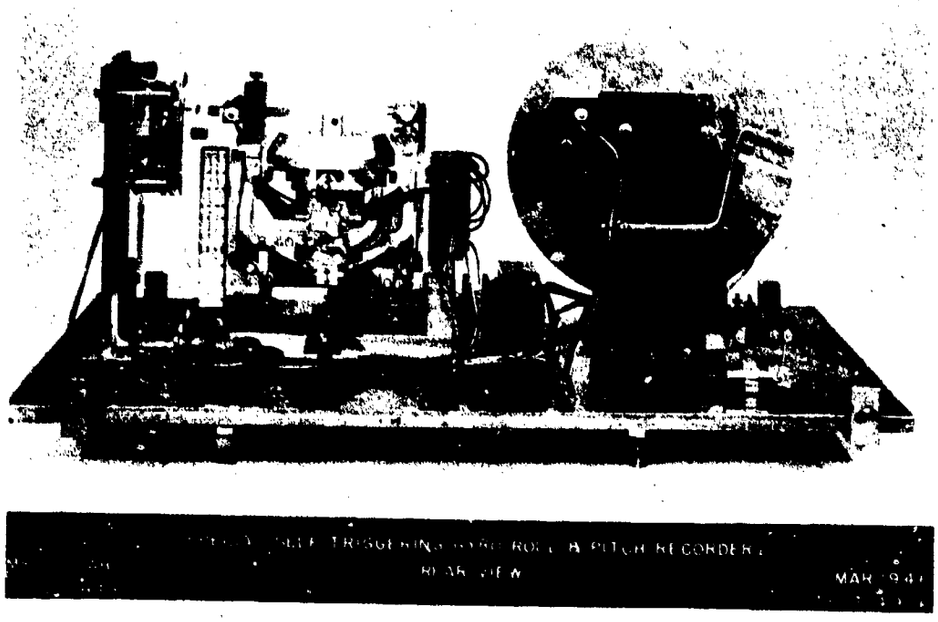

Figure 3

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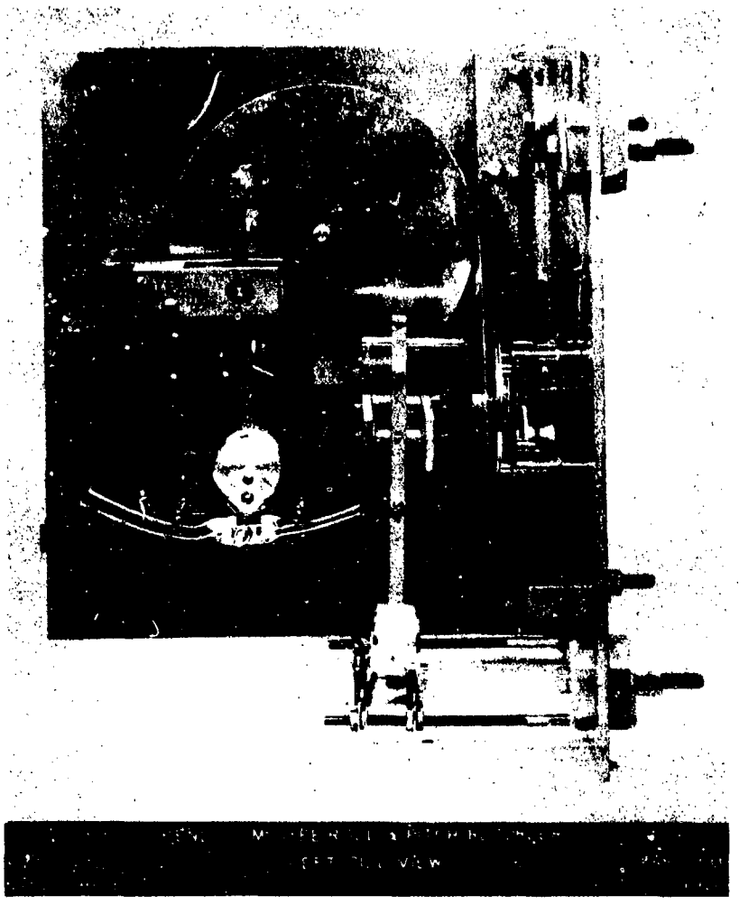

Figure 4

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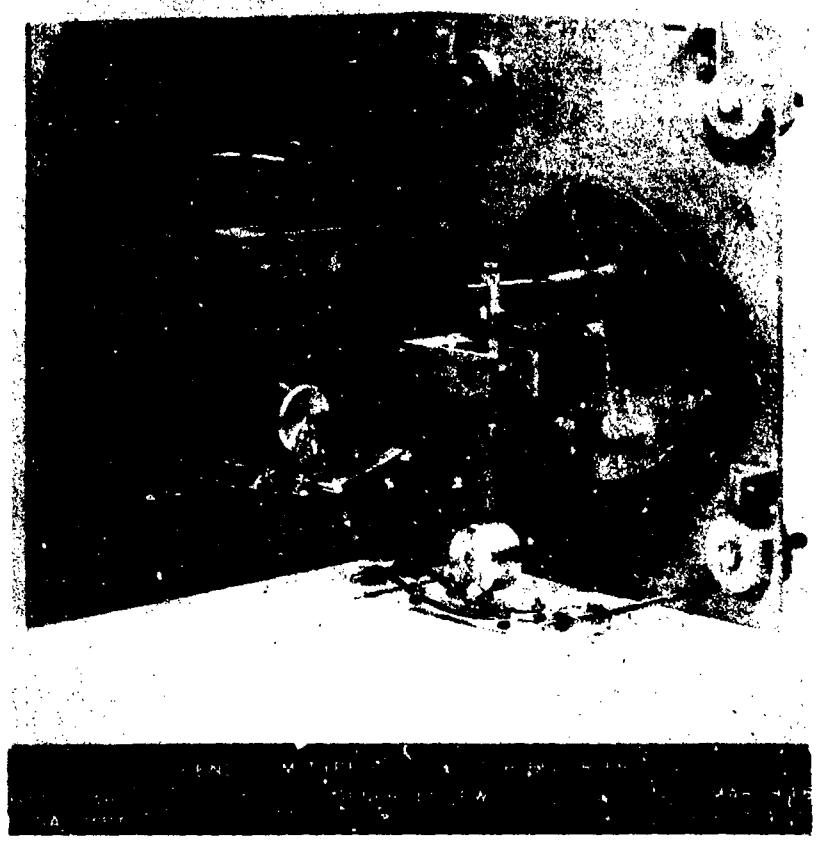

Figure 5

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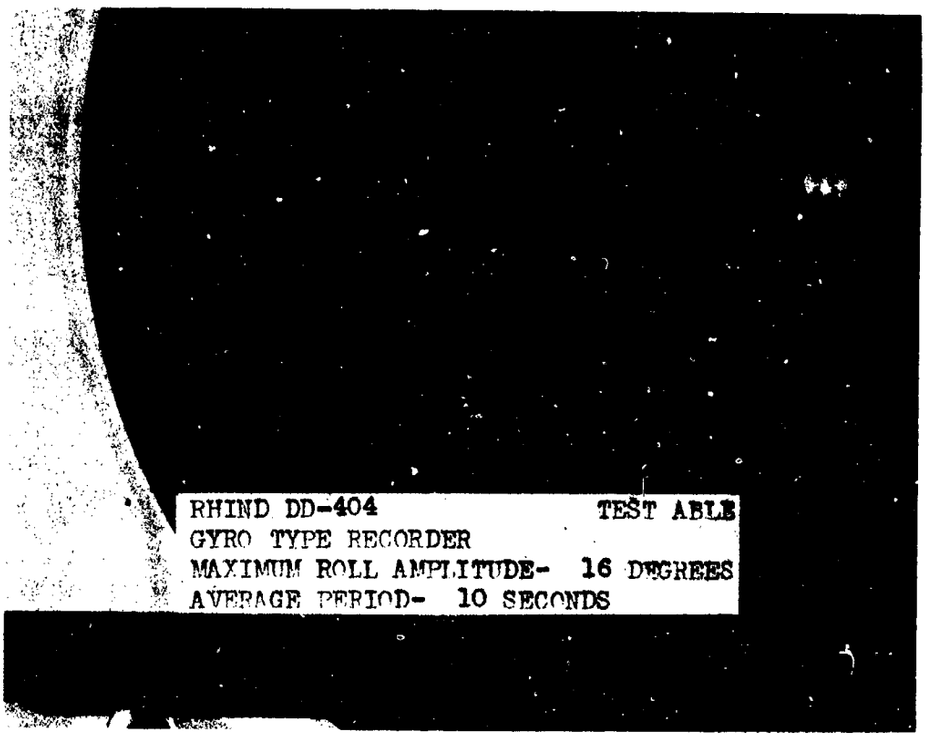

Figure 6

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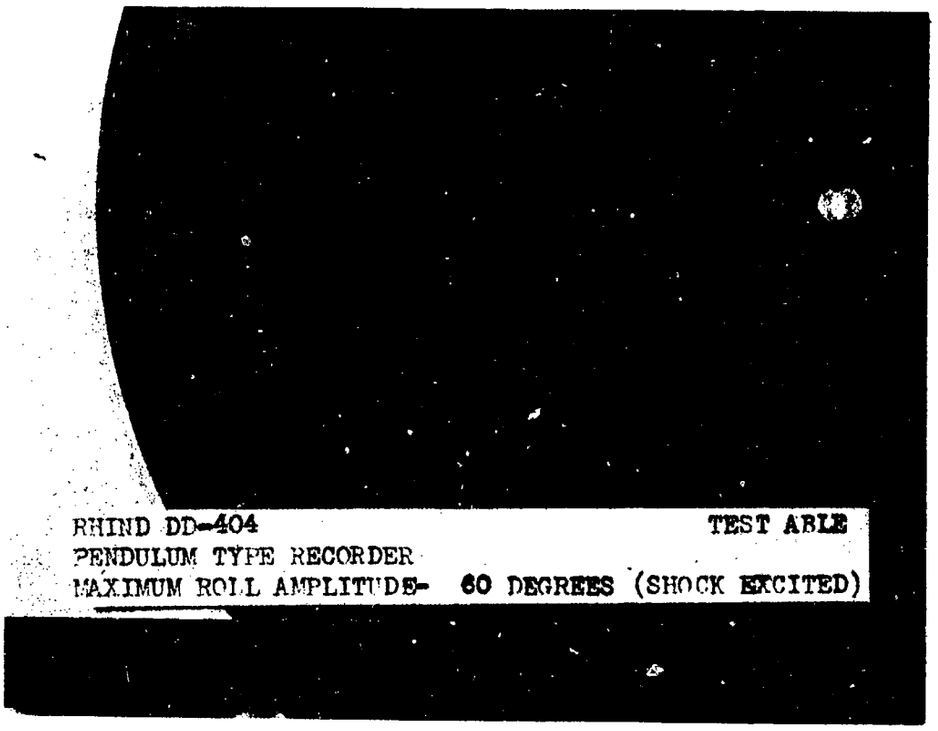

Figure 7

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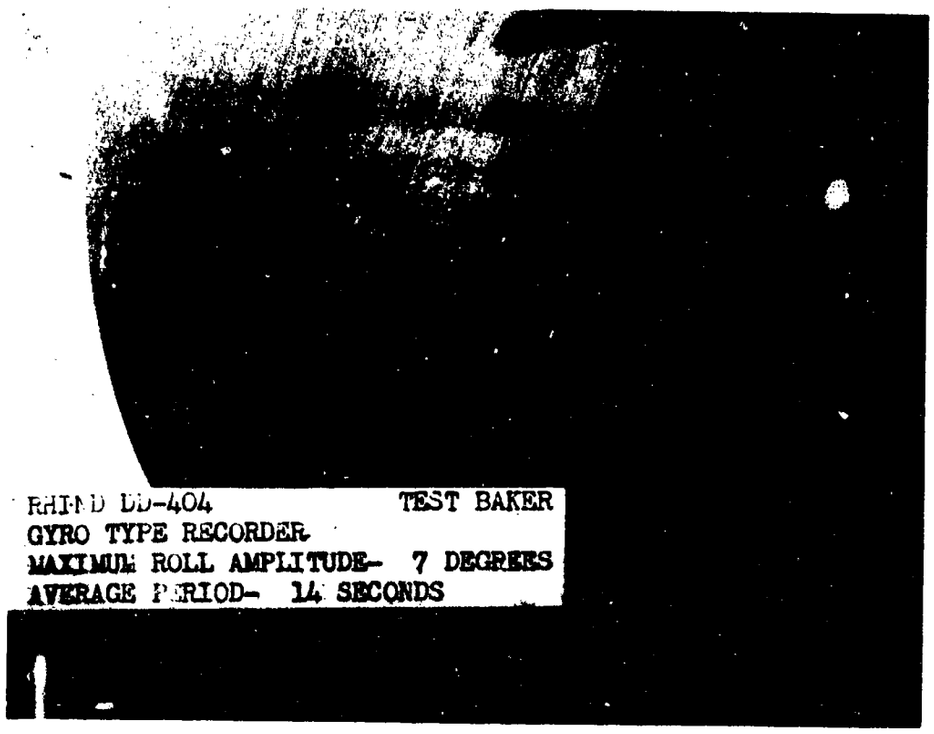
RHIND DD-404
TEST BAKER
GYRO TYPE RECORDER
MAXIMUM ROLL AMPLITUDE- 7 DEGREES
AVERAGE PERIOD- 14 SECONDS

Figure 8

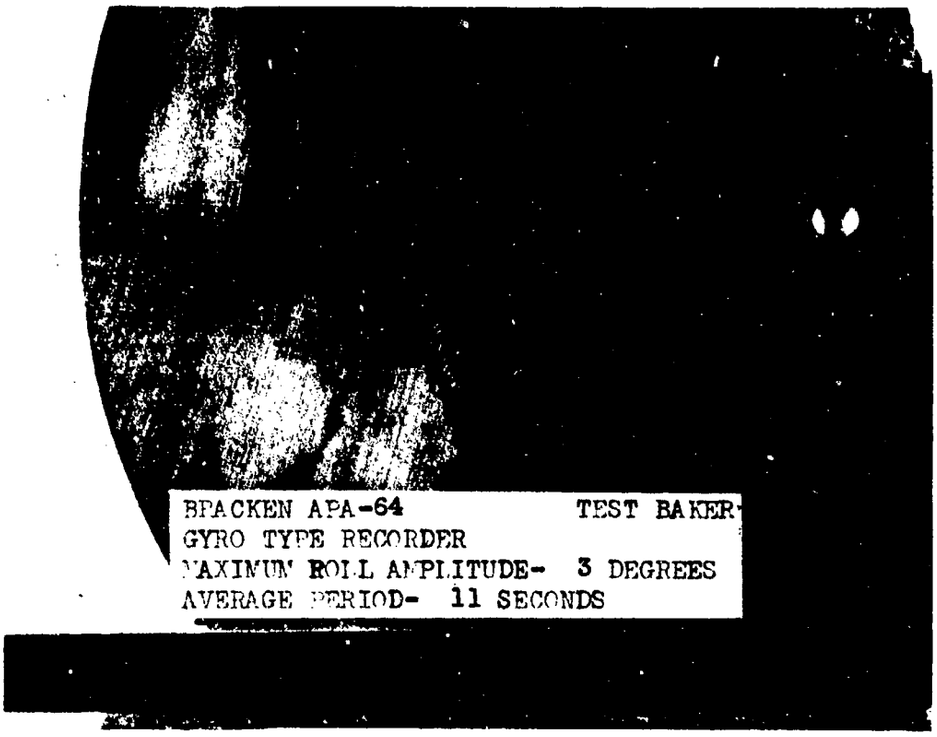

Figure 9

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

TRC

18 April 1997

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

SUBJECT: Declassification of Reports

The Defense Special Weapons Agency has declassified the following reports:

AD-366588	XRD-203-Section 12
AD-366589	XRD-200-Section 9
AD-366590	XRD-204-Section 13
AD-366591	XRD-183
AD-366586	XRD-201-Section 10
AD-367487	XRD-131-Volume 2
AD-367516	XRD-143
AD-367493	XRD-142
AD-801410L	XRD-138
AD-376831L	XRD-83
AD-366759	XRD-80
AD-376830L	XRD-79
AD-376828L	XRD-76
AD-367464	XRD-106
AD-801404L	XRD-105-Volume 1
AD-367459	XRD-100

TRC 18 April 1997

Subject: Declassification of Reports

AD-801406L ✓ XRD-114.

In addition, all of the cited reports are now **approved for public release; distribution statement "A" now applies.**

Ardith Jarrett
ARDITH JARRETT
Chief, Technical Resource Center