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AR Damper Vibration and High Voltage Tests

Research Consulting Associates

C90390

January, 1991

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Introduction:

Mr. Al Richardson of Research Consulting Associates contracted with Southern Electric International/Georgia Power Company Research Center to perform vibration and high voltage tests on AR Mod I, II, and III aeolian vibration dampers and Twister Galloping Preventors.

Corona and radio influence voltage (RIV) analyses were conducted. As-received, the corona and RIV voltages were acceptable for up to 215 kv (124 kv phase-to-ground. Minor modifications to the damper components were made to improve the corona and RIV performance above this level. The data sheets document the corona and RIV voltages on the as-received components. Modifications made, and voltages reached with modified parts are also documented in this report. The voltages recorded on the data sheets are phase-to-ground. To determine the nominal voltage class for a transmission line, the phase-to-ground voltage is multiplied by 1.73 to give the correct phase-to-phase voltage.

Vibration data was obtained based on the inverse standing wave ratio (ISWR), and power methods outlined in IEEE 664 - 1980. In addition, free vibration decay patterns were recorded for comparison to the other two methods. The project requestor retained the raw vibration data for later analysis. The data were not available at the time this report was prepared, and, the data are not included with the report. Analysis of the vibration data is outside the scope of this project.

The object of the testing is to qualify the AR dampers for use on energized transmission lines subject to aeolian vibration or galloping.

Samples and Test

Research Consulting Associates submitted mounting hardware and three interchangeable weights designated Mod. I, Mod II, and Mod III. The project requestor directed the vibration testing. High voltage testing was performed concurrently at the Research Center High Voltage Laboratory.

The Georgia Power Research Center provided personnel, facilities, test conductor, hardware, test equipment, instrumentation, and data acquisition as detailed in this report.

PROCEDURE FOR VIBRATION TESTING

The following test equipment and instrumentation were used during the vibration testing:

Manufacturer	Model #	Serial #	Description, Use, Calibration
Unholtz-Dickie	4	238	Modal Shaker, used to vibrate span
Unholtz-Dickie	TA100AMI-4	265	Power Amplifier, used to drive shaker
Ya-Man	1000	7L015	Non contact displacement measurement system, used for all vibration recordings, calibrated by dial indicator 1/7/91 and 1/8/91
Team	1532	671	Compressor, used for shaker power control
Team	1530	670	Vibration Monitor, used for conditioning and reading Kistler accelerometer, factory calibration 11/88
Team	1536	108	Sweep/dwell function generator, used for shaker frequency control, calibrated 9/90
HBM	U1T-500	398654	Load cell, used to measure force output of shaker, calibrated 4/26/90
Analog Devices/ Research Center	None	None	Load cell amplifier, used to condition load cell, calibrated 1/7/91
Kistler	8604A500	C5667	Quartz accelerometer, used to monitor and record velocity at shaker stinger. Factory calibration 6/29/83
Lebow	3174	608	Load cell, used to measure span tension, calibrated 11/90
Digitec	4041A	35661995	Load cell readout, use to condition and read Lebow load cell, calibrated 11/90

Vibration testing was performed on 1113 KCMIL 45/7 ACSR conductor. Rigid reflecting blocks were clamped on the conductor at each end of the span in accordance with guidelines of IEEE 664-1980. The free length between the reflecting blocks is 20 meters (65.5 ft.) The stinger from the shaker was attached to the span one meter from a reflecting block. The damper was attached to the opposite end of the span two meters from the reflecting block.

To excite the test span to resonance, the shaker system was operated at a fixed power setting. The frequency control was adjusted to provide for maximum displacement of the conductor at an anti-node. Then, the shaker power controls are adjusted to provide the desired anti-node displacement. Fine tuning of the frequency at the desired anti-node displacement is then done to determine the frequency that provides the maximum amplitude. Provided the difference in amplitude is not extreme, the natural frequency at the two different amplitudes is identical. This procedure provides stable standing wave vibration considered to be the natural frequency of the span.

Resonance was calculated based on the mass of the conductor, its length, and tension. Resonance as-found in the span correlated to the calculated value as follows:

# of Loops	Calculated Frequency (Hz)	As-found Frequency (Hz)
1	3.4	Not tested
2	6.8	6.86
3	10.2	10.20
4	13.6	13.63
5	17.0	16.94
6	20.4	20.55
7	23.8	24.16
8	27.2	27.50
9	30.6	31.32
10	34.0	34.87

Correlation of calculated to actual natural frequency provides a cross check of the load cell calibration, and indicates that the test span terminations are performing properly.

Testing was performed at each tunable resonance from 6.8 HZ (2.6 MPH wind speed, 2 active loops), to 34 HZ (13.0 MPH wind, 10 active loops). Figure 1 shows the layout of the test span and the mode shapes associated with natural frequencies generated in the test span.

A digital oscillograph was used to record waveforms from the displacement system, and the velocity and force signal from transducers at the shaker. The optical head of the displacement system is mounted on a track so that measurements can be made at different locations along the span. ISWR and power method measurements were made with steady standing wave vibration in the test span. For ISWR measurements, the node and anti-node nearest to the center of the span were measured. For power method measurements, the stinger force and velocity waveforms, and their phase relationship, were recorded.

Decay testing is only briefly mentioned in IEEE 664, but is, nonetheless, the preferred method at this laboratory. From the steady state vibration established for the ISWR and power methods, a relay is opened to de-energize the shaker. This provides a bump-free transition from forced to free vibration. Damping from the shaker armature is minimized by locating the shaker near the end termination so that its motion, and therefore its effective mass, is minimized. The power dissipation from the span can be determined by analysis of the decay rate. The power dissipation due to the damper on the span is the difference between power loss measured with a damper on the span, and power loss measured with no damper on the same span at the same conditions.

Analysis of raw waveforms to determine power dissipation is far from a simple undertaking, regardless of the method used. Analysis of the vibration data is outside the scope of this contract. The project requestor was provided with oscillograph recordings, and calibration constants for the instrumentation used. It is expected that an analysis of the data will be performed by the project requestor, and reported separately.

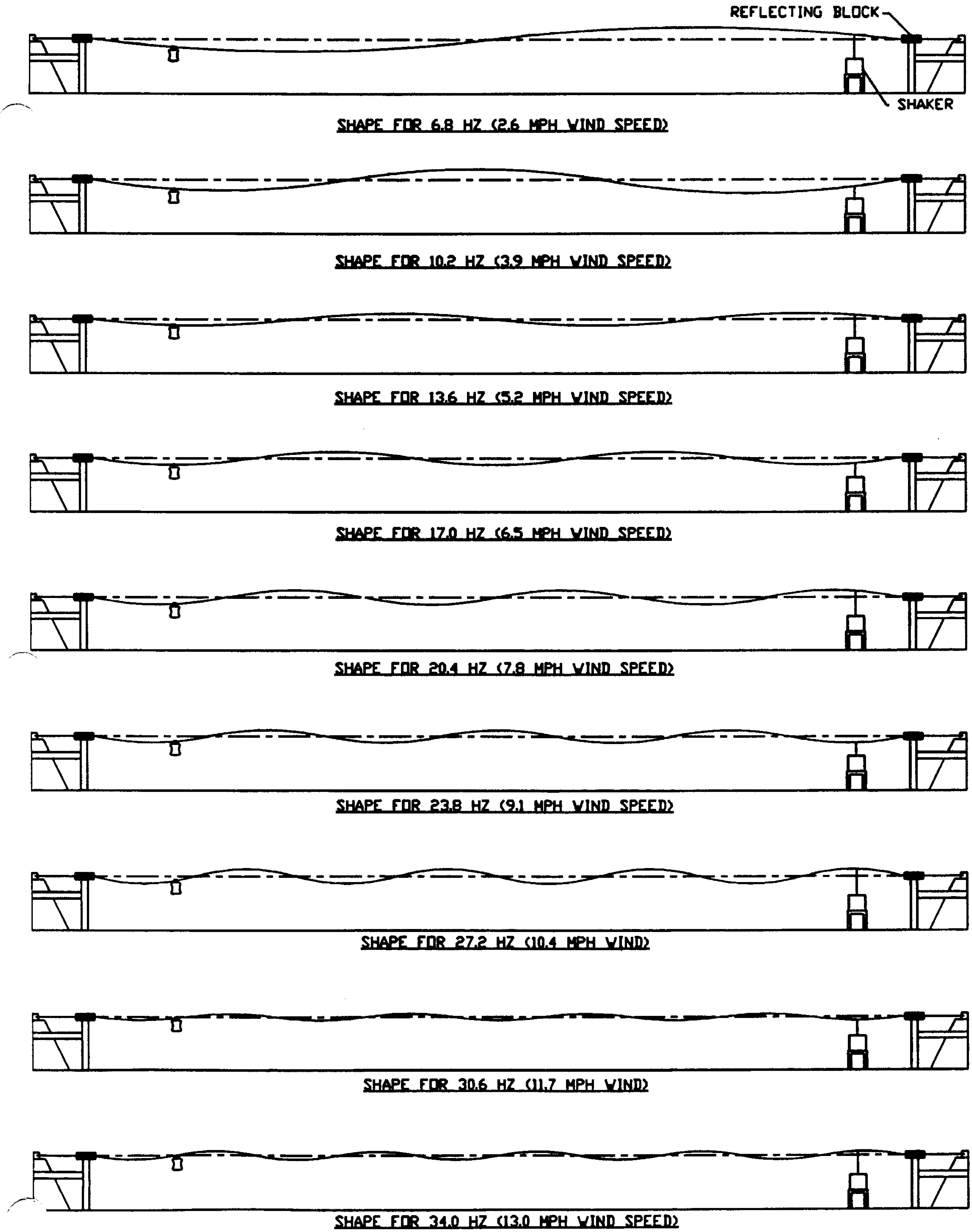

FIGURE 1

VIBRATION SPAN MODE SHAPES FOR DAMPER EVALUATION

PROCEDURE FOR RIV & CORONA TEST

Samples were individually mounted on an energized buss terminated in a corona ring. Corona/RIV was simultaneously recorded on the RIV meter and observed with a light intensifier system.

RESULTS

As received, all samples would be corona free for voltages through 138 kv (line to ground = 80 kv). For 230 kv (line to ground = 133 kv), the aluminum brackets would require modification on both ends as outlined in the report sheets. Corona produced at 345 kv (line to ground = 200kv), would be marginal on sample #4, and not acceptable on #1, #2, #3, or hook.

Two corona rings could* allow for higher corona inception voltages for all samples. Corona nuts are a definite asset for all test and would be required for line voltages above 100 kv.

*Corona/RIV data taken on the corona ring assembly, was for a single ring with no protected sample, and reflect the results of the ring only. The corona location was the area in which the halves were joined and also the outer 4 corners of the tubing bends. An increase in the size of the tubing would be required to raise inception levels.

Additional test were conducted to evaluate corona if the samples were isolated from the conductor by using protective sleeving. The purpose of this sleeve would be the protection of the conductor from mechanical abrasion caused by the damper. An isolation of metallic parts in a high voltage field, causes corona between the parts. The conductor requires electrical bonding to eliminate this corona. Any attempts at using a tension tie wire to the conductor were unsatisfactory. The wire actually produces RIV at much lower voltage levels than the sample. A better method, is the use of conductive sleeving for the protection of the conductor. This method does not change the corona levels as measured without sleeving.

GEORGIA POWER RESEARCH CENTER
High Voltage Laboratory

Date 1-91
Project # C-90390

Engineer B.M.P.

Customer RESEARCH CONSULTING

Test Sample AR TWISTER GALLOPING PREVENTOR SAMPLE #1

Test Description RIV & VISIBLE CORONA

Standards Used NEMA 107

Equipment Required
1- BIDDLE 700KV A.C. PWR SUPPL
2- BIDDLE 700KV A.C. VOLT DIV
3- STODDART NM 25 RIV METER
4- JAVELIN LIGHT INTENSIFIER
5-

Atmospheric Conditions
Station Press.= 750.6 mmHg
Wet Bulb = 56.0 deg.F
Dry Bulb = 71.0 deg.F
Application Standard NONE
Applied this Test N.A.

Requirements: INFORMATION ONLY

Results: INFORMATION ONLY

Conditions:
- All parts as received
- Unit in fixed position/bolt away from weight
- Aluminum brackets unmodified

(test a):
- 124 kv corona inception voltage. RIV was intermittently exceeding 500 microvolts due to discharges originating from the exposed parts of the aluminum brackets below the weight

(test b):
- Removed approx 7/8" from the aluminum brackets (2), thus allowing bracket ends to remain within the confines of the weight
- Corona inception was raised to 151 kv with RIV reading <10 microvolts at 150 kv but exceeding 1000 microvolts at 151kv
- Corona was now located on the opposite end of the bracket as it extended beyond the corona nuts.

(test c):
- Unit was changed to moveable position/bolt towards weight
- Bracket ends shortened by 7/8"
- 164 kv corona inception voltage. RIV >1000 microvolts
- Corona location on bracket corners as they extended beyond the corona nuts.

(test d):
- Bracket corners radiused approx 1/4" and edges on of the radiused area were rounded and smoothed.
- Corona inception was raised to 196 kv, RIV being less than 10 microvolts below this level and exceeding 1000 microvolts above this level.

(test e):
-Unit changed back to fixed position/bolt away from weight
-Both ends of aluminum bracket modified
-Corona inception @ 201 kv.

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Test Sample AR TWISTER GALLOPING PREVENTOR SAMPLE #2

Test Description RIV & VISIBLE CORONA

Standards Used NEMA 107

Equipment Required
1- BIDDLE 700KV A.C. PWR SUPPL
2- BIDDLE 700KV A.C. VOLT DIV
3- STODDART NM 25 RIV METER
4- JAVELIN LIGHT INTENSIFIER
5-

Atmospheric Conditions
Station Press.= 750.6 mmHg
Wet Bulb = 56.0 deg.F
Dry Bulb = 71.0 deg.F
Application Standard NONE
Applied this Test N.A.

Requirements: INFORMATION ONLY

Results: INFORMATION ONLY

Conditions:
- Unit in fixed position/bolt away from weight
- Aluminum brackets modified

(test a):
- 214 kv = RIV of 50 microvolts
- 216 kv = RIV of 2000 microvolts, Corona source was top of casting which attaches to the conductor.

(test b):
- A "Duxseal" corona ring of about 1/2" was added across the top of the bracket to simulate a redesign of the bracket to incorporate a corona ring at this point
- Corona inception was raised to 239 kv with RIV reading 85 microvolts.

(test c):
- Unit was changed to moveable position/bolt towards weight
- Duxseal removed from mtg. brackets
- 209 kv corona inception voltage. RIV >1000 microvolts
- Corona location on mtg brackets with slight glows located on the outer corners of the weights

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Test Sample AR TWISTER GALLOPING PREVENTOR SAMPLE #3

Test Description RIV & VISIBLE CORONA

Standards Used NEMA 107

Equipment Required
1- BIDDLE 700KV A.C. PWR SUPPL
2- BIDDLE 700KV A.C. VOLT DIV
3- STODDART NM 25 RIV METER
4- JAVELIN LIGHT INTENSIFIER
5-

Atmospheric Conditions
Station Press.= 742.8 mmHg
Wet Bulb = 63.5 deg.F
Dry Bulb = 74.0 deg.F
Application Standard NONE
Applied this Test N.A.

Requirements: INFORMATION ONLY

Results: INFORMATION ONLY

Conditions:
- Unit in fixed position/bolt away from weight
- Aluminum brackets modified

(test a):
- 213 kv = RIV of 100 microvolts
- 214 kv = RIV of 1000 microvolts, Corona source was bottom of weight.

(test b):
- Unit was changed to moveable position/bolt towards weight
- 204 kv = RIV of 100 microvolts
- 206 kv = RIV of 1000+ microvolts, Corona source was bottom of weight.

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Test Sample AR TWISTER GALLOPING PREVENTOR SAMPLE #4

Test Description RIV & VISIBLE CORONA

Standards Used NEMA 107

Equipment Required
1- BIDDLE 700KV A.C. PWR SUPPL
2- BIDDLE 700KV A.C. VOLT DIV
3- STODDART NM 25 RIV METER
4- JAVELIN LIGHT INTENSIFIER
5-

Atmospheric Conditions
Station Press.=______mmHg
Wet Bulb =______deg.F
Dry Bulb =______deg.F
Application Standard NONE
Applied this Test N.A.

Requirements: INFORMATION ONLY

Results: INFORMATION ONLY

Conditions:
- Unit in fixed position/bolt away from weight
- Aluminum brackets modified

(test a):
- 200 kv = RIV of 45 microvolts
- 220 kv = RIV of 100 microvolts
- 222 kv = RIV of 1000 microvolts, spitting intermittent from lower edge of weight

(test b):
- Unit was changed to moveable position (bolt towards weight)
- 200 kv = RIV of <10 microvolts
- 219 kv = RIV of 400 microvolts (intermittent), ambient RIV was 150 microvolts. Source was both top of brackets and lower part of weight.

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Test Sample AR TWISTER GALLOPING PREVENTOR SAMPLE #5 Hook

Test Description RIV & VISIBLE CORONA

Standards Used NEMA 107

Equipment Required
1- BIDDLE 700KV A.C. PWR SUPPL
2- BIDDLE 700KV A.C. VOLT DIV
3- STODDART NM 25 RIV METER
4- JAVELIN LIGHT INTENSIFIER
5-

Atmospheric Conditions
Station Press.=_______mmHg
Wet Bulb =_______deg.F
Dry Bulb =_______deg.F
Application Standard NONE
Applied this Test N.A.

Requirements: INFORMATION ONLY

Results: INFORMATION ONLY

Conditions: - Unit as received

(test a):
- No corona nuts
- 184 kv = RIV of <10 microvolts extinction
- 188 kv = RIV of >1000 microvolts inception (top of brkt)

(test b):
- Added corona nuts
- 201 kv = RIV of <10 microvolts extinction
- 205 kv = RIV of >1000 microvolts inception

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Test Sample AR TWISTER GALLOPING PREVENTOR SAMPLE #6 Corona Ring

Test Description RIV & VISIBLE CORONA

Standards Used NEMA 107

Equipment Required
1- BIDDLE 700KV A.C. PWR SUPPL
2- BIDDLE 700KV A.C. VOLT DIV
3- STODDART NM 25 RIV METER
4- JAVELIN LIGHT INTENSIFIER
5-

Atmospheric Conditions
Station Press.=______mmHg
Wet Bulb =______deg.F
Dry Bulb =______deg.F
Application Standard NONE
Applied this Test N.A.

Requirements: INFORMATION ONLY

Results: INFORMATION ONLY

Conditions:
- Unit as received
- No corona nuts required

(test a):
- 232 kv = RIV of <10 microvolts extinction
- 241 kv = RIV of 220 microvolts inception
- 245 kv = RIV of 400 microvolts
- 250 kv = RIV of 500 microvolts

- Corona Source was outer edges of Corona Ring & where two halves are joined together

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Customer RESEARCH CONSULTING

Test Sample AR TWISTER GALLOPING PREVENTOR SAMPLE #1 & #2

Test Description RIV DURING OPERATION

Standards Used NEMA 107

Equipment Required
1- BIDDLE 700KV A.C. PWR SUPPL
2- BIDDLE 700KV A.C. VOLT DIV
3- STODDART NM 25 RIV METER
4- JAVELIN LIGHT INTENSIFIER
5-

Atmospheric Conditions
Station Press.=______mmHg
Wet Bulb =______deg.F
Dry Bulb =______deg.F
Application Standard NONE
Applied this Test N.A.

Requirements: INFORMATION ONLY

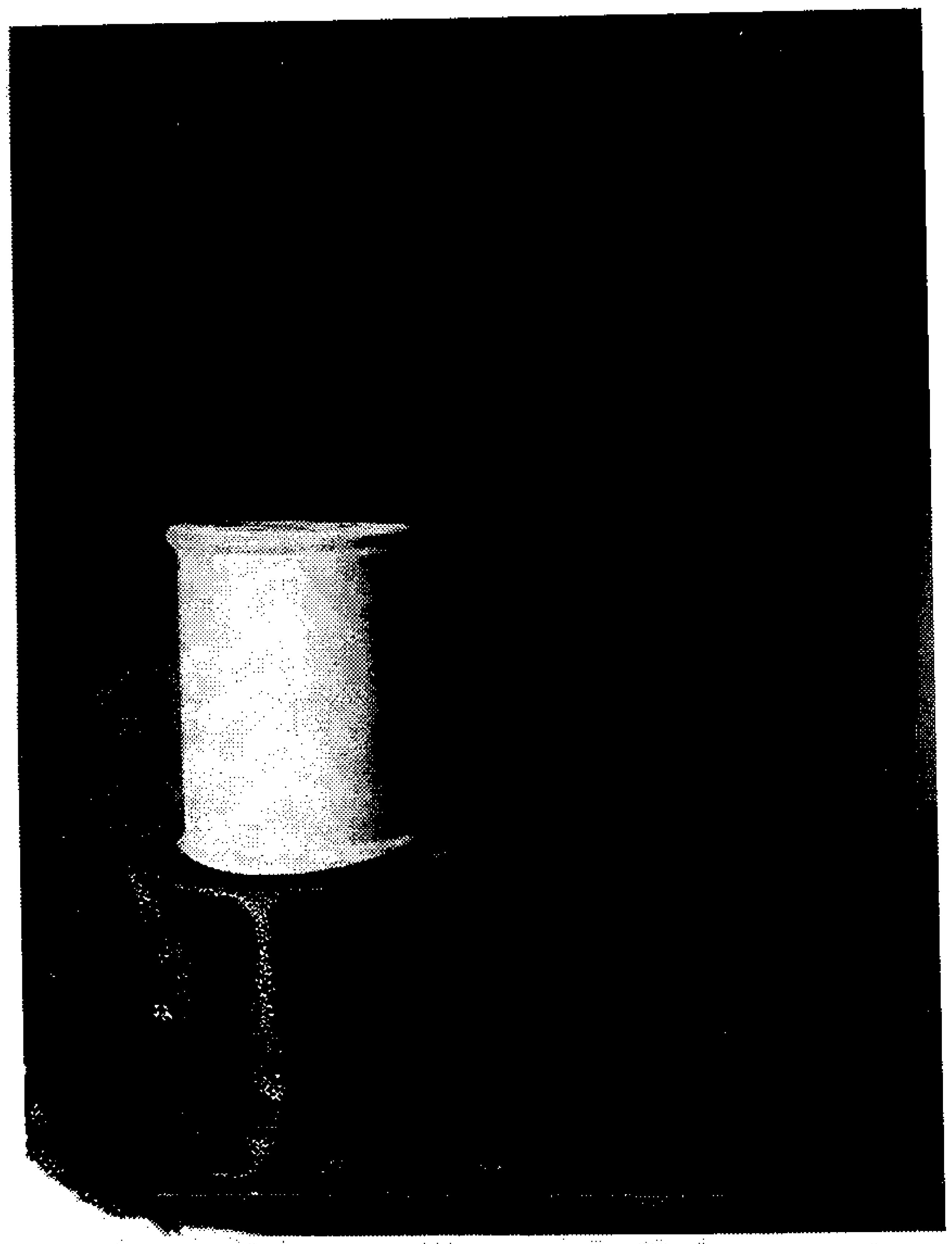
Results: INFORMATION ONLY

Conditions: - Both units mounted using modified brackets

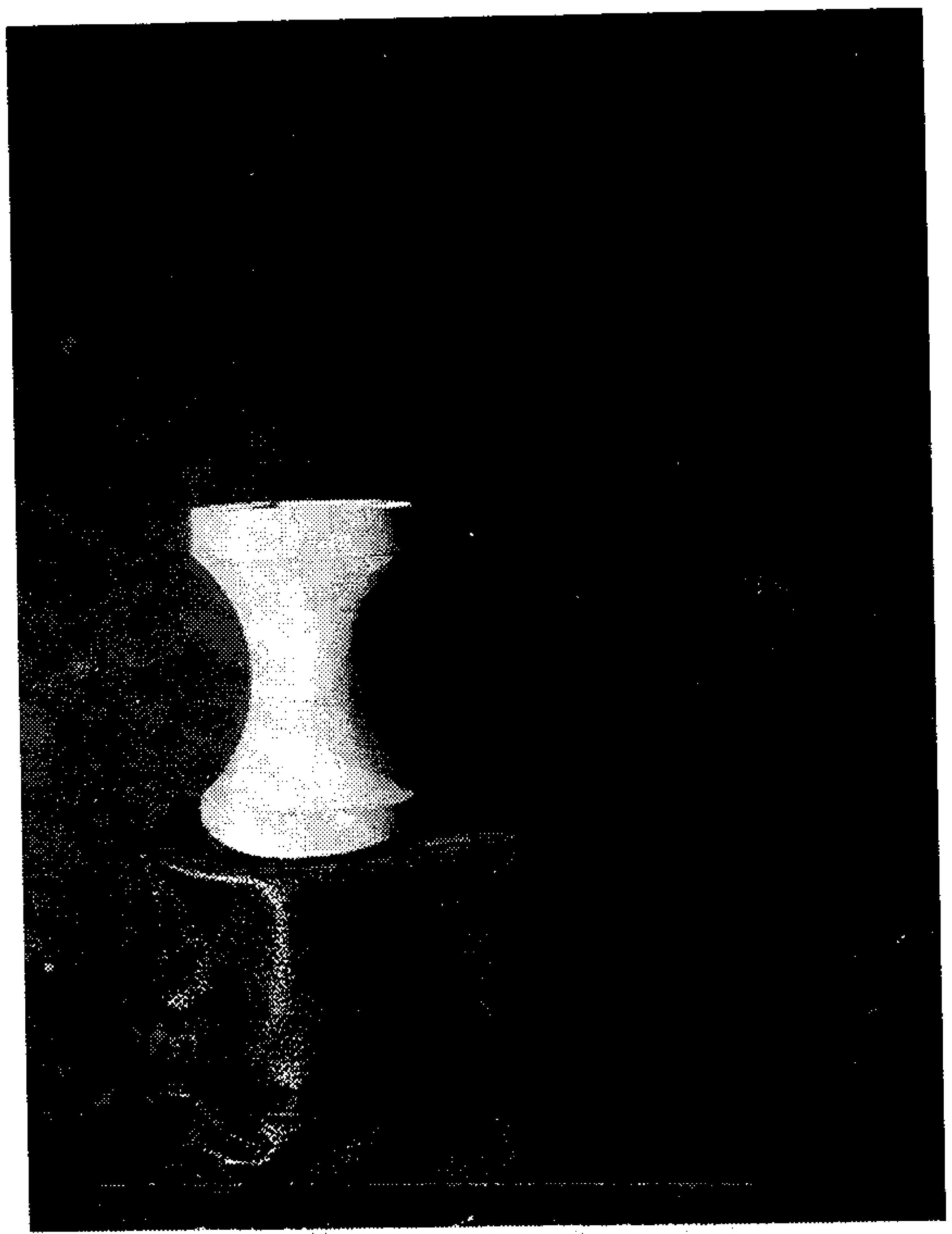
(test a): - Sample #1 were configured on the high voltage buss and several ropes were attached to allow the weight to be moved up and down with varying frequency on the mounting brackets. Also side to side motion was employed. The purpose was to simulate mechanical activity similar to what would be expected during "damping" action of the unit.

- The buss voltage was raised to 150 kv, and the RIV meter was observed during movements of the dampener. No evidence occurred that the mechanical action created any Radio Influence Voltages.

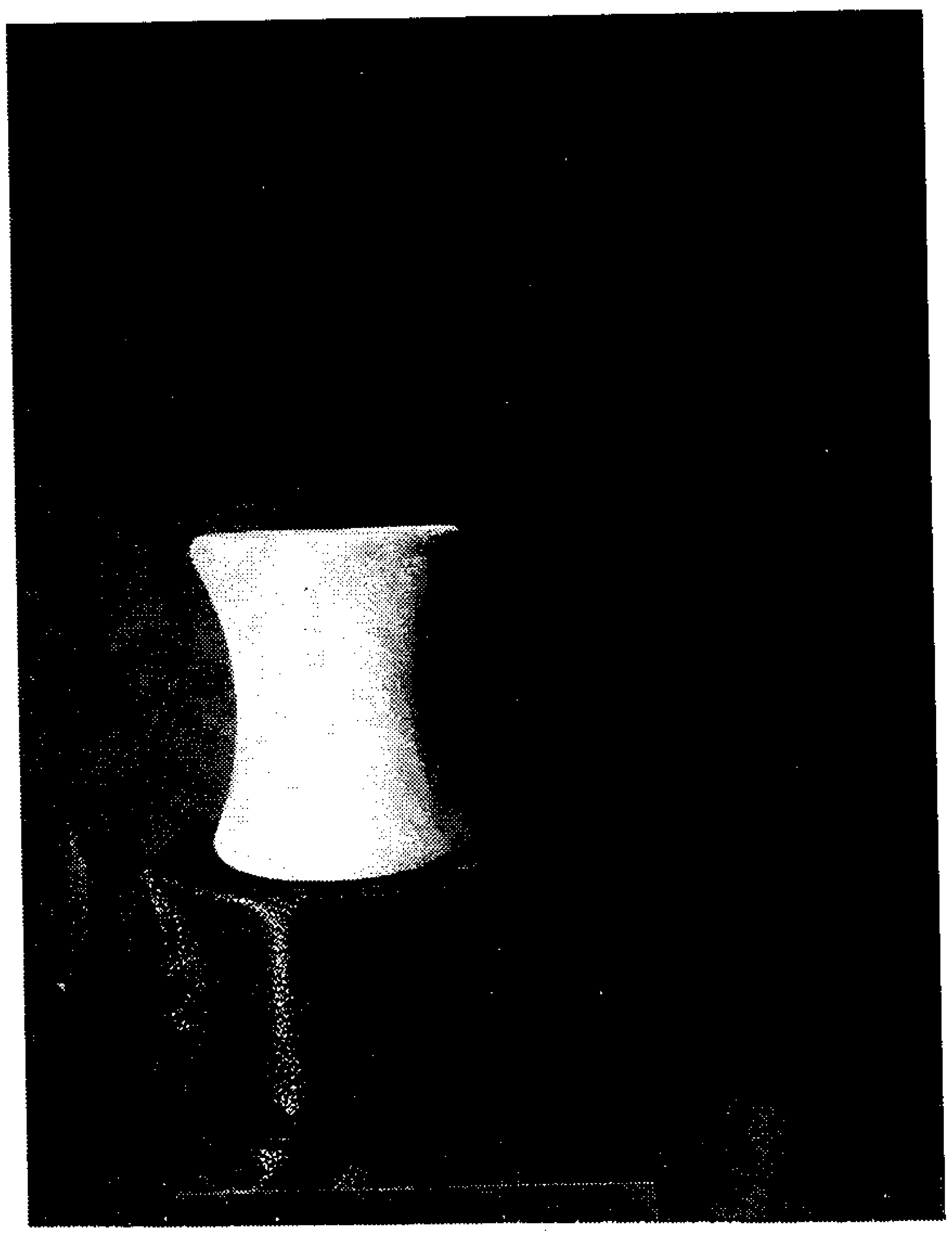
(test b): - Sample #2 was tested in a like manner to sample #1, with the same results.



SAMPLE #1



SAMPLE #2



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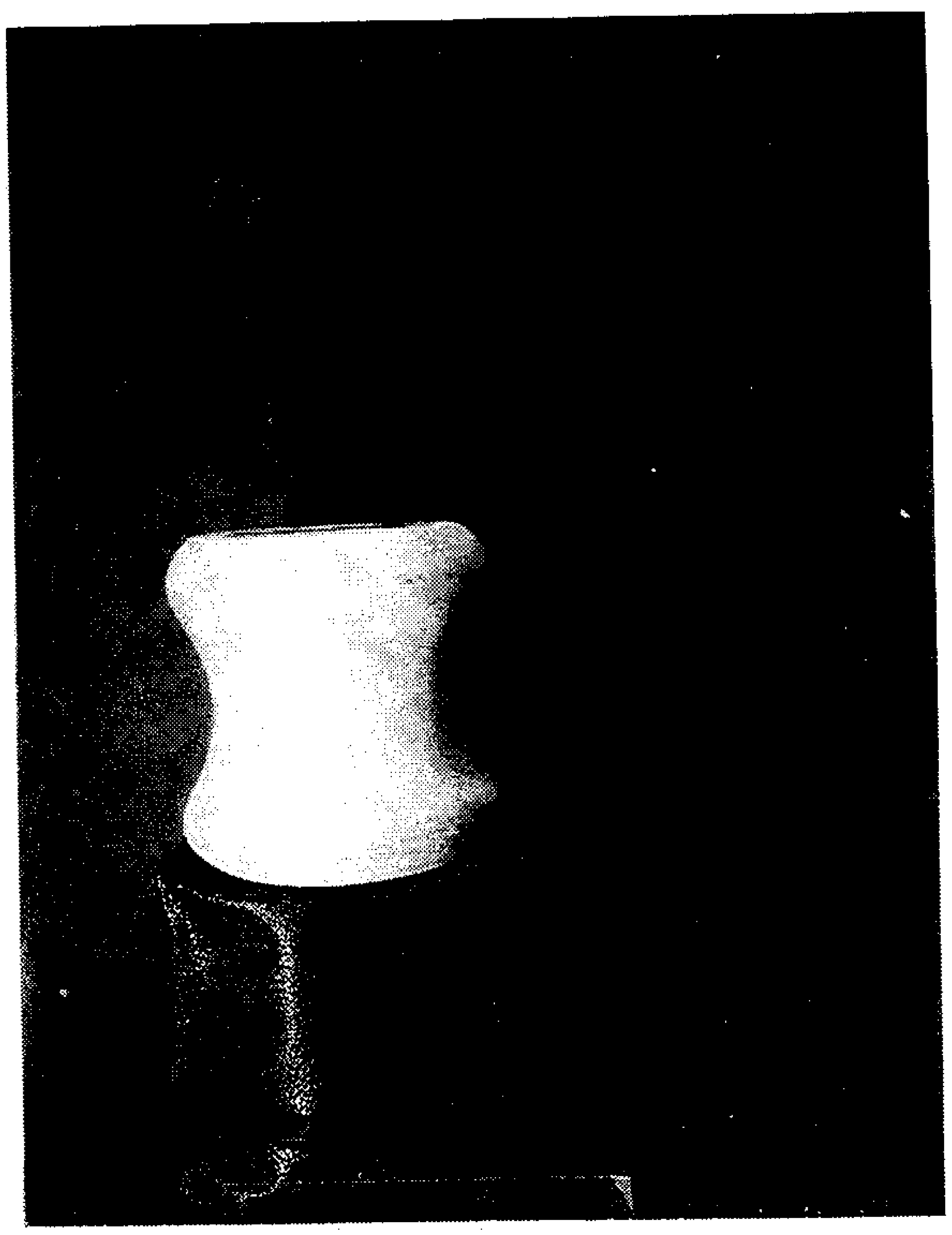

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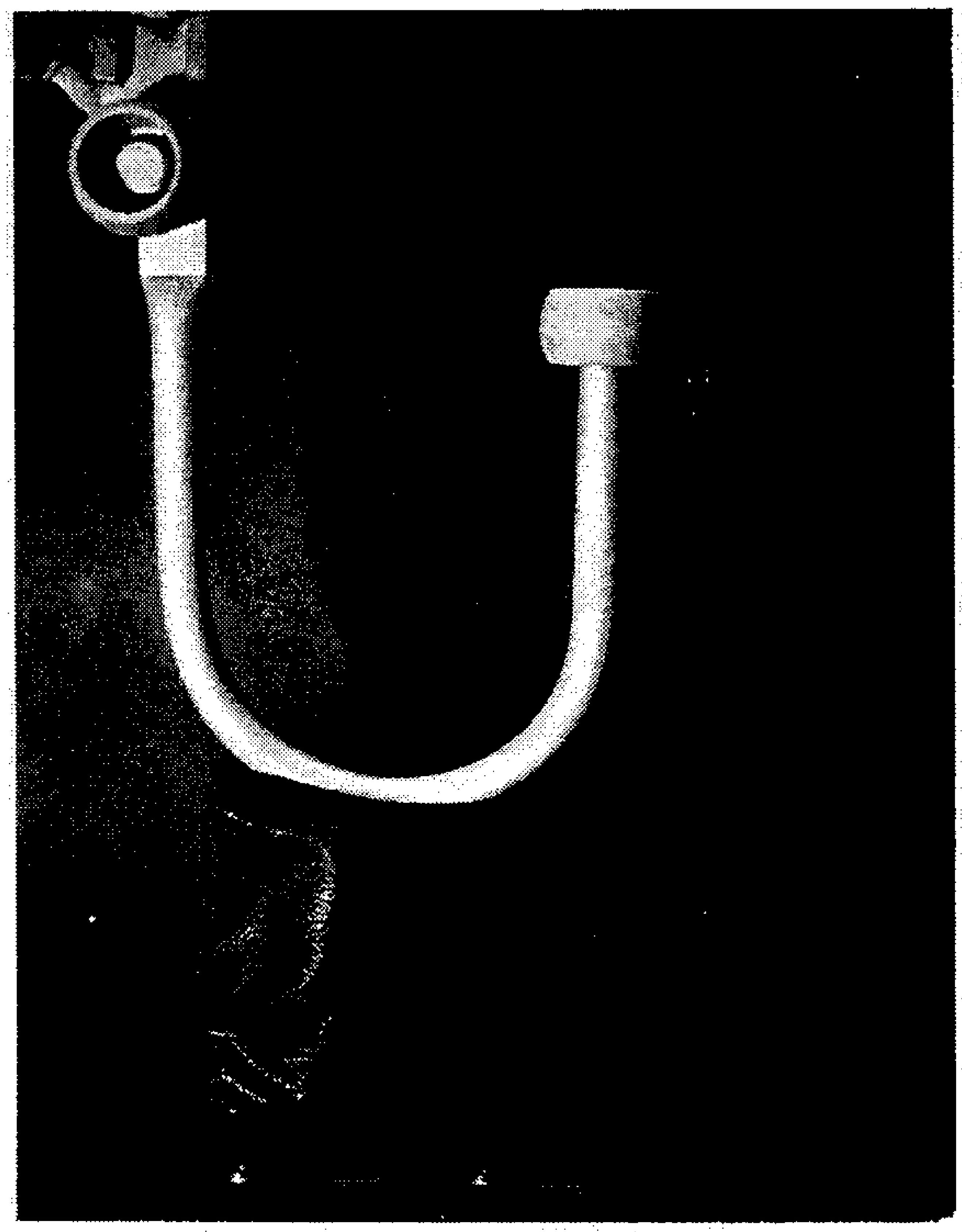
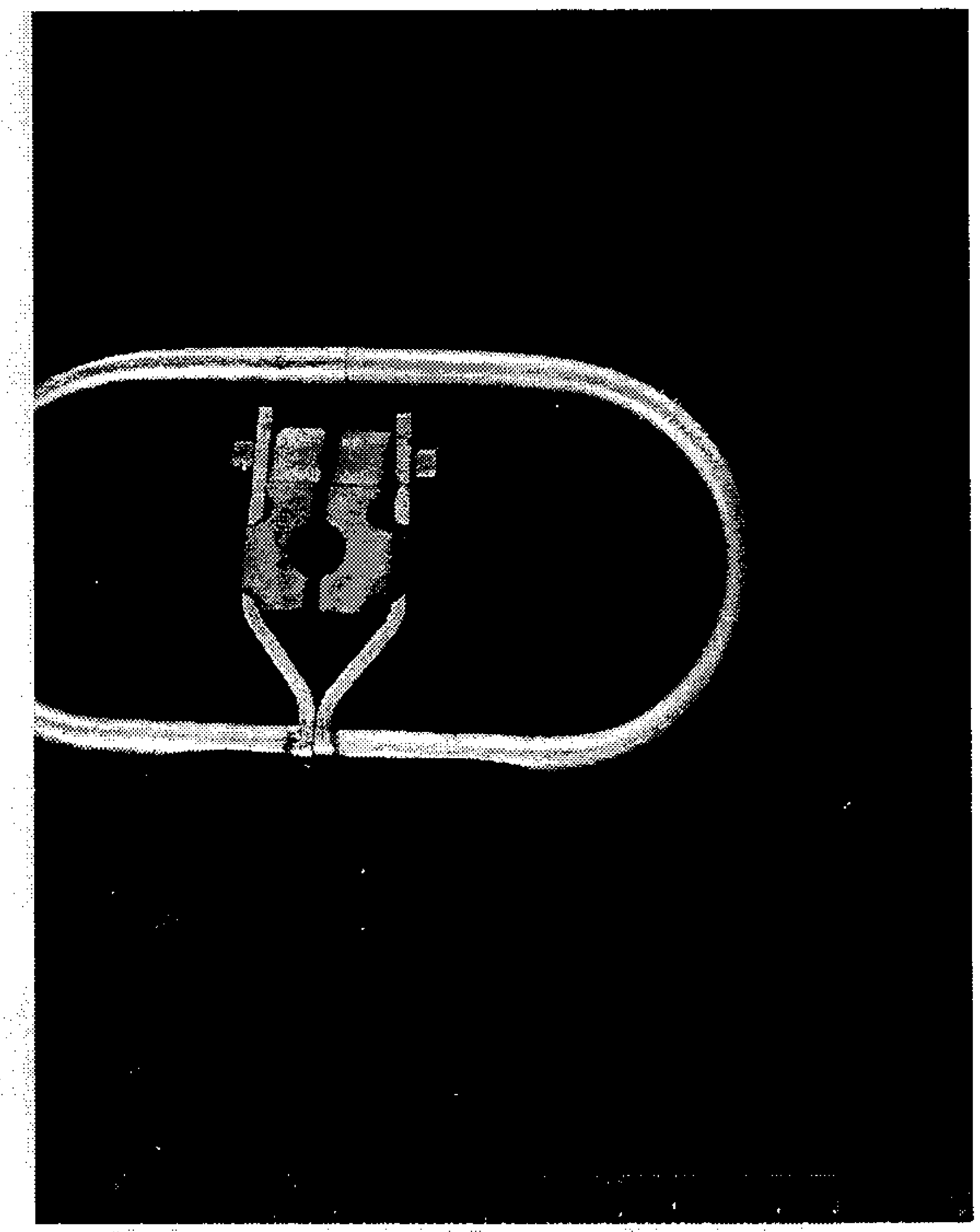
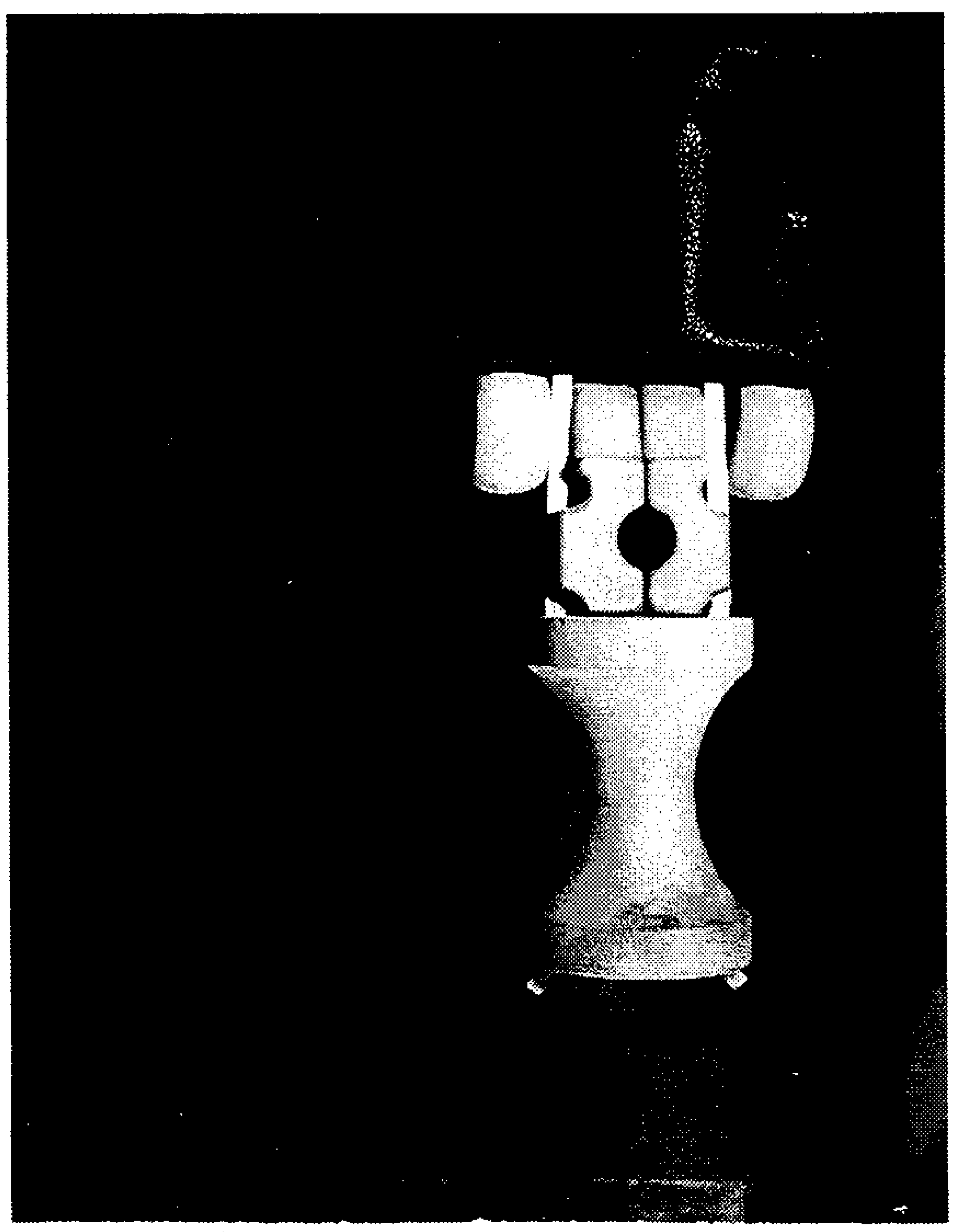


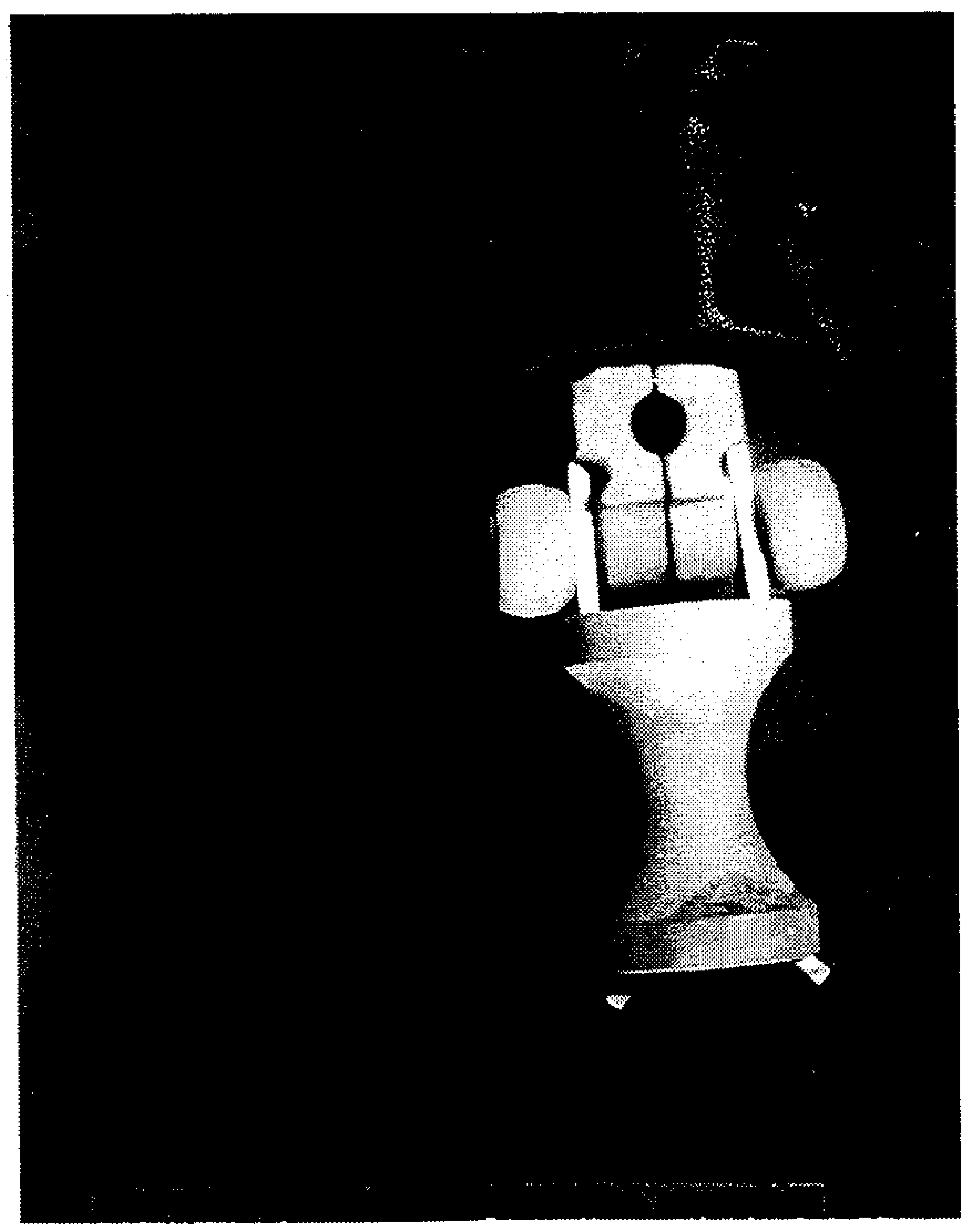
HOOK



CORONA RING



FIXED POSITION



MOVEABLE POSITION