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SUMMARY

During this period, the moving bump system for simulating a gust has been fabricated, installed, and check-out tests have been run. The theoretical analysis is completed. Design of the venetian-blind gust generator is completed and fabrication is in process. A major part of the hot-wire and lift-measuring instrumentation is completed.

The report has been divided into 5 sections, which are:

I. Bump System

II. Vortex Generator

III. Sink Method of Gust Generation

IV. Literature Survey

V. Work Planned for Next Period

I. BUMP SYSTEM

The first system which will undergo testing is that of a moving bump. In this system a movable bump is located downstream of the model. When the bump is moved, a nonuniform flow field sweeps across the model, thereby simulating the flight of an aircraft through a gust.

A. Bump Analysis

As currently understood, the loads on a wing in a rapidly changing flow field differ from the instantaneous steady-state values because of apparent mass and wake effects. Calling $L_Q'(t)$ the steady-state lift corresponding to the instantaneous position of the bump and $L'(t)$ the true dynamic lift, it is clear that the pertinent quantity to measure is the lift lag $L'(t) - L_Q'(t)$, and that this must be large compared to the dynamic error and sensitivity limits of the instrumentation.

The flow pattern about a test model as the bump moves downstream has been computed. From this information and nonstationary wing theory, the lift lag has been calculated as a function of bump travel (gust penetration). The ratio of bump speed to tunnel speed appears as an important parameter in the analysis. Theoretical consideration has also been given to the separation of apparent mass and wake effects and to the tunnel-wall interference effect. These calculations are the basis for the following design recommendations:

Bump Size	7 inches high
Tunnel Speed	30 feet/second
$\frac{\text{Bump Speed}}{\text{Tunnel Speed}}$	0.1
Model Size	6-inch chord

B. Description of Bump System

A description of the tunnel and operating mechanism of the bump follows:

1. Test Section. A cut-away sketch of the test section is shown in Fig. 1. Figures 2a and 2b are photographs of the test section with and without its side panels. As shown in these sketches and photographs, the side walls are made in three interchangeable sections, allowing the window section to be placed in any region of the tunnel.

The inside dimensions of this section are:

Width 29-3/4 inches

Height 21-1/8 inches

Length 104-1/4 inches

The tunnel was constructed as follows: A box frame made of angle iron is used at the inlet and exit of the test section to form the basic structure. Top and bottom walls, made of 3/4-inch plywood, are attached directly to this frame. At the edges of the outer surfaces of the top and bottom floors, a heavy angle rim is attached along the length of the tunnel. This angle iron both increases the rigidity of the structure and serves as an attachment face for the side panels.

Two of the three panels on each side of the test section are solid and made of 3/4-inch plywood. The remaining panel is built from 5 by 1-1/2-inch lumber and has a window 17-1/2 inches high, and 23-1/4 inches long. All the panels are quickly removed by the use of a few wing nuts.

In order to operate the moving-bump system from the outside, a slot 5/8-inch wide is cut along the floor centerline from the exit to a station 24-1/4 inches from the inlet. The bump moves along aluminum tracks that are bolted to the tunnel floor.

2. Bump and Operating Mechanism. The aerodynamic contour of the bump is shown in Figs. 3a and 3b. The bump is fabricated from sheet aluminum and is built in such a manner that its contour can be changed easily. Small ball bearings serve as wheels and also serve to prevent the bump from yawing.

The mechanism used to operate the bump is illustrated in Fig. 4. The accelerating force that moves the bump is obtained by winding a 3/16-inch-diameter shock chord about a drum until the proper tension is obtained as indicated by a counter geared to the drum shaft. As the bump nears the end of its travel it is decelerated by allowing the bump to actuate a piston in an air cylinder that has a small bleed orifice. The piston diameter is 1-1/2 inches and a stroke of 6 inches is generally used.

To measure the position of the bump, a 10-turn micropotentiometer is used. The potentiometer has a drum about which a chord is wound, the other end of the chord being attached to the bump. A clock spring is used to keep this chord taut at all times.

In operation, the shock-chord tension is released by means of a ratchet on the drum and the bump is drawn forward until the catch is engaged. The chord is then wound about the drum until the proper tension, as indicated by the counter, is obtained. When the catch is released, the bump travels in the downstream direction and at the end of its travel the shock-absorber piston absorbs its energy.

C. Tests to Date

To date the following tests, preliminary to testing the system as a gust tunnel, have been made:

1. Velocity Survey. A velocity survey of the tunnel with the bump removed and the floor slot open to the atmosphere is in process. Figures 5a and 5b are respectively a sketch and a photograph of the pressure rake being used. This rake has 6 total-head probes and 3 static probes. Pressures are registered on an inclined multiple monometer board using water as the measuring fluid.

The analysis and interpretation of the data for these tests has not been completed at the time of this writing.

2. Bump Flow Separation Tests. In order to check whether or not flow separation occurs over the bump surface, tufts were cemented on the bump; they can be seen in Fig. 3b. Only a slight local separation was observed in the downstream corners next to the tunnel walls. Observations were then made of the tuft behavior while the bump was in motion; no noticeable difference was seen.

3. Bump Velocity and Repeatability Tests. The mechanical action of the bump is described in Part B. The instrumentation used to obtain the bump displacement history is as follows:

The position of the bump is determined by operating a 10-turn micropotentiometer through a range of approximately 8-1/2 turns. The output voltage is fed to the Y input of a scope and d-c attenuation is used to limit the scope deflection to a reasonable value. A hook-up sketch is shown in Fig.

In order to obtain a single trace, the scope is used in the driven sweep mode with external synchronization. The sweep is triggered by means of a microswitch which in turn is triggered by the bump after it has traveled 1-1/2 inches from the release mechanism. A sweep period of about 0.7 to 1.0 second is used.

To obtain time markings on the trace, z-axis modulation is used. A sine-wave oscillator set at a frequency of 50 cps is used with a voltage output sufficiently large to blank out the trace during a portion of the negative cycle of the oscillator.

The oscilloscope used is a dual-beam Du Mont type 322. One beam of the scope is used to record the bump position and time pulse. The other beam, driven by the same sweep, records the hot-wire data or force-balance measurements.

Records of the oscilloscope trace are obtained by using a Du Mont type 297 oscilloscope camera. This camera uses Polaroid-Land film and is very convenient for this application.

In Figs. 7a and 7b are shown oscillograms of the bump-displacement history. Tabulated below are pertinent data regarding these oscillograms

	Fig. 7a	Fig. 7b
Time pulse	50 cps	50 cps
Vertical Scope Displacement vs Bump Displacement	5-1/2 units on scope = 10-inch bump travel	5-1/2 units on scope = 10-inch bump travel
Observed bump speed	6.8 ft/sec	7.0 ft/sec
Tunnel speed	50 ft/sec	67 ft/sec
Shock-chord drum turns	3	3

In Figs. 7a and 7b the trace starts at the left and proceeds to the right. The distance the bump has traveled downstream is indicated by the vertical distance above the origin. In Fig. 7a it will be noticed that the trace also covers a portion of the deceleration period and that the body actually travels forward after being stopped by the shock cylinder. This forward travel is largely due to the tension of the potentiometer cable drawing the bump upstream. In Fig. 7b the x-axis is expanded to such an extent that this portion of the trace is not recorded in the scope face.

D. Test Methods to be Used

Two methods will be used to check the gust-generating ability of the moving bump. The methods have not been tested as yet; however, a major portion of the work preliminary to their use has been completed and is described below:

1. Hot-Wire Method. In order to determine the flow direction, an "X" hot-wire arrangement will be used in the tunnel. An electronic switch will be used to switch from one wire to the other in order that both may be recorded on the same scope channel. Either the Thiele-Wright or the Bureau of Standards type of hot-wire anemometer will be used.

A photograph of an "X" probe is shown in Fig. 8a and the Thiele-Wright hot-wire equipment and scope are shown in Fig. 8b.

2. Force Measurements. The second method of determining the effectiveness of this type of gust generator involves measuring the transient lift force and comparing it with the steady lift.

An airfoil of 6-inch chord and 12-inch span will be used. The forces will be registered by means of a balance system attached to each end of the airfoil span. Photographs of the balance system are shown in Figs. 9a and 9b.

The force-sensing unit is a Schaevitz Linear Deflection Transformer with its core attached to the end of a bent cantilever beam which supports the model. To operate this transformer, a unit manufactured by Industrial Electronics, Inc., called "Dyna-Myke", will be used. It consists of an oscillator, amplifier, and detector. The a-c signal of the oscillator is modulated by the lift force and then amplified and detected by the Dyna-Myke. The output of the Dyna-Myke thus follows the lift history and is fed to the oscilloscope.

Bench tests of this balance system are in process.

II. VORTEX GENERATOR

The design of the vortex generator has been completed and the generator is being fabricated. Figure 10 is an operational sketch.

The operation of the unit is as follows: a series of full spanning airfoils are placed across the tunnel from top to bottom. Initially the airfoils are at zero angle of attack. By the simultaneous deflection of the airfoils to a given angle and immediate return to neutral, vortices are introduced into the tunnel stream. The flow discontinuity is carried with the stream past the model and simulates a gust.

Mechanically the system will operate in the following manner: (reference should be made to Fig. 10).

The airfoils are attached to shafts similar to that of A, and a small arm B extends from this shaft. Two links, C and D, connect arm B to pivot point E. As the links C and D are drawn from position 1 to position 2, the airfoil rotates from zero to the maximum angle and back to zero again. A piano wire drawn by spring F is used to draw the links from position 1 through to position 2. Cam H is used to control the cycle rate of the airfoil and is pulled through its range by spring I.

III. SINK METHOD OF GUST GENERATION

Consideration has been given to the use of a moving sink as a gust generator. Preliminary calculations indicate that a volume flow of 20 cubic feet per second per foot of tunnel width would be required to produce a measurable gust.

One possible configuration which might be used to test this technique is shown in Fig. 11 and would operate as follows:

The source is provided by evacuating tank I and keeping it pumped below the critical pressure. By drawing plug F out of its seat E, air can be made to flow into the vacuum tank and the distance plug F is withdrawn controls the mass flow rate. Cam G controls the plug motion and is driven by a rack-and-pinion gear arrangement.

The position of the sink in the tunnel is established by removing the center portion of the tunnel ceiling and using a properly supported curtain in its place. This curtain acts in the same manner that a focal-plane camera shutter operates. That is, it has a slit across its width and is drawn from roller B across the tunnel opening and onto roller A. Curtain motion and valve operation are tied together through the use of gearing and a single motor.

It should be remembered that the description given above is of only one possible configuration.

IV. LITERATURE SURVEY

The end point of gust studies is the determination of airplane response to gusty air, and the gust-generation device is being designed with this in mind. The pertinent factors are (1) nature of atmospheric gust structure, (2) air loads on an aircraft developed by motion through nonuniform air and, (3) dynamic response of the aircraft to unsteady loads. A survey of the literature that treats these factors has been made and a representative list of papers has been compiled.

Though a number of experiments have been performed to determine atmospheric gust structure and the nature of nonstationary aerodynamic effects, little has been reported on the actual simulation of an airplane penetrating a gust. The Langley Gust Tunnel permits scaled models to be launched horizontally into a vertical jet that has a controllable velocity profile. The aircraft response is observed directly from moving pictures. Kueth's experiments yielded the circulation build up on a model wing that is passed through a vertical jet of known profile. In each case the gust progresses over the wing in a manner simulating the flight of an airplane through gusty air.

Other experimentation, specifically that of Halfman, Bratt and Scruton, Farren, Walker, Silversteen and Joyner, and Reid and Vincenti is concerned with the experimental verification of nonstationary aerodynamics. Their methods involve starting a model from rest or oscillating a model in a uniform stream.

Evidently there is a need for an experimental facility that will permit the detailed measurement of (1) nonstationary airloads on wings of arbitrary planiform and (2) the aeroelastic response of wing of complicated planiform and structure. To meet these ends, the gust-simulating system is being designed with the model stationary in order to facilitate taking data. Other considerations affecting the design of the gust generator are described in Section IA.

V. WORK PLANNED FOR NEXT PERIOD

In the next period it is expected that the following will be accomplished:

1. Tests will be run on the moving bump. Hot-wire and balance data will be obtained.

2. The vortex generator will be placed in operation and data on its practicality as a gust generator will be obtained.

3. An evaluation of the effectiveness of the above two systems should be completed.

4. Detailed design of a sink-type gust generator and its fabrication will be started if evaluation of the other two methods indicates its desirability.

5. If sufficient results are available, a conference with Air Force representatives will be requested for the purpose of obtaining authorization to proceed with the design and construction of gust generation on a larger scale. The purpose of the larger-scale would be to obtain gust simulation tests at Reynolds numbers permitting extrapolation to flight conditions.

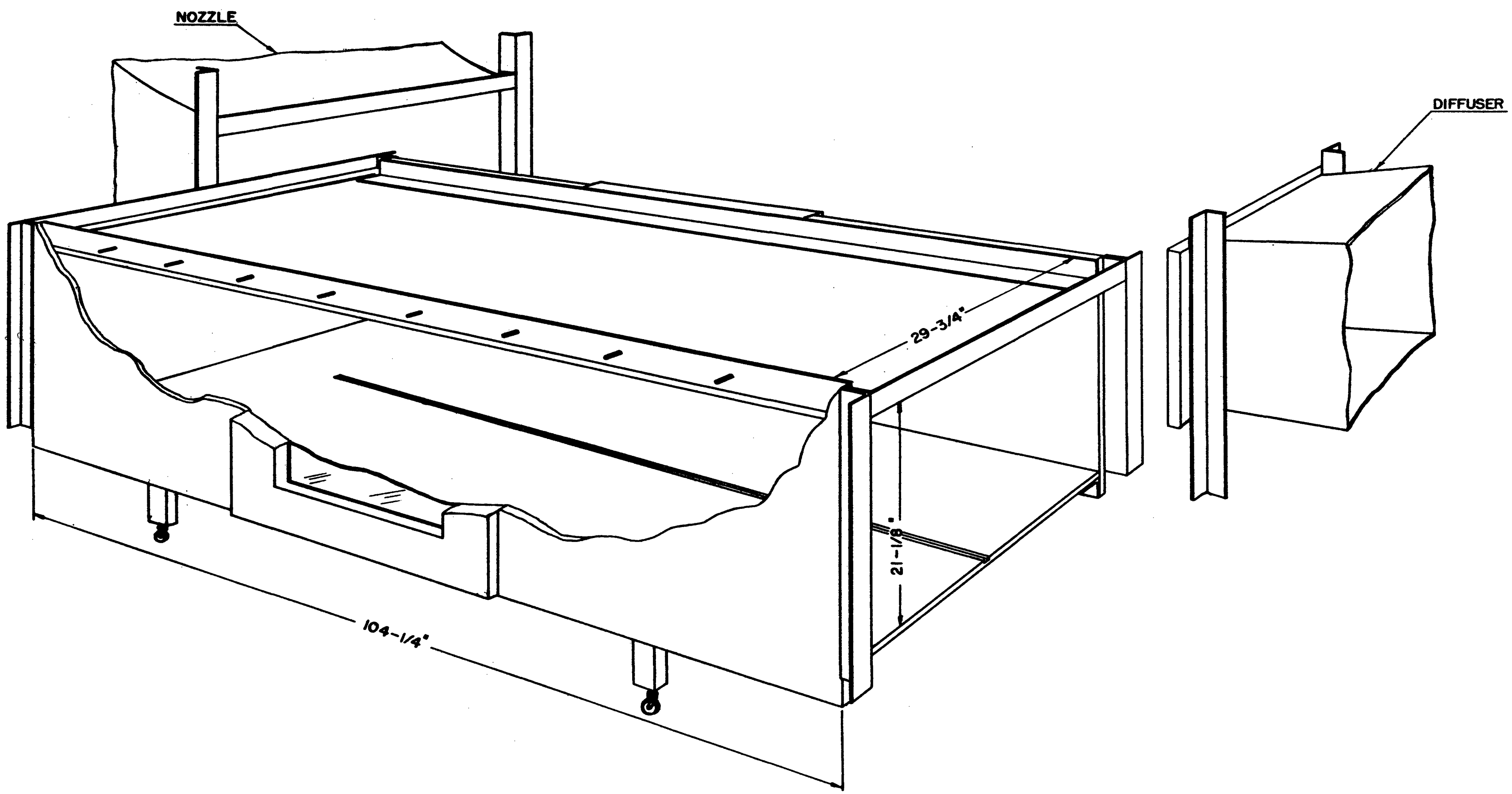

FIG. I
CUT AWAY SKETCH OF TUNNEL TEST SECTION

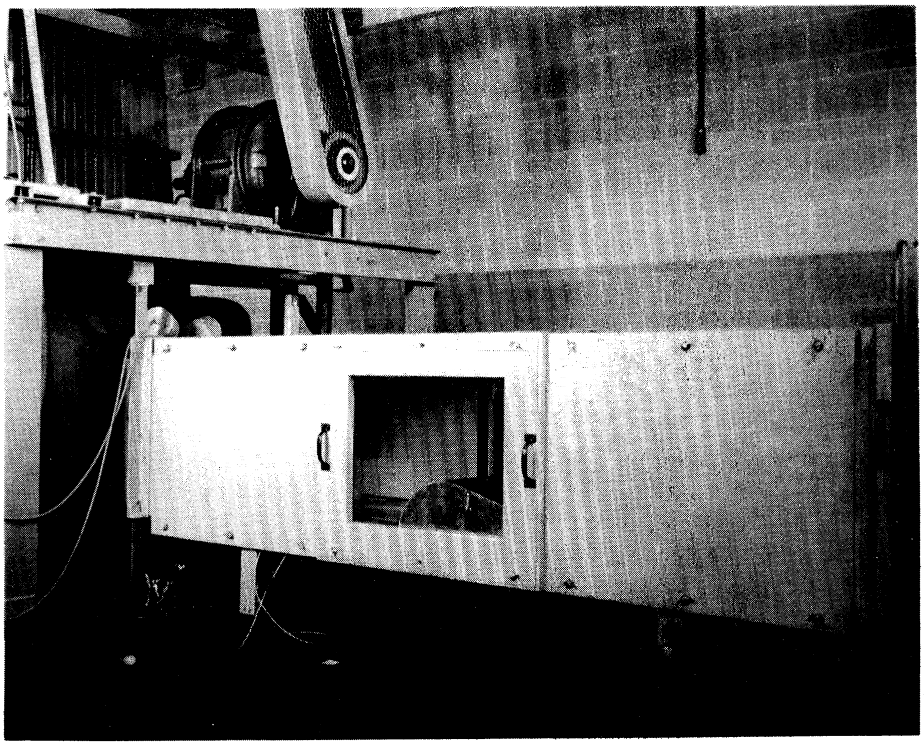

Fig. 2a. View of Tunnel Test Section

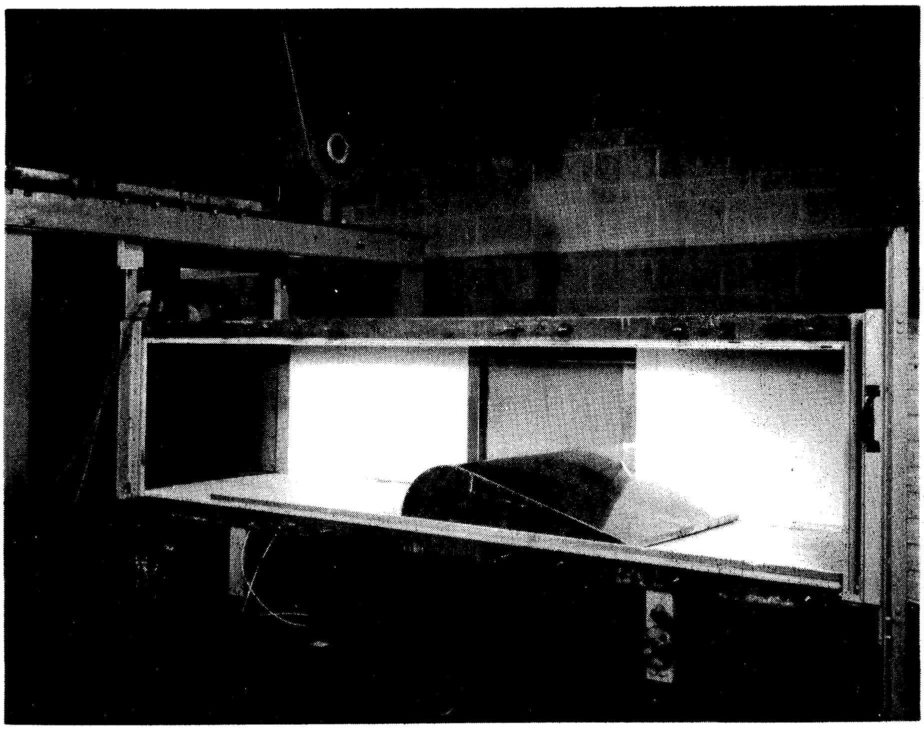

Fig. 2b. Tunnel Test Section with Side Panels Removed

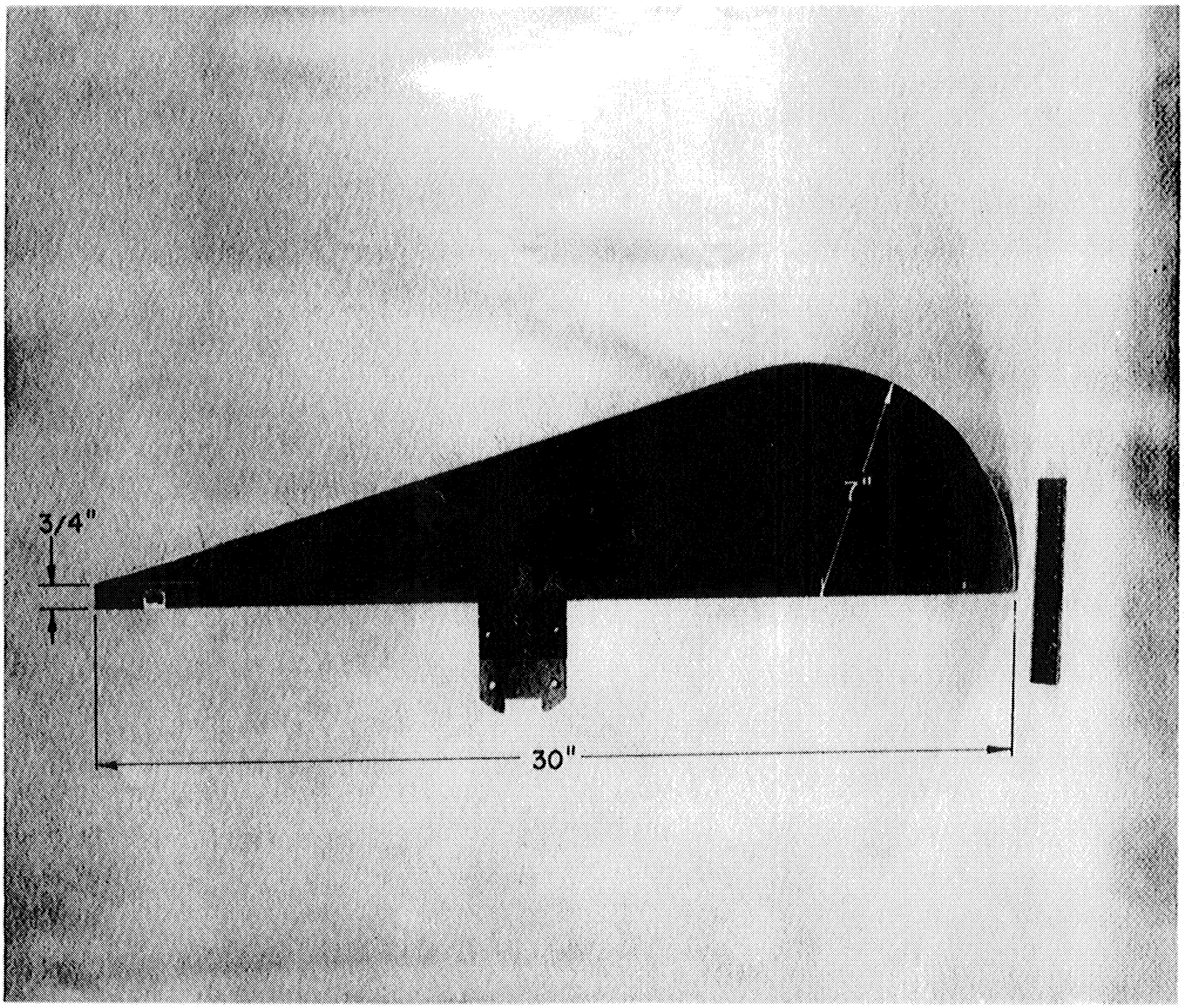

Fig. 3a. Side View of Bump and its Dimensions

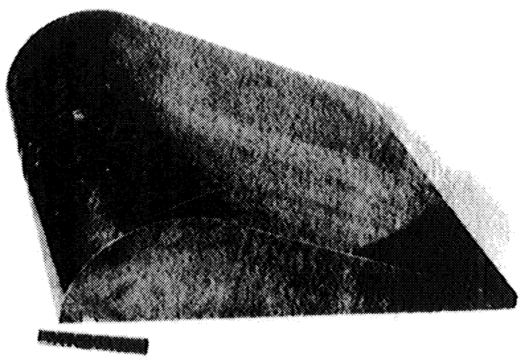

Fig. 3b. Perspective View of Bump

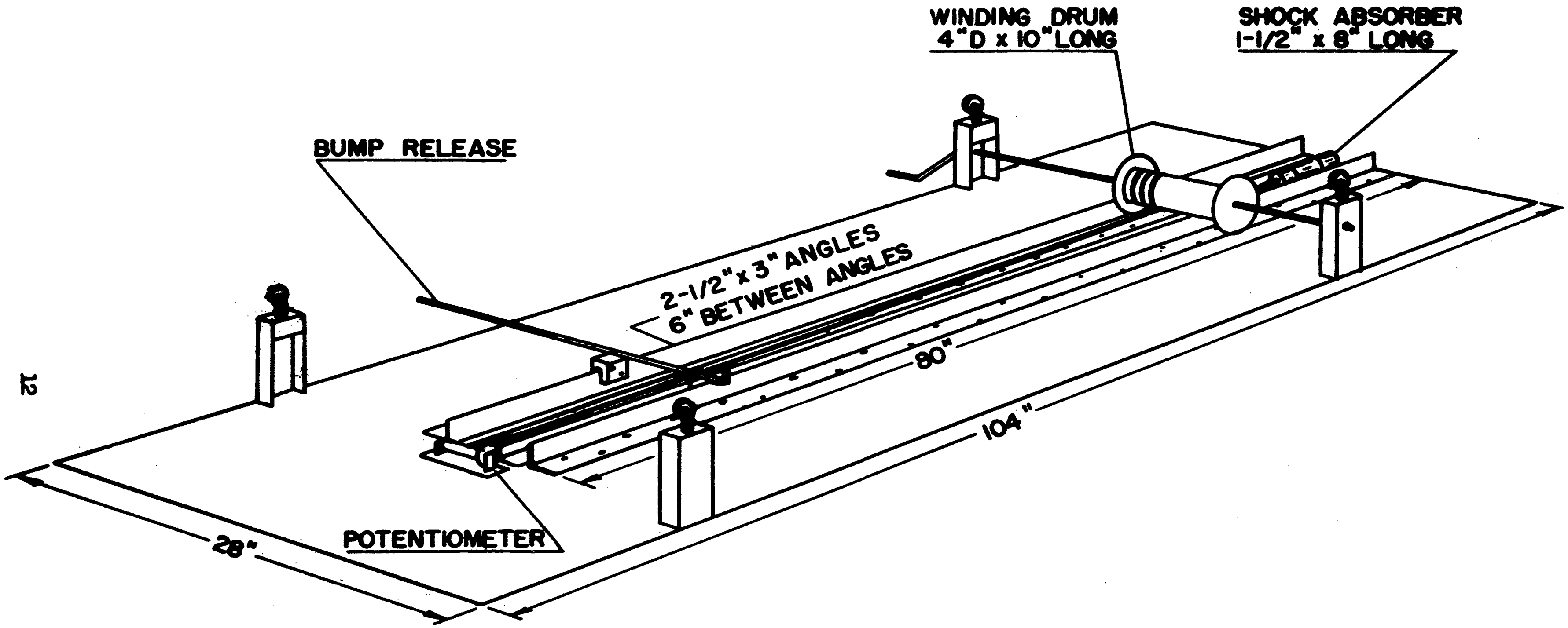

FIG. 4
SKETCH OF BUMP OPERATING MECHANISM

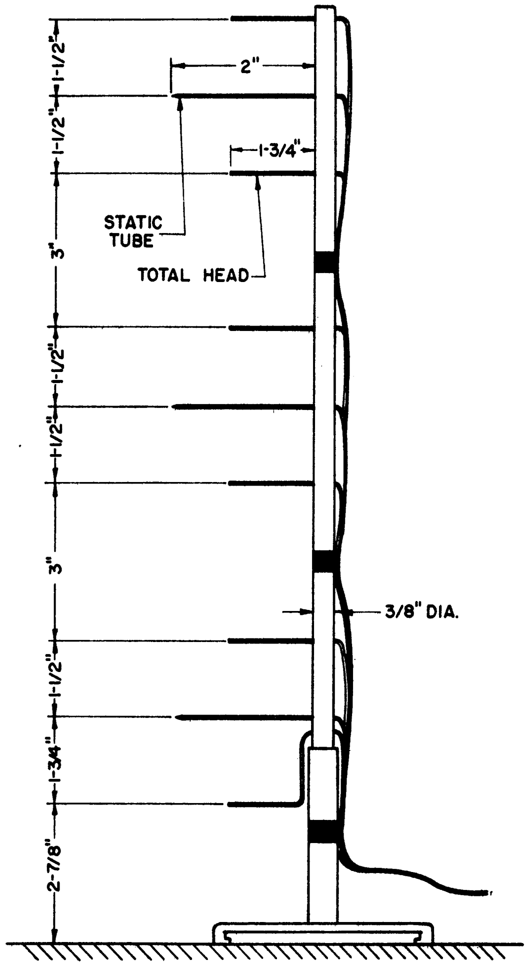

Fig. 5a. Sketch of Pressure Rake

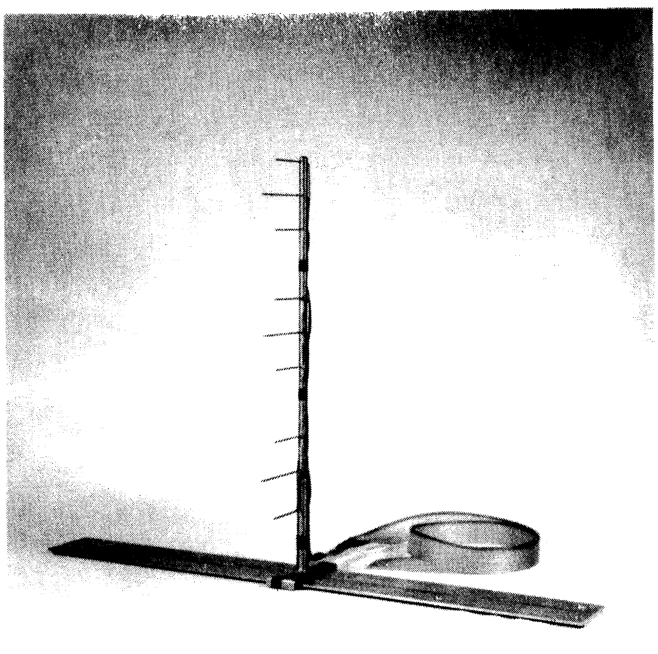

Fig. 5b. Photograph of Pressure Probe Rake

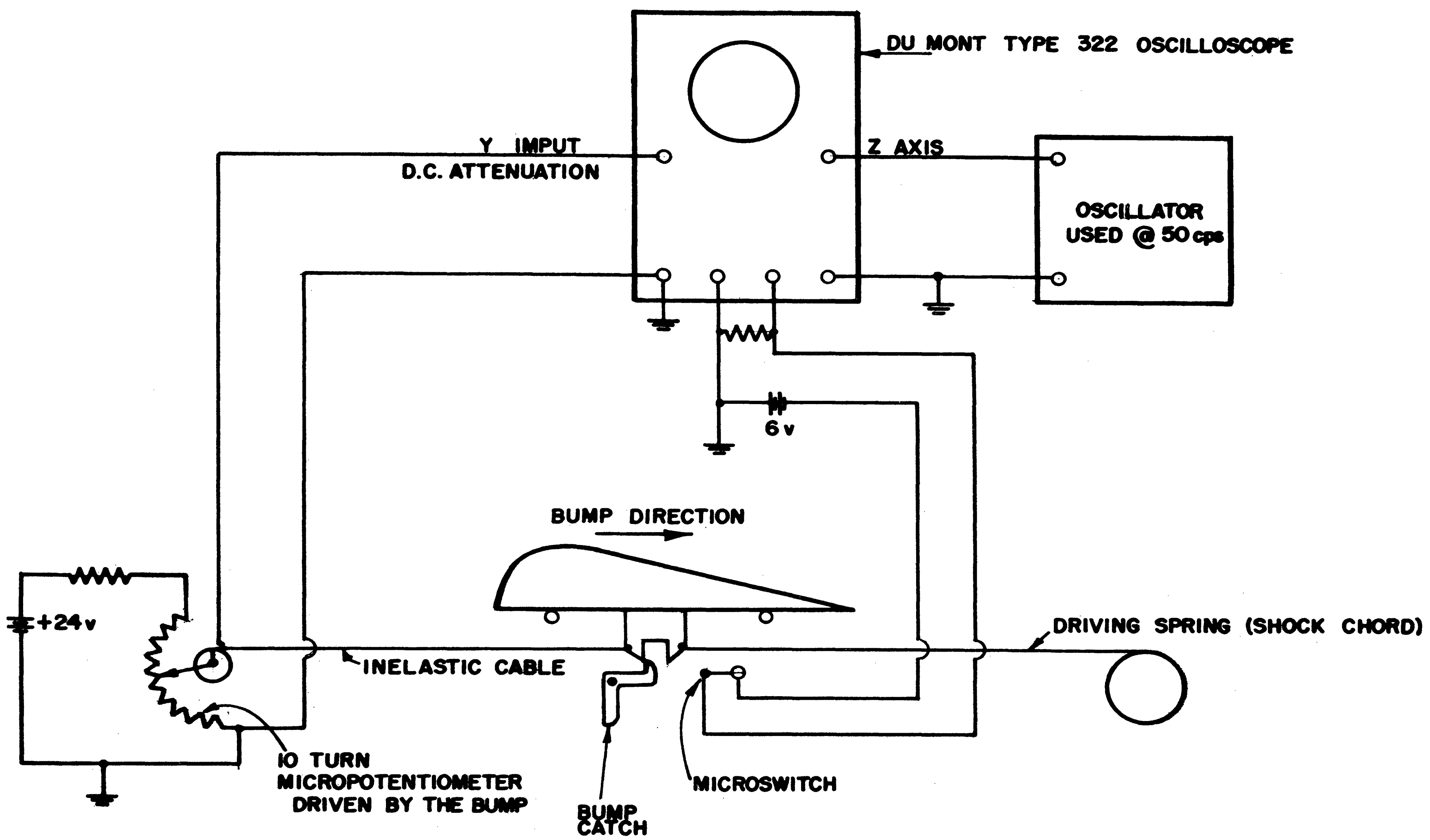

FIG. 6
CIRCUIT HOOK-UP FOR RECORDING BUMP POSITION

Oscillograms of Bump Displacement-History

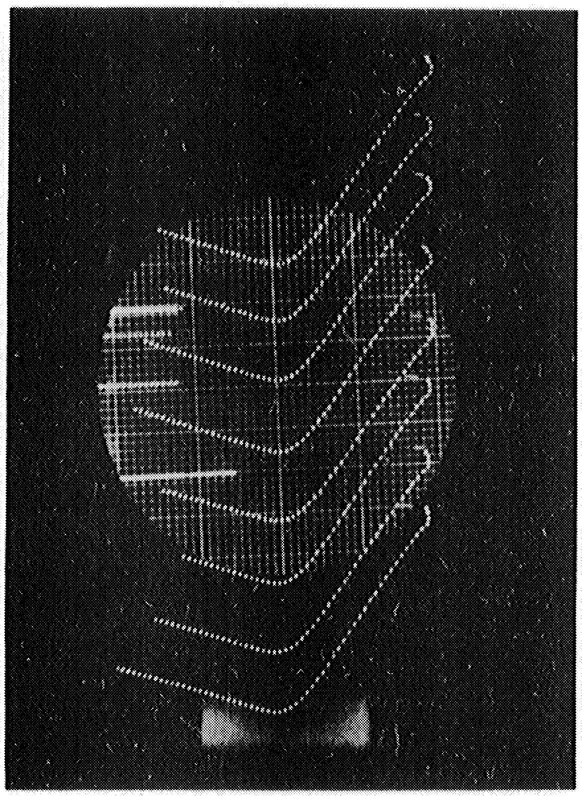

Fig. 7a. Tunnel speed 50 ft/sec, bump speed 6.75 ft/sec, 50 cps time pulse

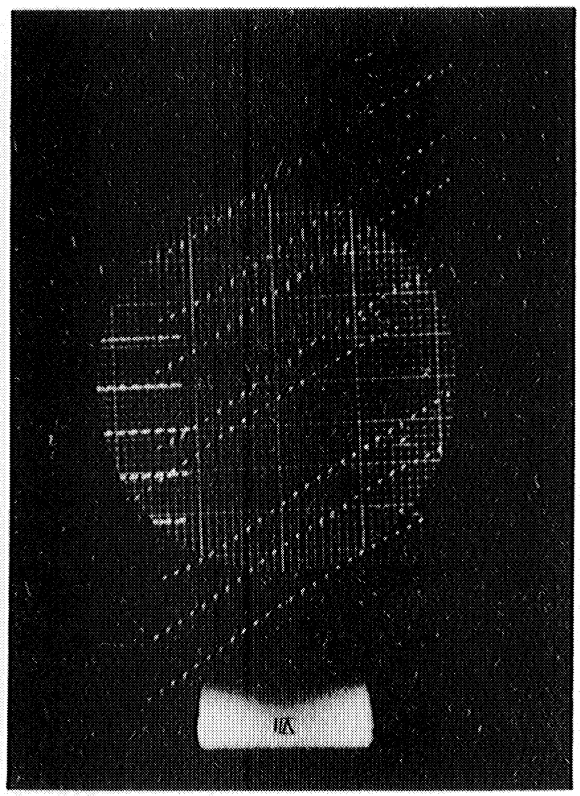

Fig. 7b. Tunnel speed 67 ft/sec, bump speed 6.95 ft/sec, 50 cps time pulse; note that the x-axis scale is greatly expanded over that of A in the above case

Equipment Used to Measure Flow Direction by the Hot-Wire Technique

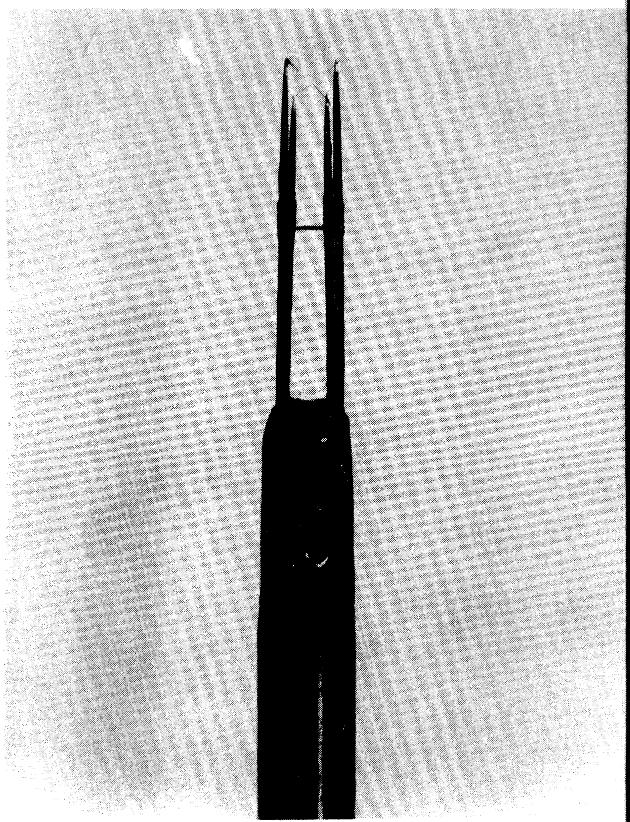

Fig. 8a. Close-Up View of an "X" Hot-Wire

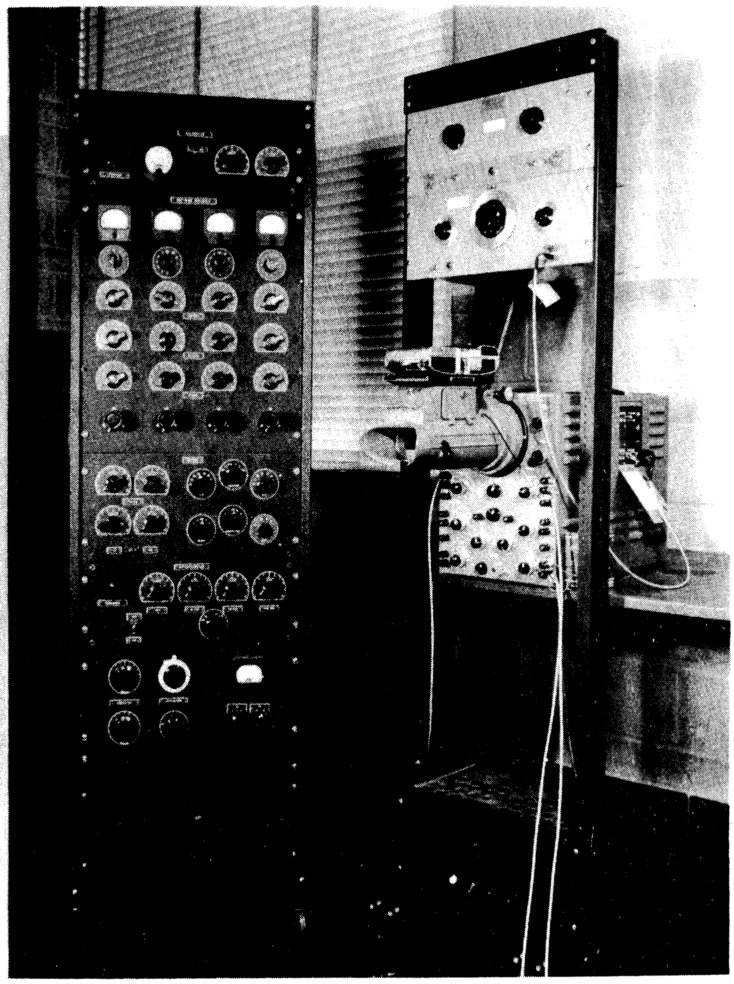

Fig. 8b. Thiele-Wright Hot-Wire Anemometer and Du Mont Dual-Beam Scope and Recording Camera

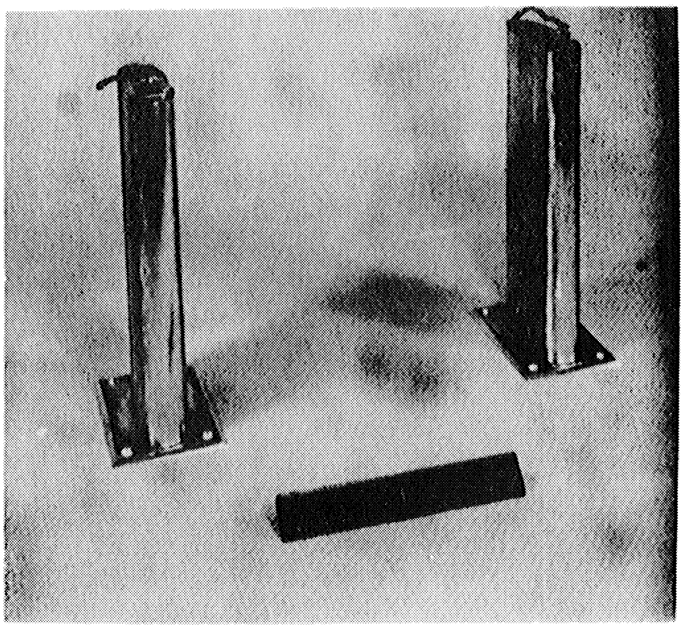

Fig. 9a. View of **Assembled Balance** System

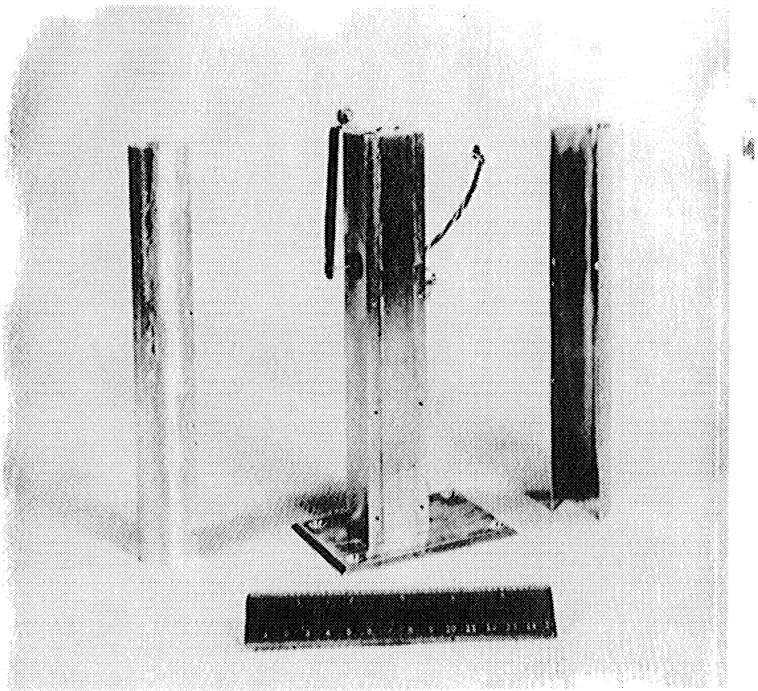

Fig. 9b. Details of **Single** Balance Unit

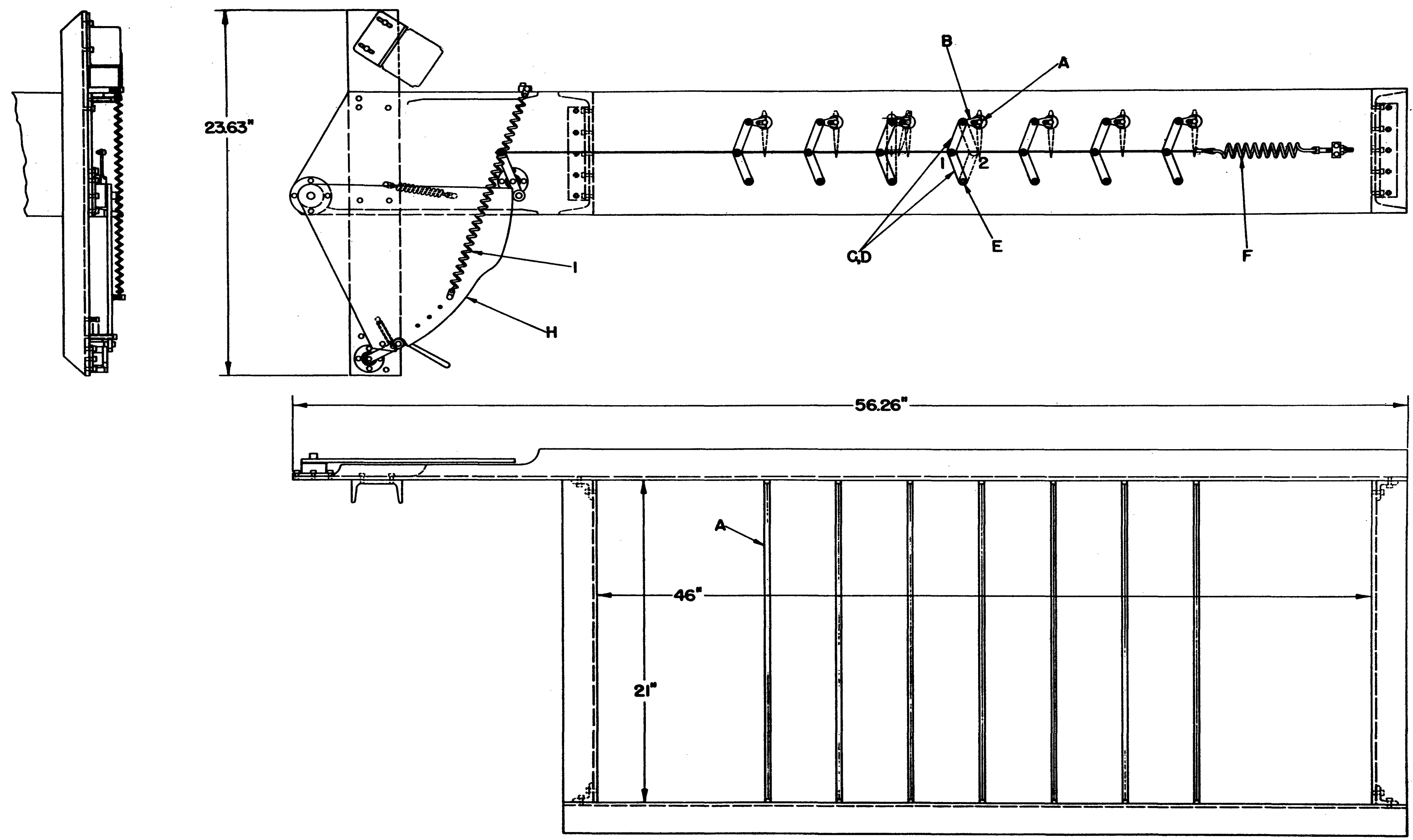

FIG. 10
DESIGN OF VORTEX GENERATOR

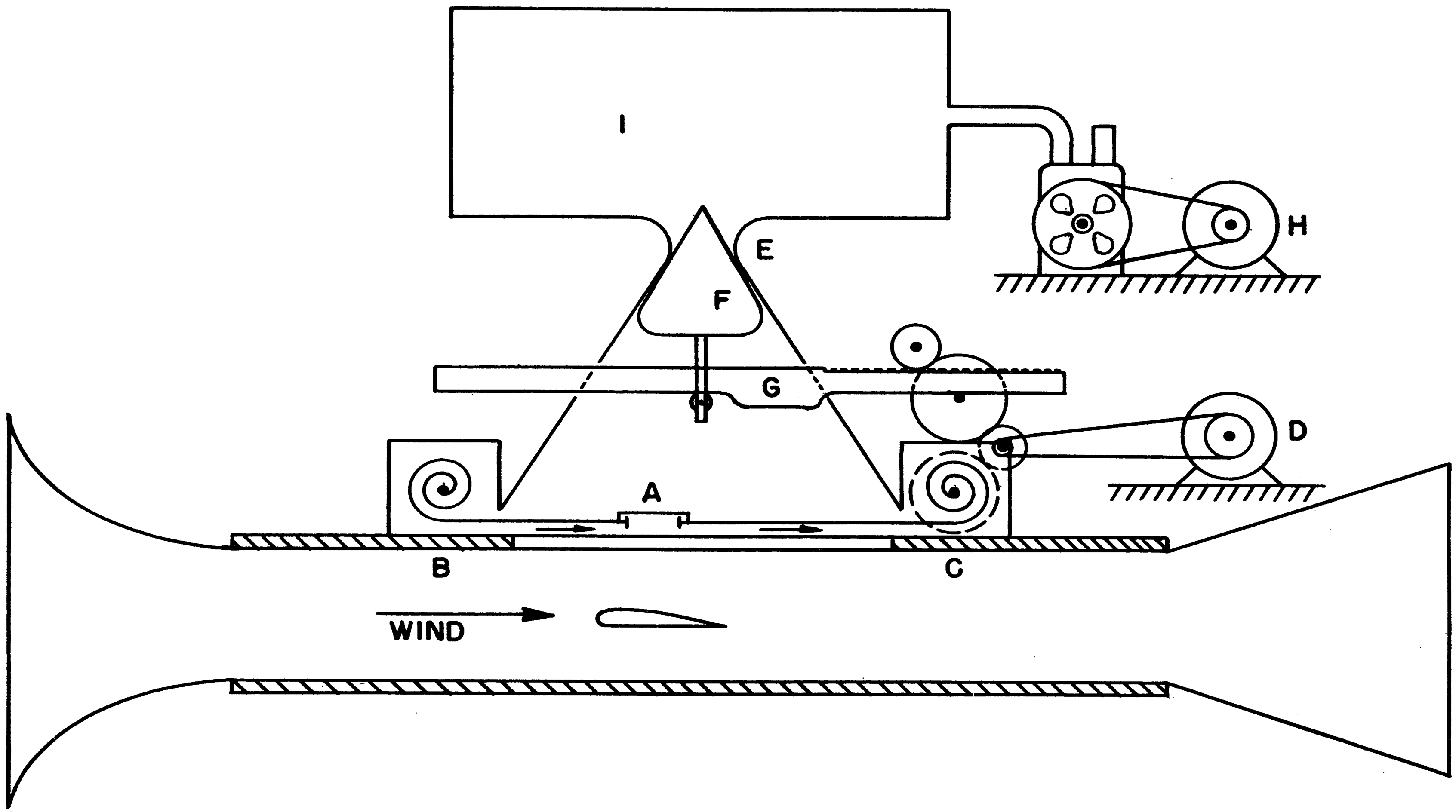

FIG. II
SKETCH OF POSSIBLE SINK TYPE GUST GENERATOR