Investigation of the air-flow in an acoustic jet at resonance.

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Investigation of the airflow in an acoustic jet at resonance.
A Thesis

Dedicated to the Faculty of the Department of

Science of the School of Arts and Sciences,

of the University of Texas,

Ralph C. Jones

April 1951
A Thesis

Submitted in Partial fulfillment of the requirements for

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by

H. C. Janes

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The airfoil phenomenon, known as an "acoustic jet" and associated with an oscillating excitement created by an oscillating, gas-injected pulser with a mechanical, piston-type pulsator with piston stroke varied in the range of one to one foot. The objective was the quantitative examination of the pressure distribution by light and for combustion, and determinations of the overall flow patterns and behavior, and Hathaway's principles (Ref. 12).

The work grew out of two recent investigations relating the acoustic phenomenon to oscillation, in which case there was the classical work of J. W. Huston and W. R. Smith (Ref. 2), and the other of related nature at the University of Wisconsin by R. M. S. Strieder (Ref. 1).

Lateral and longitudinal plane pressure distributions are presented for a basic configuration dealing the general character of the pressure distribution of the effect of variation of the levels of pulsation excitation.

In our study the major portion of the research required to be conducted longitudinally, and much attention was given to general correlations. No external correlation or predictions were possible.
involved a pulse in the through an opuscular, and a centric through a central jet. The interaction of the end vortex was found to be modified in- creased with time of radius first, but then rapid, shallow, and to consist mainly of internal and part of the external circulation.

Work was carried out at the Laboratory of the Biological and Medical School, University of the University of Minnesota, under the guidance of Dr. W. H. H., and as a preliminary phase of a more detailed investigation, performed by the University with United Aircraft Research Depart- ment support.
Many phenomena encountered in the jet propulsion field remain obscure and little understood. Among the foremost of the problems requiring further analysis and investigation are those relating to intermittence and pulsating gas flow. These phenomena are utilized to regulate the gas flow in the under jet. The airflow phenomenon known as the "acoustic jet" is associated with various configurations of 'pulsers' or resonators, placed on an engine, excited by a pulsator. Interests are heightened by the long established fact that under certain conditions a significant amount of thrust is produced by these simple devices with only a small input of energy to the pulsator. Further, engineers testing jet engines have sometimes observed performance improvement associated with resonance.

A comprehensive history of the "acoustic jet" field, while outside the scope of this work, is contained in Refs. 1-3. The thrust of this effort was to relate recent investigations and results that are essentially theoretical to practical problems experienced in the design of jet engines. Although significant theoretical research is now proceeding in this field, most of this nature is available (at least) in Refs. 1-3.
it appears that further analysis and investigation is needed in the case of the acoustic jet.

Previous investigations (Refs. 1, 2) have concentrated largely on directly relating the acoustic phenomena to thrust and have ignored another thing that the acoustic jet device is extremely sensitive to: open-end edge conditions, and that it is possible to increase the thrust by increasing the amplitude of the forcing vibration. A broad program of further quantitative and qualitative determination of the flow fields in acoustic jets is needed for the attainment of adequate understanding of this special problem and for further insight into the general characteristics of pulsating flow. Pressure surveys, parallelizing the thrust measurements, are needed.

A mechanical pulsator was designed and built by the University of Minnesota mechanical engineering staff for use in a broad program of research in pulsating flow, employing both airmass and instantaneous observational. This program was made possible by United Aircraft Research Project support. The pulsator was initially made available for the present work which was proposed as a preliminary phase of the broad program.

The primary objectives were twofold: (1) establish
of the flow patterns and behavior employing tufts, smoke, and dust as flow visualization techniques, and thus establish whether possible, the salient characteristics of the flow associated with the basic resonator configuration in the available range of amplitude of pulsator vibration; (2) obtaining static and total pressure data, using liquid manometer gages, showing the pressure distribution in the basic resonator and jet excited by the light available (about one inch) amplitude of pulsator vibration.

The work was carried out in the Engines Laboratory of the Mechanical and Aeroplane Engineering Department of the University of Minnesota, under the guidance of Dr. T. A. Hall. The author wishes to express his appreciation for the use of the pulsator, which made possible through Airplane Research Squadron support, and to express his thanks and appreciation to the following: Dr. T. A. Hall, for his direction and counsel; Professor T. Z. Murphy, for his suggestions; and Professor E. L. Kelly, for his encouragement and assistance.
<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0a</td>
<td>Gauge mean static pressure, inches of water, referred to atmospheric pressure.</td>
</tr>
<tr>
<td>0b</td>
<td>Gauge mean total pressure, inches of water, referred to atmospheric pressure.</td>
</tr>
<tr>
<td>1a</td>
<td>Ambient atmospheric pressure, inches of mercury, absolute.</td>
</tr>
<tr>
<td>1b</td>
<td>Ambient atmospheric temperature, degrees Fahrenheit. Also used for time in seconds.</td>
</tr>
<tr>
<td>2</td>
<td>Absolute temperature, degrees Kelvin. Thermal inertia.</td>
</tr>
<tr>
<td>3</td>
<td>Distance along resonator axis, in inches, measured from the plane normal to the axis, at the open end of the resonator, towards the closed end (piston).</td>
</tr>
<tr>
<td>4</td>
<td>Same as item measured in the other direction (external).</td>
</tr>
<tr>
<td>5</td>
<td>General variable for distance along resonator measured from plane of closed end.</td>
</tr>
<tr>
<td>6</td>
<td>Resonator length, in inches.</td>
</tr>
<tr>
<td>7</td>
<td>Angular position in degrees, in the plane normal to the resonator axis; referred to a zero line established from the axis vertically upward, and extending in a clockwise direction to the plane for a half closed resonator and from the opposite. This is used in the tables (see Table VII and subsequent tables for legend) to locate the position and direction of the probe at the introduction point. Thus, if Table VII shows a null pressure at the probe introduction point at the top of the resonator, the volume for 0° and for 180°, and is at the bottom of the pressure data column for 180° and for 360°.</td>
</tr>
<tr>
<td>8</td>
<td>Initial distance from the front of the device, inches, positive along the line defining, negative along the line defining.</td>
</tr>
</tbody>
</table>
Distance, in inches, measured from the inside surface of the resonator wall along a line extending through and normal to the resonator axis. Thus it has its largest magnitude at the resonator axis. It is not used negatively.

Revolutions per minute of the pulsator crankshaft unless otherwise noted.

Piston stroke in inches measured from head-end dead center.

Unit of time in seconds.

Angular position of the pulsator crankshaft from dead-center.

Angular velocity variable.

Velocity parallel to resonator axis, positive in direction of positive end.

Speed of propagation of a sound wave.

Frequency, cycles per second.

Angular velocity, radians per second.

For aUSED IN TABLES

Basic resonator configuration. Refers to the basic resonator configuration as described in detail in apparatus.

Null static. Refers to the instrumentation array not described, and to referred to, in the section on apparatus.

Internal statics. Refers to the instrumentation array not described, and so referred to, in the section on apparatus.
Used with reference to the open end and edge of the resonator, it signifies that the tube was cut squarely off in a plane normal to the axis and that the resulting edge was not finished by tapering.

Used with reference to the open end and edge of the resonator, it signifies that the edge was tapered to a sharp edge or surface at the end of the inner wall.
The simple theory, concerning the possible resonant modes of vibration in air columns traversed by plane pressure waves or regular, is well established and appears in many textbooks (Refs. 7, 8). It should suffice to review briefly the theory directly related to the resonator configuration which was used in this work, namely a circular tube open at one end and closed at the other.

Simple Acoustic Theory

Pressure impulses (waves) in a tube by plane surfaces normal to the axis are generally assumed to propagate as plane waves. Plane waves reflect here as linear waves. Once encountering a plane wall, a closed end of a tube, the wall of another portion of tube, they reflect with a one-hundred eighty-degree change of phase, i.e., compressions are reflected as rarefactions and rarefactions are reflected as compressions. Those waves travel at local sonic and 1/2, or higher with respect to the air particles as dependent upon their intensity. When the tube length to frequency of oscillation are related in such a way that reflected waves never
at the origin, just as a conclusion of the case. Then as in starting and resonant occurs, the current may greatly increase, and it is said that is due to the oscillation.

The wave length is four times the distance between a node and the origin. What is the nature of the standing wave produced in a resonating tube? Is it at the closed end, just as the node always be a minimum at the open end? The closed end oscillations at 1.3 times into one at the resonant wave length, period, and frequency. Let the tube closed at one end and open at the other, we follow the motion of a wave over the tube a close cycle. A resonant can be started at the closed end, reflected at the one, and then opened, of the closed end. The closed end can resonate, of 3.1412, 4 of the one, if the condition of a wave is the same. The standing wave length of the tube is the length of the tube, 4L, while the frequency is the frequency of 3.1412. In closed tube, the frequency is 4L/c, and in the formulas, the same frequencies can be used, or frequency of 2L/c, 3L/c, etc.

Then the tube length required for resonance

\[ L = \frac{n\lambda}{4} \]

where \( n \) is the order of resonance and \( \lambda \) is the wavelength.
experiment that a "first conclusion" is reached. Also, the generally accepted formula for the fundamental frequency of such a\nresonator is (1.2.1),

\[ \omega = \sqrt{\frac{1}{l}} \left( \frac{1}{2} l \cdot c^2 \right) \]

**Diagram of Finite Element Plane.**

When the succession is entered in the single

plane situation, one finds the following hypotheses that

the compressions and rarefactions are equal when these are produced

instantaneously at the center plane position of the plate, they

are interested to follow the superposition of these compressions and

rarefactions in an idealized "time-distance diagram" (\( t = \) time

\( c \) = ) such that enough to it are to. The well known relation to

the relation of the velocity, increases, etc. is that it appears

by, for example, the applied moment in order to the superposition

the absolute value. Only, only, one is obtained. Once the given

into the final equation, it is that. Look of simplicity to be the

only the energy level of the production is in agreement with the

whereas, all of these yield the mean have followed from various

planes.
The motion of the piston is restricted because it originates at the upper and determines the boundary conditions at the closed end. The pulsator employed in this investigation consisted of a conventional cylinder and connecting rod with provision for adjusting the piston travel in the range of zero to one inch. Thus (Ref. 10), the piston displacement from two and dead center (0) is:

\[ x = a + \frac{1}{2} \left( \frac{a^2 + 4}{2} \right)^{1/2} \cos \theta \]  

where \( a \) is the center-to-center length of the connecting rod; \( a \) is the stroke setting; and \( \theta \) is the angular position of the crank from dead center. The maximum linear velocity (7) is felt for second is:

\[ v = 0.00873 \pi \left( \frac{a + 1}{2} \right) \]  

where \( \frac{a}{2} = b \); \( a \) is in inches; and \( l = \sqrt{a} \). The instantaneous acceleration of the piston velocity (1) is given by:

\[ a = 0.00914 \pi \left( \frac{a + 1}{2} \right) \]  

where the units are as before.
...
of a small body wave, each propagate itself at the local speed of sound, relative to the fluid at that point, and will therefore overtake the initial increment of the wave, after a finite time, corresponding to a discontinuity such that the compression wave plane practically instantaneously. This must occur because the value of a compression wave is characterized by an increase in velocity and temperature, and thus velocity of propagation) over the approach conditions. The time is needed by this to occur is given as (Ref. 17, p. 47).

\[ t = \frac{(1 + 1/l)}{(1/l^2)} \]

where \( m = \left( \frac{v_c}{l_c} \right) \) is the relative slope of the impressed velocity-distance curve. The relative slope of the velocity-distance curve for the piston is taken as a crude approximation of this value, one finds, for the case of one-inch piston stroke and 1005 psi, related to a nine foot long resonator, that the time required to form a discontinuity would be approximately 0.038 seconds, while the time required for the pulse to reach the end of the resonator would be approximately 0.220 seconds, so that a discontinuity would not occur. If the reinforcement reached the point where the relative slope of the velocity-distance curve for the pulse were six to seven times the value for the piston. 

\[ t = \frac{(1 + 1/l)}{(1/l^2)} \]
would appear near the open end of the resonator.

The required situation is true for an expansion wave, each succeeding point cut off by a wave front itself traveling in a slightly cooler air than the interior of a high order. It, and thus at a slightly lower rate. Air initially more rare
to be at least steady and be ignored. There is no natural mechanism for the formation of a resonant wave zone (def. 16). The approach film velocity relation to an expansion
wave increases an increment of velocity increase, whereas compressive waves impart a decrement.

Measurement of Capillary Waves

Special problems arise in connection with the simplest
measurement of oscillating pressure. The film is continuously
forming as well at the output of the measurement transmission system and this is a non-isentropic process involving shear and non
converting pressure losses. The natural frequency of the instru
mentational, controlled, and completely distinct the actual system. The tilt feature are dispensable attenuation, whereas the loss

Attenuation refers to the pressure drop along a tube
and its loss forces (not frequency effects) and be generally
considered in the sense of Nusselt's law of viscous energy

which is given as (Ref. 12):

\[
\frac{\partial p}{\partial x} = -\left(\frac{12\mu}{\pi}\right) \left(\frac{\rho}{D^2}\right) q
\]  

(12)

where \( p \) is the instantaneous pressure at any point in the connecting tube; \( x \) is the distance along the tube measured from the entrance; \( \mu \) is the fluid's viscosity; \( D \) is the tube diameter; \( \rho \) is the volumetric flow at any point in the tube. Equation (12) is combined with the non-steady, one-dimensional equation of continuity, in Ref. 11, to obtain a full-time function of the loss caused by the amplitude of pressure for instantaneous pressure transducer and devices. Since the flow in the entrance is assumed (about the mean pressure), it is assumed that the fluid motion has been shown as to vary slightly from non-water effects.

An "exact" work (Ref. 12) for small times was computed by solving the variation with time, with the magnitude not added to estimation of the attenuating effect on any pressure record.

In this case, equation (12) was integrated for short, constant volume flow times up to 1 to, obtaining, for various flow \( q < \frac{\mu D^2}{\rho} \):

\[
q_1 - q_2 = \left(\frac{12\mu}{\pi}\right) \left(\frac{\rho}{D^2}\right) x
\]  

(11)
and for turbulent flow (1000 ≤ Re ≤ 100,000),

$$ \Delta = \frac{1}{2} \left( \frac{\nu}{\tau} \right)^{7/4} \left( \frac{\nu}{\nu_w} \right)^{1/7} \left( \frac{\rho}{\rho_w} \right) \left( \frac{L}{D} \right)^{3/4} $$

(18)

where the units and the symbol have the usual meaning, \( \nu \) is the viscosity of the fluid, and the other terms are self-explanatory. A relation for determining the loss of flow in a circular pipe for turbulent flow, from the critical Reynolds number at each point, is shown:

$$ \Delta \frac{L}{D} < 0.06 \text{ Re}^{-6} $$

(19)

For laminar flow, where \( \Delta \) is in inches, \( \Delta \frac{L}{D} \) is expressed as a function of any suitable unit of length.

**References**

The day is the measure of our activity. The
work of the week is the measure of our work.
This is the
[181, 199, 218, 248, 272, 303, 333, 363] 1819
and June
The mechanical pulsator (see Figure 1) was designed and built by the University of Minnesota mechanical engineering department, and a detailed description is given in the following section. A small flywheel was attached to a shaft and the device was mounted to the pulsator and driven by a small electric motor. The device was intended to be a simple, low-cost, and easily built pulsator for applications such as blood circulation or respiratory support. This type of pulsator has been used in various medical settings due to its simplicity and reliability.
possible stroke magnitudes available in the range of zero to one inch. The values of piston stroke used in this investigation were: 0.054, 0.282, 0.542, 0.782, 0.982. These values included the minimum and maximum for the apparatus. A needle pierc ing connecting rod (five in. long, center to center) was screwed to a thrust shaft. The thrust shaft was provided with a guide bearing. The piston moved to the head end of the thrust shaft and fitted into a steel cylinder provided in an oil bath. The piston, connecting rod, thrust shaft, and needle bearing were all of steel. The piston led out the th eneal clearance in the cylinder from end, and lead on the thin end of the taper so that they could be placed in the lubricant oil. The cylinder was fitted with a half length (equal corresponding to the inside diameter of the reservoir) and 1.0 inch 1.2 five in. The rod was ended at the end of the cylinder at smooth to six inches. In between the is connecting metal.

The metal connecting metal, at the 20° C. and 100° C., were the freezing temperature as described in the paragraph. The metal is 3.0 inches long; 0.25 inches O.D., 0.195 inches I.D.) were fitted together as stated previously in their作文 supports
One end was inserted in the pularter receiver section. The building unit was sealed with butah tape which was easily removable. Small patches of the same material were used to seal surfaces which were not in use. The overall length of the resonator, measured from the open end to the main piston position (two-inch radius), was found to be an important factor and must be taken into account. The plastic tube ends were square-cut, and in particular, the size of the end of the resonator was square-cut on each. Eighteen orifices (0.270 in., filled with about 0.50 drill) were spaced sixty inches apart, in a straight line along the upper surface. These were numbered as stations one through eighteen starting at the open end. The orifices near the open end were drilled 0.250 by 0.250 inch. The end of about 3/12 inches to 0.050 inch at 0.037 in. They were all oriented 0.020 inch from the axis of stations 2, 7, 12, and 17. These, together with the top orifices, were given equivalent angular sizing (50° apart). The orifices were carefully aligned with the axis of the pularter piston. The resonator was 0.014 inch right for the piston wall and the resonator center was 36.74 inches from the face.

The additional to the basic resonator configuration considered in this work, as described in this paper, to investigate the effect of a sharp versus a blunt nose conical edge (Figure 2). This
was done by making a cylindrical tin collar about one-half inch long, which fit snugly inside the open end of the resonator. It was inserted one-half inch into the open end, with a small amount of cement filling the open end of the tin collar to produce first the snug, and then the 'sharp, open-end edge configuration. A pressure tap over the edge of the tin collar was used at station 11. A similar tin collar was used at the intersection of the tube sections for some flow visualization tests (Figure 10). It fit over the outside of the holes and was cemented to the inside of the holes, and then cement was used to fill the open-ended section (Figure 10). Two identical plenum chambers were built (see Figures 1, 2). They were made from 4 inch galvanized rain spouts and were fifteen inches long. Two of the galvanized rain spouts were welded together to provide the openings at the outside ends. Six inch galvanized pipe was used with an attached 'Y' fitting, which was connected to the cold room and directly to one of the holes in the cold wall (1/16 inch OD). A similar fitting was attached to the other end in the cold room. (Four inch OD, 1/16 inch ID, 3/16 inch thick) was attached to each of the end fittings and connected to a X fitting,
The other side glass was part of the liquid, with each type (Fig. 1). The one which can used for all the two was found with the plate almost in place. The full of the plate to be a laboratory glass. 4. The dial and volumetric, however, in addition to the. The device was kept to either the plate only the line with the part to be measured. A small three and scale, draft and zero (preferred), called and distilled water, at used until the plate closer nearer the apparatus, except for occasional readings at the. No. 1 inch were off the scale. These numbers could be read to the third decimal place on the millimeter scale and to the general decimal place on the vernier scale. All readings were taken perpendicular to the scale.

The pressures measured in the apparatus were of three types: (1) an internal balance, and for most of the measurements the same static pressure at one side of each; (2) internal pressure, used for the remaining two total head, pressure balances; and (3) the internal pressure, on the other side. The readings to the four.
The plenum charber to resonator fittings. A bell from the plenum and a piece of copper tube is less connected to the same apparatus as shown. The copper is...
characteristic of the tube and fitting. Flattened
and cut out, and if necessary, the inside of the tube
and fitting may be lined with a coating of brass
which may be soldered on, and if this is done, the
end of the tube will be the inside of the reverse will. The tube
should be cut to a right angle or bend, and is then
traversed with rivets. A further point of interest, the tube is then
riveted to a case, and the rivets are soldered on the reverse side, and
then the tube is soldered to the fitting. The tube is then
riveted to the case, and the fitting is soldered to the tube.
Figs. 2 and 3 show in detail the filling, welding, and finishing operations used in the fabrication of the brass fittings, which were made from a blank of rolled brass. The blank was cut into the desired lengths and finished on the machine, in order to meet the dimensional requirements for the completed fittings. The brass fittings were then polished, and the required finish was obtained by filling and drilling, so as to meet the dimensional requirements for the final assembly. The brass fittings were then assembled and the required dimensions were obtained by the use of gauge blocks. The resulting assembly was then polished and the required finish was obtained by filling and drilling.

A thorough test of the finished units with the internal brass and magnesium valves.

(1) A valve for the application of the magnetron to the production of X-rays and rays of X-ray radiation and to the production of low energy X-rays. The valve is designed to operate at high vacuum conditions, and is made of a high purity material. The valve is designed to be used in conjunction with other components, such as the magnetron, to produce X-rays of a particular energy and to produce a controlled number of X-rays. The valve is made of a high purity material, which is selected to provide the required properties for the valve.
be divided. This probe was fabricated and tested for use in the study of the effect of shear on the growth of cracks.

(2) Another simple probe similar to (1) was made. It was 2 inches long and 0.125 inches in diameter. The probe was made of brass and had a length of 0.125 inches. The probe was made of brass and had a length of 0.125 inches. The probe was made of brass and had a length of 0.125 inches.

(3) A total length probe was made from brass tubing with the same dimensions as (2) except that it had a length of 0.125 inches. The probe was again made of brass and had a length of 0.125 inches. The probe was again made of brass and had a length of 0.125 inches. The probe was again made of brass and had a length of 0.125 inches.

(4) A total length probe was made from brass tubing with the same dimensions as (2). It was 2 inches long and 0.125 inches in diameter. The probe was made of brass and had a length of 0.125 inches. The probe was made of brass and had a length of 0.125 inches. The probe was made of brass and had a length of 0.125 inches.
The side of the probe entering a channel of an autoclave tube, which is only slightly different from the inside diameter of the probe (about 0.020 inch). This probe has been referred to as a cylinder-flat tube (CFT) probe. It is based on the fact that stagnation occurs at the leading edge of a cylinder placed normal to a steady flow.

The external traverse - Fig. 7 shows a typical arrangement as above in Fig. 1. The probe fitted a flat plate in one inch opening in a mounting plate. The support frame could be moved and rotated for any desired angle of the probe for positioning. Vertical positioning could be effected by moving the mounting plate up and down between the two vertical support bars. When positioned vertically, the mounting plate position was fixed by a stop arrangement. The vertical support bars could be rotated about a vertical axis providing another degree of freedom. The external traverse probes were connected to the probe using by a flexible piece of rubber tubing (3/16 in., 17) and a one-way stop-cock.

A description of the probe and thus the external traverse arrangement follows.
(a) The (metal-lead) tube (cf. 11) was handled by hand only, available in three sizes and for all of the external (metal-lead) measurements. The smaller tube inside the outer shell of the wire tube inside the tubing of the wire tube was approximately two inches in length. It led to a larger metal tube which also served as the support for part of the wire tube inside the shell, the wire tube being a right angle to the cross section. The whole was eighteen inches long, making about twenty inches overall, five thirty-seconds of an inch in inside diameter and three sixteenths of an inch outside diameter. The outer shell of the tube inside the inner wire tube was inside the tubing of the wire tube and was shifted from the side of the tubing five eighths of an inch.

(b) Another tube for one-third of the battery, with a side wire, free wire tubing, into the shape of a 2, was the short part of a five-inch long part, which ended in a proper length, eight inches long, in the lead and lead tubing in the shaft of the wire
tube (c), but this was (almost) a joint too near the short end of the bend. This bend on the smaller section of the tube was the &former in overall length, not (or) of an iack in bending (gravity). The end of the short part of the "L" was not square - polished a bit so that, if the plane of the end exactly parallel to the flow, the tube would provide only the static pressure. It was desired in this way, varying from, the end plane lying in the horizontal plane, symmetric through the central axis of the resonator and jet.

Various methods of producing smoke were tried. The most satisfactory method employed was sand and water.

Quantities of a fibre, plastic, alkali-free, insoluble material, with the innards of internal (rounded circular template) were studied. This material is extremely light, with a fluffy, dusty-like feature. The fibre particles, however, are very low conductivity. The fluid entered the jet at the midpoint. In the center we had a large fluid layer. By simply tilting a little along, we could the fluid flow from the start of a run.
The apparatus should be made by tubing and rubber or a rubber hose, so as to have a good vibration and to prevent the escape of gas. The first resonant frequency of the resonant system should be low, of order to have a high frequency resonance. This should be achieved by oscillating the gas pressure with a tube as close to the resonator as possible. The length for obtaining the pressure wave should be about as short as possible. With a liquid manometer the resonator, or resonant tube, should be made as little as possible.
The static and total pressure distribution along the chamber into a cylinder.

Values of static pressure increase with local increase
along with the pipe opening, being the same and will
produce an increase in the static portion. The
opening area, being a part of the total opening area,
will increase the pressure in the resonator.

The total values have a maximum at a resonator
position, while the static pressure remains
constant in the pipe, but the pressure, more stable in the resonator.

In total, the pressure increases in the pipe, with the total opening
increasing, reaching the resonator. The resonator is composed of
the static and total pressures, producing a maximum at
the resonator position, while the static pressure remains
constant in the pipe. The resonator is composed of
the static and total pressures, producing a maximum at
the resonator position, while the static pressure remains
constant in the pipe.
The reversal of total and local head values at the mouth suggests that the air is "pulsating" in tidal alternation over the whole canal, and that the air movement is tidal, although the "total" airflow from one end of the canal to the other is small and oscillates over a relatively short time. Although it takes, "the two effects (influx and efflux of the air flow jet) are so strong in reality alternating, and only appear in their relative magnitudes an influence of the instability of the jet to follow such rapid changes".

The total head reversals, of course, result from oscillations of the jet and the surrounding jet in the direction that depends on the geometry inside the major portion of the resonator, which appears to be partially oscillatory in the central region and jet flow which appears to be jet flow all in radial circular directions. Generally, these are the result of the acoustic resonator. Visual observations (Figure 24) suggested that each of the vortex motions that caused this cycle of the current of air, which circularly sweeps out the region at the mouth of the canal and then sweeps.

With increased inter-channel distance from the upper end of the resonator..."
entering the resonator. It appears that the "primary" region of
resonance and axial support is then.</p>

The relative differences between static and total "velocity" values (approximate "three and one-half" inches of water) are
sure just inside the resonator and not indicative of any
values on the order of the "desired velocity" ultra sound.
The root velocity at the point where the resonator is indicated
as about eighty feet per second, and the wall velocity at a line
twice of three feet outside. The pressure is indicated to about
eighty feet per second. These values compared with the central
values in the pipe velocity of eight and constant times per inch
of 0.265, 0.379, respectively.

Critical Pressure Changes

A comparison of the mean static pressure distribution
along the wall of the resonator with the axial static pressure
distribution in another figure 6. The axial pressure is
greater than the wall gradient near the resonator by about
greater values than along the wall of the pipe of the
resonator as approaches. The values are very weak until the
near the closest exit. They are removed of the pipe. Outside
these occur just inside the ground, which are independent
to the effect of the edge vortex system. All 25 of these of the
axial and wall static pressure distributions correlate with the visual observations of greatly increased dust particles, with length near the open end, visual motion, and the latter are an indication of increased flow from the open end.

Profiles of mean static pressure distribution inside the resonator are shown in Figure 14. These profiles, with the velocity of flow for static one, very closely predict from the mean of static observations at each station as a check upon the accuracy of pressure distribution.

Profiles of mean static and total pressures on the external jet area (horizontal plane) are presented in Figure 27 for different perturbations. As noted previously, some turbulence from the open end of the resonator.

Total head profiles are presented in Figure 28. These gradients appear to be small except in the region near the open end of the resonator.

Variation in Static Pressure Distribution with Stroke Length

The mean static pressure distribution along the resonator wall for various magnitudes of plenum stroke is shown in Figure 2. The pressure gradient is greatly decreased with plenum stroke, although the critical area is determined entirely by
variations in pressure for a blunt and sharp edged open-end resonator configuration.

The difference in null steady state pressure distribution for resonators with blunt and sharp edged open-end resonator configurations is shown in Figure 10. On both lower values were obtained with the sharp edge.

Variation in null head static pressure with frequency for fixed resonator length.

The variation of head static pressure along the null head wall is shown in Figure 11 for various pulsator end values. A rough plot of pressure versus frequency for selected pulsator end values in Figure 10. It is evident that a longitudinal pressure gradient is produced much as in the usual...
that the limit equals $\nu$, at or near, the closed end (piston), and $\nu$ is a value of $\nu_i$ (from $1/2$). The limit is obtained by substituting the present frequency $\nu$ in the following expression; this value is then compared with $\nu_i$ in Figure 4, and for the second configuration in Figure 5. The curves show the change in configuration as before in Table 1, which is the theoretical formula (Equation 1) gives values of $\nu_i$ and $\nu$, respectively.

The positive values of $\nu$ move in a well-determined 1.07, the slope on either side of the peak. The positive slope changes in an almost linear approach while the negative slope changes with much more rapidly. In Figure 4, showing the points of the peak, moves the tabulated expression with the parameters that cause a well-defined reaction, and the values are quite different. The literature on these may give the more important value. The experimental limit is at a closed phase of the sound - at frequencies lower, than that of the open phase, which gives increased in the pressure.
The maximum value of the calculated value for the nodal dust heap described by early observations may have been distinctly identified in pictures of the dust heap, and it was simply difficult to reproduce the first, second, and third type of calculations.

For further analysis, the first type of calculations will be presented in detail:

As stated in our previous paper (Figure 12), the analysis of the nodal dust heap was initially conducted for the dust heap in Figure 12, followed by the dust heap in Figure 13, and finally the dust heap in Figure 14. It should be noted that in the first type of calculation, Figure 12, 1.54 in. is considered to be the best.
The tendency was for a lead jet to form across the width of the jet channel from the core region. This lead edge led to choking, which in turn led to the diffusion of L-... in... distribution of large quantities of jet did not appear to be associated with any specific location. However, the primary effect was a decrease in the intensity of the... jet flow, but this effect appeared to be weakly associated with... relatively shallow jet penetration. The situation is shown in Figure 22 for the jet in the depicted...
A comparison of the vortex system with small and large motions showed that the magnitude is represented by Figure 27 here. The oscillation increases in proportionality till a critical value where a condition is obtained in which the flow field and other considerations.

Small particles oscillating in a straight line appear to the eye as straight lines of the pulsation in fast motion. The observation of fine, Individual, suspended particles of dust or liquid inside the resonator was quite regular, etc. The best observations were possible when only a few, fine particles were present at that. Individual, suspended particles were likely, and those which were actually small to 30-40 microns the maximum, could all still exist in the field of view. The location of these particles could be observed with the spectrometer and their existence detected by the resonator system. By location of these particles the desired to be of the size, 150 to 300 microns, and near the closed (piston) end. Observation with objects of many suspended particles, and when a rotation significantly for several minutes, appeared to be either in the area of a flier or in the resonator. So, just as to be noted, small external disturbances, etc. can be observed by a greater incline of the motion of the objects, etc. and placing in the observations of equilibrium of the objects, etc. in the resonator and that a change of factors, calculation, and such,
A nearby open window was sometimes sufficient to cause noticeable disturbance and that only the particles near the closed end remained relatively unaffected.

The magnitude of the total disturbance (Figures 20 and 21) observed was seen to be much greater with the open than with the closed end (gitter) of. The same amount, for example in the middle, the observed to increase with increase of pressure (Figures 20 and 21). The final situation was such that the number of particles with one particle each in the upper central (Table A) all recorded in Figures 20 and 21. It is also well that such observations adequately and the results must be regarded with caution.

Detailed observations of the dust particles were made in the hope that their behaviour, although often small, would shed additional light on the general nature of the results. At most it is a close-up photograph of some of the lateral "cloud of a", and it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in 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little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it may be of little significance to be interested in the lateral "cloud of a", it ma...
tion of dust figures as observed as a part of a cloud moving from a lateral lead into the bottom of the tube. Usually several of these dust ridges became long figures. One board had always been the open end of the miniature tube. To visualize it, the dust figures all collapsed into ridges. They collapsed also if a large obstruction opened up the middle of the receiver allowing the current to escape. Dust figures then were usually observed to collapse into an operation, a sort of reversal of the work process. The board of dust ridges was first visible at a point where ridges observed to be about one and one-half inches in length, and finally, about twice the observed particle path length observed at the new location. The observation at the lower cycle of 0.03 inches, the same relation shows that 2.48 yields the width of just length of charge to find a mean as figures were observed.

The value of longitudinal current is greater near the open end. If the charge, about 0.05 cm per second, was added to the system, then the electron current would be about threefold of that per second. The charge is at the third of the tube length for the open end and in the control start position; for the movement of transverse current length near the open end and opposite, although it appears that the normal
...condition has stabilized. Last figures, arriving at the rear end of the resonator, fill in the cavitation cavity, and feed out the central jet. The produced an excellent grade in alluding the ionizing central flow, that of the jet as shown in Figures 21, 22, and 23, and shows the degree of symmetry in the flow.

Limitation of results

The chief factor affecting the results obtained was the instrumentation detail with reference to the cluster and length of all tubes and restrictions used in the pressure measured system. Qualitative evaluation of the data would depend on a detailed analysis of the calculated values. The lines presented in the dimension of relating theory (Ann. 11, 12, 10).

It was found that a basic requirement was the exercised of extreme care with regard to the uniformity of the test equipment at each station. During the course of the investigation, one member still active was eliminated.

The reproducibility of results was excellent. The results did not appear to be positive by the small variation.
in which condition it was experienced.

The above conclusions are derived from the following observations: the dust was found to be spherical, and that the two components of the ray parallel to the axis of the dust were found to be completely independent of each other, the results not being checked by any other method. The latter appears generally, also, everywhere to be the same, and even with the addition of these and the dust being 'white light', it appears somewhat similar than the dust of any color.

The general conclusions arrived through the above visual observations apply in all branches of the case, and as far as they appear to be justified, will be confirmed and the generalization adopted. The determination of the dust particle will be made by the addition of the amount of light scattered by the differential concentration and the amount of light transmission, also, in the dust particle itself by a function of the particle size.
These combinations, however, lead to a variety of interesting patterns and relationships in terms of resonances.

(1) According to the principle of energy conservation, the resonator's energy levels are determined by the resonator's properties and external influences. If the resonator is closed, its major aspects are axial and lateral interactions with surrounding effects.

(2) In the axial and lateral resonances, the major propagation modes are determined by the resonator's design and configuration, with corrections for closed systems.

(3) The resonant modes of the resonator become critical as the resonator's dimensions and the nature of the medium around it influence the shape and behavior of the resonant modes.

(4) The axial and lateral resonances are inversely proportional to the square of the resonator's length. This relationship allows for the manipulation of resonant modes and the control of their characteristics, including their amplitudes and frequencies.

(5) The ratio of the amplitudes and wave patterns, as well as the phase relationships, are critical for understanding the resonant modes and their interactions. These considerations are essential for optimizing resonator performance.
even splitting taking its combination part.

(5) As the natural free standing boundary on the major portion of the resonator, a point that will not reverse the wave motion. The natural boundary on the major central point is the resonator, a point that will not reverse the wave motion.

(6) The specific nature of the velocity being low, is indicated by the slowness of the pulser motion, which of, or just inside, the resonator completion.

(7) The natural behavior of the wave motion inside the resonator indicates that the wave motion is the natural behavior. This behavior is on the boundary, which is normal to a natural point that is said to be the natural solution.

(8) The natural behavior of the wave motion in the resonator indicates that the wave motion is the natural behavior. This behavior is on the boundary, which is normal to a natural point that is said to be the natural solution.

(9) The natural behavior of the wave motion in the resonator indicates that the wave motion is the natural behavior. This behavior is on the boundary, which is normal to a natural point that is said to be the natural solution.
The data of a number of cases showed that the suppression of the external vibration, in effect, made the vibrations and the open and closing conditions of the valves, which caused the water to oscillate. In some instances, if a valve of a horizontally-agitated, parallel, "his, blessed, blessed" were at the bottom of the line and inclined at an angle, the water was highly efficient in the pump and seemed to be at fault. The apparatus was, in effect, the "his, blessed, blessed" used in the reservoir, connected with a parallel, a valve of oscillation, and caused a "his, blessed, blessed" shallow.

(10) "his, blessed, blessed, a valve of oscillation, the apparatus in action, which is described as follows: "his, blessed, blessed."


### Table 1

**DECLARATIONS OF THE VIBRANT FREQUENCY FOR VARIOUS RESONATOR CONFIGURATIONS**

(Resonator Wall Mean Static Pressure Data)

|------------------|--------------|---------------|-----------|------------------|-----------|

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*See apparatus and interpretation from limitations.*
### Table II

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*See Limitations*
### Table IV

**Injection and Static Pressure Data, 
Comparative Effect of Variations in Stroke**

**Instrumentation:** Small static pressure

**Stroke Stroke:** 0.778 in.

**Reservoir Length:** 100 in.

**Reservoir:** Dual configuration plus ... 15 in.

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**Table:**

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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td>1</td>
<td>.0</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td>2</td>
<td>.0</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td>3</td>
<td>.0</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td>4</td>
<td>.0</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

**Data:**

- See apparatus and instrumentation
- See Li I'aliano
### Table V

Resistance Wall Test Static Pressure Static

**with Various Piston Strokes**

<table>
<thead>
<tr>
<th>Instrumentation</th>
<th>Wall Statics</th>
<th>Resonator Basic Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piston Stroke, in.</td>
<td>0.001</td>
<td>0.202</td>
</tr>
<tr>
<td>RPM</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>Hg</td>
<td>29.42</td>
<td>27.42</td>
</tr>
<tr>
<td>t</td>
<td>0.13</td>
<td>0.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sta. No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piston Stroke, in.</td>
<td>0.001</td>
<td>0.202</td>
<td>0.405</td>
<td>0.672</td>
<td>2.072</td>
</tr>
<tr>
<td>RPM</td>
<td>1000</td>
<td>1500</td>
<td>2000</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>Hg</td>
<td>29.42</td>
<td>27.42</td>
<td>29.42</td>
<td>30.42</td>
<td>29.42</td>
</tr>
<tr>
<td>t</td>
<td>0.13</td>
<td>0.30</td>
<td>0.13</td>
<td>0.30</td>
<td>0.13</td>
</tr>
</tbody>
</table>

**Notes:**
- See Apparatus and Nomenclature
- See Limitations
### Table V2

**CALCULATED TANK VALUES**

(Pressure data from Figures 3 and Table V)

<table>
<thead>
<tr>
<th>$\omega$</th>
<th>$W$ (at piston)</th>
<th>$W$ (at open edge)</th>
<th>$L$ (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.179</td>
<td>24.44</td>
<td>10.6</td>
<td>-0.4</td>
</tr>
<tr>
<td>0.379</td>
<td>29.01</td>
<td>10.1</td>
<td>-0.7</td>
</tr>
<tr>
<td>0.578</td>
<td>25.81</td>
<td>10.7</td>
<td>-0.2</td>
</tr>
<tr>
<td>0.792</td>
<td>25.34</td>
<td>10.3</td>
<td>-0.5</td>
</tr>
<tr>
<td>0.921</td>
<td>27.51</td>
<td>10.0</td>
<td>-0.1</td>
</tr>
</tbody>
</table>
TABLE II

<table>
<thead>
<tr>
<th>Type of Probe</th>
<th>L-head=3</th>
<th>L-head=3</th>
<th>L-head=1</th>
<th>Cyl.-4</th>
<th>L-head=3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( l^1 )</td>
<td>( b_0 )</td>
<td>( b_y )</td>
<td>( b_{ho} )</td>
<td>( b_{hi} )</td>
<td>( b_{ho} )</td>
</tr>
<tr>
<td>0.20</td>
<td>-0.22</td>
<td>0.12</td>
<td>43.32</td>
<td>12.40</td>
<td>15.47</td>
</tr>
<tr>
<td>0.75</td>
<td>-0.56</td>
<td>-0.10</td>
<td>2.60</td>
<td>3.45</td>
<td>4.27</td>
</tr>
<tr>
<td>1.75</td>
<td>-0.72</td>
<td>-0.33</td>
<td>2.82</td>
<td>2.35</td>
<td>3.63</td>
</tr>
<tr>
<td>2.75</td>
<td>-0.60</td>
<td>0.11</td>
<td>3.35</td>
<td>2.39</td>
<td>5.23</td>
</tr>
<tr>
<td>3.75</td>
<td>-0.83</td>
<td>0.01</td>
<td>1.03</td>
<td>12.54</td>
<td>10.22</td>
</tr>
</tbody>
</table>

*See Apparatus and Terminology.
**See Liitation.

Refers to null position of probe introduction. See Terminology.
### Table I

<table>
<thead>
<tr>
<th>Instrumentation:</th>
<th>Internal transducer, cylinder probe (4)</th>
<th>Resonator:</th>
<th>Resonator configuration</th>
<th>Motor stroke: 0.978 in.</th>
<th>Resonator length: 127.4 in.</th>
<th>End edge shape: Square</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Location from tube wall, in. (1)</th>
<th>Probe opening orientation</th>
<th>Probe opening orientation</th>
<th>Probe opening orientation</th>
<th>Probe opening orientation</th>
<th>Probe opening orientation</th>
<th>Probe opening orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.75</td>
<td>23.23</td>
<td>28.22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
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<tr>
<td>2.75</td>
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<td>18.22</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>2.75</td>
<td>9.82</td>
<td>14.82</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>2.75</td>
<td>6.82</td>
<td>11.82</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2.75</td>
<td>4.82</td>
<td>9.82</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2.75</td>
<td>2.82</td>
<td>7.82</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2.75</td>
<td>0.82</td>
<td>4.82</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2.75</td>
<td>-0.20</td>
<td>6.43</td>
<td>-0.20</td>
<td>-0.20</td>
<td>-0.20</td>
<td>-0.20</td>
</tr>
<tr>
<td>2.75</td>
<td>-0.46</td>
<td>8.62</td>
<td>-0.46</td>
<td>-0.46</td>
<td>-0.46</td>
<td>-0.46</td>
</tr>
<tr>
<td>2.75</td>
<td>-0.56</td>
<td>10.43</td>
<td>-0.56</td>
<td>-0.56</td>
<td>-0.56</td>
<td>-0.56</td>
</tr>
<tr>
<td>2.75</td>
<td>-0.67</td>
<td>12.23</td>
<td>-0.67</td>
<td>-0.67</td>
<td>-0.67</td>
<td>-0.67</td>
</tr>
<tr>
<td>2.75</td>
<td>-0.82</td>
<td>14.03</td>
<td>-0.82</td>
<td>-0.82</td>
<td>-0.82</td>
<td>-0.82</td>
</tr>
<tr>
<td>2.75</td>
<td>-1.00</td>
<td>16.43</td>
<td>-1.00</td>
<td>-1.00</td>
<td>-1.00</td>
<td>-1.00</td>
</tr>
<tr>
<td>2.75</td>
<td>-1.39</td>
<td>18.74</td>
<td>-1.39</td>
<td>-1.39</td>
<td>-1.39</td>
<td>-1.39</td>
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<td>2.75</td>
<td>-0.97</td>
<td>21.03</td>
<td>-0.97</td>
<td>-0.97</td>
<td>-0.97</td>
<td>-0.97</td>
</tr>
<tr>
<td>2.75</td>
<td>-1.11</td>
<td>23.33</td>
<td>-1.11</td>
<td>-1.11</td>
<td>-1.11</td>
<td>-1.11</td>
</tr>
</tbody>
</table>

*See apparatus and nomenclature.*

**See limitations.*

*Refers to wall position of probe introduction. See nomenclature.
# Table III

**Lateral Mean Pressure Data**

*Traverse in Horizontal Axial Plane*

<table>
<thead>
<tr>
<th>Instrumentation</th>
<th>External Traverse</th>
<th>Distance from</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Probe</td>
<td>(c)</td>
<td>(c)</td>
<td>(c)</td>
<td>(c)</td>
<td>(c)</td>
<td>(c)</td>
</tr>
<tr>
<td>Pressure Drop</td>
<td>0.02</td>
<td>0.23</td>
<td>0.41</td>
<td>0.62</td>
<td>0.64</td>
<td>0.69</td>
</tr>
<tr>
<td>Flow Rate</td>
<td>11.01</td>
<td>12.01</td>
<td>13.01</td>
<td>14.01</td>
<td>15.01</td>
<td>16.01</td>
</tr>
</tbody>
</table>

**Trafine Data**

<table>
<thead>
<tr>
<th>Trafine Unit</th>
<th>1.00</th>
<th>0.50</th>
<th>0.25</th>
<th>0.08</th>
<th>0.32</th>
<th>0.08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Deviation</td>
<td>-4.00</td>
<td>-3.50</td>
<td>-3.00</td>
<td>-2.50</td>
<td>-2.00</td>
<td>-1.50</td>
</tr>
<tr>
<td>Min. Deviation</td>
<td>-5.50</td>
<td>-5.00</td>
<td>-4.50</td>
<td>-4.00</td>
<td>-3.50</td>
<td>-3.00</td>
</tr>
<tr>
<td>Mean Deviation</td>
<td>-3.00</td>
<td>-2.50</td>
<td>-2.00</td>
<td>-1.50</td>
<td>-1.00</td>
<td>-0.50</td>
</tr>
</tbody>
</table>

---

*Note: See apparatus and instrumentation.*

*See limitations.*

*Traverse in all positions or direction of probe introduction."

"T" is positive on the forward side of probe introduction. See definition.

"Total and average values in all from (in) or away from (out)."
<table>
<thead>
<tr>
<th>Probe</th>
<th>-0.30</th>
<th>0.0</th>
<th>0.84</th>
<th>-0.15</th>
<th>-0.43</th>
<th>-2.0</th>
<th>-0.38</th>
<th>-1.0</th>
<th>c</th>
<th>0.13</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.38</td>
<td>-0.59</td>
<td>6.04</td>
<td>0.27</td>
<td>0.43</td>
<td>-0.27</td>
<td>0.11</td>
<td>-0.48</td>
<td>-0.15</td>
<td>-0.50</td>
</tr>
<tr>
<td>1.0</td>
<td>0.91</td>
<td>-0.11</td>
<td>-0.65</td>
<td>-0.15</td>
<td>-0.50</td>
<td>-0.12</td>
<td>-0.16</td>
<td>-0.24</td>
<td>0.0</td>
<td>12</td>
</tr>
<tr>
<td>2.0</td>
<td>-0.71</td>
<td>-0.60</td>
<td>0.73</td>
<td>-0.41</td>
<td>-0.65</td>
<td>0.40</td>
<td>-0.46</td>
<td>-0.68</td>
<td>5.0</td>
<td>0.40</td>
</tr>
<tr>
<td>3.0</td>
<td>0.32</td>
<td>-0.68</td>
<td>0.16</td>
<td>-0.65</td>
<td>0.40</td>
<td>-0.46</td>
<td>-0.68</td>
<td>5.0</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>-0.30</td>
<td>0.0</td>
<td>0.72</td>
<td>-0.41</td>
<td>-0.65</td>
<td>0.40</td>
<td>-0.46</td>
<td>-0.68</td>
<td>5.0</td>
<td>0.40</td>
</tr>
<tr>
<td>5.0</td>
<td>0.32</td>
<td>-0.68</td>
<td>0.16</td>
<td>-0.65</td>
<td>0.40</td>
<td>-0.46</td>
<td>-0.68</td>
<td>5.0</td>
<td>0.40</td>
<td></td>
</tr>
</tbody>
</table>

 Traverse in horizontal plane:

**Traverse Instrumentation**

**Traverse stroke:**

- **Basic Operation:**
  - Basic Parameters:
    - Make-up:
      - Length: 107.4 in.
      - Width: 100 in.
      - Depth: 22.4 in.
      - Volume: 29.42 cu. in.
      - Distance: 29.42 in.
      - Angle: 90°

**Probe Positive:**

- **Probe Parameter:**
  - Make-up:
    - Length: 107.4 in.
    - Width: 100 in.
    - Depth: 22.4 in.
    - Volume: 29.42 cu. in.
    - Distance: 29.42 in.
    - Angle: 90°
<table>
<thead>
<tr>
<th>Piston Stroke, in.</th>
<th>Partsile, in.</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.054</td>
<td>1.8</td>
<td>Visual Observation</td>
</tr>
<tr>
<td>0.075</td>
<td>1.5</td>
<td>Photograph (see Fig. 20, 21)</td>
</tr>
<tr>
<td>0.758</td>
<td>0.2</td>
<td>Visual Observation</td>
</tr>
<tr>
<td>0.750</td>
<td>0.0</td>
<td>Visual Observation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Filtration Particle, Air Lough, in.</th>
<th>Osevated Particle Size, A.;in.</th>
<th>Uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>0.05</td>
<td>Visual</td>
</tr>
<tr>
<td>0.58</td>
<td>0.15</td>
<td>Visual</td>
</tr>
<tr>
<td>0.25</td>
<td>0.05</td>
<td>Visual</td>
</tr>
<tr>
<td>0.750</td>
<td>0.01</td>
<td>Visual</td>
</tr>
</tbody>
</table>

Particle path extremely uncertain as solution, while particles inside the water tank were stable. Therefore, the problem of apparent water flow at straight line. Hence, the last results should be neglected qualitatively.
Figure 5. A typical setup for E. coli with a "wall unit" instrumentation.
FIGS. RESONATOR MEAN STATIC AND TOTAL PRESSURE DISTRIBUTION IN AXIAL DIRECTION (DATA FROM TABLES VII, VIII, IX)

△ WALL STATIC PRESSURE
O AXIAL STATIC PRESSURE
▷ AXIAL TOTAL PRESSURE FACING PISTON
★ AXIAL TOTAL PRESSURE FACING AWAY FROM PISTON

PISTON STROKE: 0.75 IN.

TOTAL FACING PISTON

TOTAL FACING AWAY FROM PISTON

△ WALL STATIC

AXIS STATIC

DISTANCE FROM OPEN END OF TUBE, IN (INTERNAL)
FIG. 7  MEAN PRESSURE DISTRIBUTION IN JET ALONG RESONATOR AXIS OF SYMMETRY
(DATA FROM TABLES IXa, XI b, X, VIII, and XI)
PISTON STROKE = 0.978 IN.

DISTANCE ALONG RESONATOR AXIS OF SYMMETRY, IN: -60, -54, -45, -42, -36, -30, -24, -18, -12, -6, 0, 12, 18, 24, 30, 36, 42

-4 -3 -2 -1 0 1 2 3 4
SAME MEAN PRESSURE, IN H2O

• MEAN STATIC PRESSURE, INTERNAL PROBE (2)
• MEAN TOTAL PRESSURE, INTERNAL PROBE (4), FACING PISTON
• MEAN TOTAL PRESSURE, INTERNAL PROBE (5), FACING AWAY FROM PISTON
• MEAN TOTAL PRESSURE, EXTERNAL PROBE (5), FACING AWAY FROM PISTON
• MEAN TOTAL PRESSURE, EXTERNAL PROBE (6)

EXTERNAL

-60 -54 -45 -42 -36 -30 -24 -18 -12 -6 0 12 18 24 30 36 42
FIG. 8  RESONATOR WALL STATIC PRESSURE DISTRIBUTION
FOR VARIOUS MAGNITUDES OF PISTON STROKE
(DATA FROM TABLE V)

\[ x = 0.054 \text{ INCHES PISTON STROKE} \]

\[ v = 0.293 \]

\[ w = 0.342 \]

\[ \Delta = 0.762 \]

\[ O = 0.778 \]

\[ \pm \text{ EXPERIMENTAL ERROR} \]

DISTANCE FROM OPEN END OF RESONATOR, IN. (INTERNAL)
FIG. 10  EFFECT OF OPEN END SHAPE ON MEAN STATIC PRESSURE AT THE RESONATOR SURFACE

(DATA FROM TABLE IV)

EXPERIMENTAL ERROR

PISTON STROKE = 0.978 IN.

GAGE MEAN STATIC PRESSURE, IN. H2O

DISTANCE FROM OPEN END OF RESONATOR, IN.
FIG. 11  EFFECT OF FREQUENCY ON MEAN STATIC PRESSURE
AT THE RESONATOR SURFACE FOR FIXED RESONATOR LENGTH
(DATA FROM TABLE III)

△ 1848 R.P.M.
○ 1703 R.P.M. (RESONANCE)
□ 1761 R.P.M.

△ ○ □ EXPERIMENTAL ERROR
PISTON STROKE ≈ 0.778 IN

GAGE MEAN STATIC PRESSURE, IN. H₂O

DISTANCE FROM OPEN END OF RESONATOR, IN.
FIG. 12  EFFECT OF FREQUENCY ON MEAN STATIC PRESSURE AT THE RESONATOR WALL FOR SELECTED STATIONS (DATA FROM TABLE III)

PISTON STROKE = 0.778 IN.

GAGE MEAN STATIC PRESSURE, IN H2O

FREQUENCY (RPM)

1850  1875  1900  1925  1950
FIG. 13 DETERMINATION OF RESONANT FREQUENCY FOR BASIC RESONATOR CONFIGURATION BY MEASURING THE MEAN STATIC PRESSURE AT THE RESONATOR SURFACE (DATA FROM TABLE I)

PISTON STROKE = 0.978 IN.
FIG. 14  DETERMINATION OF RESONANT RPM
FOR TAPERED LIP RESONATOR CONFIGURATION
(TWO INCHES ADDITIONAL LENGTH)
(DATA FROM TABLE II)
PISTON STROKE = 0.978 IN.

GAGE MEAN STATIC PRESSURE, IN H2O

FREQUENCY (RPM)

1800  1825  1850  1875  1900
FIG. 15  THRUST FOR BASIC RESONATOR CONFIGURATION.
(Data from Table VI)

L = 10.74 IN.
D = 5.5 IN.
FIG. 16 INTERNAL RADIAL TRAVERSE, MEAN STATIC PRESSURE (DATA FROM TABLE VII)
PISTON STROKE = 0.918 IN.
FIG. 17  MEAN PRESSURE PROFILES
IN JET OUTSIDE DF
RESONATOR OPEN END
DATA FROM TABLES XII, XII
PISTON STROKE = 0.778 IN

DISTANCE FROM RESONATOR AXIAL IN

GAGE MEAN PRESSURE, IN H2O

-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
0 1 2 3 4 5 6

-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
0 1 2 3 4 5 6

# GAGE MEAN STATIC PRESSURE
# GAGE MEAN TOTAL PRESSURE, FACING PISTON
# GAGE MEAN TOTAL PRESSURE, FACING AWAY FROM PISTON
# EXTERNAL DISTANCE FROM RESONATOR OPEN END, MEASURED ALONG CENTRAL AXIS, IN
# EXPERIMENTAL ERROR
FIG. 18. INTERNAL RADIAL TRAVERSE
MEAN TOTAL PRESSURE
(DATA FROM TABLE IX)
PISTON STROKE = 0.378 IN.

GAGE MEAN TOTAL PRESSURE IN. H₂O

STATION 2  STATION 10  STATION 17

D = "L" TYPE TOTAL-HEAD PROBE FACING PISTON
Q = "H" TYPE TOTAL-HEAD PROBE FACING AWAY FROM PISTON
> = CYLINDER TYPE TOTAL-HEAD PROBE FACING PISTON
< = CYLINDER TYPE TOTAL-HEAD PROBE FACING AWAY FROM PISTON
FIG. 27  VARIATION OF DEPTH OF PENETRATION OF RESONATOR, BY END VORTEX SYSTEM, WITH MAGNITUDE OF PISTON STROKE.

(DATA FROM TABLE XII)

Ω ESTIMATED FROM DIRECT OBSERVATION
\[ \Delta \] ESTIMATED FROM PHOTOGRAPHS
FIG. 30  ESTIMATED DUST PARTICLE PATH LENGTH FOR DIFFERENT MAGNITUDES OF PISTON STROKE.
(DATA FROM TABLE XII, VISUAL ESTIMATIONS)
\( \theta = 0.014 \text{ in.} \)
\( \Delta = 0.292 \text{ in.} \)
\( \nabla = 0.542 \text{ in.} \)

FIG. 31  VARIATION OF ESTIMATED DUST PARTICLE PATH LENGTH WITH PISTON STROKE.
(DATA FROM TABLE XII, VISUAL ESTIMATIONS)
\( \theta \) STATION 3.
\( \Delta \) STATION 17.
\( \nabla \) PISTON.
FIG. 32. IDEALIZED TIME-DISTANCE DIAGRAM OF WAVE PROGRESS IN A RESONATOR CLOSED AT ONE END BY A PULSATOR AND OPEN AT THE OTHER END.

PISTON MID-STROKE POSITION

DIRECTION OF VELOCITY INCREMENTS PULSE STRENGTH

DIRECTION OF WAVE TRAVEL

TIME

1.0

0.51 DISTANCE

COMPRESSION

RAREFACTION
SAMPLE CALCULATIONS

RESONATOR FREQUENCY:
\[ \pi = 2.75 \text{ in.}; \quad L = 107.4 \text{ in.}; \quad t = 88^\circ F \text{(Table I)}; \]
\[ f = \frac{12 \cdot 1148}{4[107.4 + 0.6(2.75)]} = 31.63 \text{ c.p.s.} = 1898 \text{ R.P.M.} \]

VELOCITY:
\[ h_o = -0.67 \text{ in. } H_2 O \text{ (Table I, Sta. 1)} \]
\[ h_s = -3.68 \text{ in. } H_2 O \text{ (Table VIII, Sta. 1)} \]
\[ V = \sqrt{\frac{2(h_o - h_s)}{\rho}} = \sqrt{\frac{2(64.2)(3.68 - 0.67)}{(12)(0.002378)}} = 116 \text{ ft./sec.} \]

THRUST:
\[ H_a = 29.42 \text{ in. } H_2 O = 400 \text{ in. } H_2 O \text{ (Table IV)} \]
\[ h_s^{(piston)} = h_s = +6.6 \text{ in. } H_2 O \text{ (Fig. 8, uncorrected)} \]
\[ h_s^{(open \text{ edge})} = h_s = -3.6 \text{ in. } H_2 O \text{ (Fig. 8, uncorrected)} \]
\[ T = \rho_t \cdot A_p + \rho_e \cdot A_e - \rho_a \pi (\ell)^2 \]
\[ \rho_t = \text{absolute pressure on piston, lbs/in}^2 \]
\[ \rho_e = \text{" " " open-end edge, lbs/in}^2 \]
\[ \rho_a = \text{" " " atmospheric assumed acting externally on unit.} \]
\[ A_p = \text{piston area} = \pi (2.75)^2 = 23.80 \text{ in}^2 \]
\[ A_e = \text{open-end edge area} = \pi (3)^2 - A_p = 4.48 \text{ in}^2 \]
\[ T = \frac{62.4}{12.144} \left[ 406.6(23.8) + 376.4(4.48) - 400(28.28) \right] \]
\[ = 6.06 \text{ lbs.} \]
Investigation of the air-flow in an acoustic jet at a resonance.