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BULLETIN OF THE
INSTRUMENTATION
PANEL

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PROJECT SQUID

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Project SQUID is a program of fundamental research on liquid rocket and pulse jet propulsion for the Bureau of Aeronautics and the Office of Naval Research of the Navy Department.

This Bulletin of Project SQUID is published to provide practical information regarding techniques and instrumentation in the field of jet and rocket propulsion.

Papers are contributed by scientists and engineers, working in this field at laboratories throughout the country. The Bulletin will serve as a medium of exchange for these workers in order to expedite progress in the field of propulsion.

PROJECT SQUID

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PAPERS

APPARATUS FOR MEASUREMENT OF GAS
TEMPERATURES UNDER TRANSCIENT CONDITIONS

by

Max Carbon, R. J. Albert and G. A. Hawkins
Purdue Research Foundation and Purdue University
Lafayette, Indiana

The design and construction of apparatus capable of detecting, amplifying, and recording the voltage generated by a thermocouple that is in contact with a gas, the temperature of which fluctuates rapidly presents many problems. Since very rapid temperature changes (120 times per second) are encountered, the apparatus to be useful must operate with extreme rapidity.

The ordinary methods of thermocouple voltage recording are much too slow for use in this research program. Therefore, it was decided to use an oscilloscope and a rotating drum camera to record the voltage fluctuations. A schematic diagram of the apparatus is shown in Figure 1.

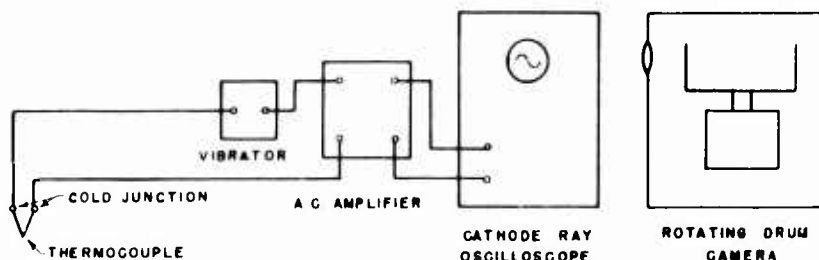


FIG 1 SCHEMATIC DIAGRAM OF TEST APPARATUS

The use of an oscilloscope for this work necessitates the use of an instrument to amplify the thermocouple voltage. Since direct current amplifiers are often unstable, it was decided to "chop-up" the voltage and use an alternating current amplifier. A rotary switch was designed to perform

the chopping operation, although such a switch has definite disadvantages.

A modulator tube, operating at 60 cycles per second was used for timing the voltage fluctuations. By proper focusing, it was hoped to obtain timing marks on the recording paper from which it would be possible to interpret the results.

EQUIPMENT

Oscilloscope

A Du Mont Type 247 Oscilloscope with a blue, 5 inch screen was chosen since it was immediately available for use.

Rotating Drum Camera

A rotating drum camera was available for use without alteration.

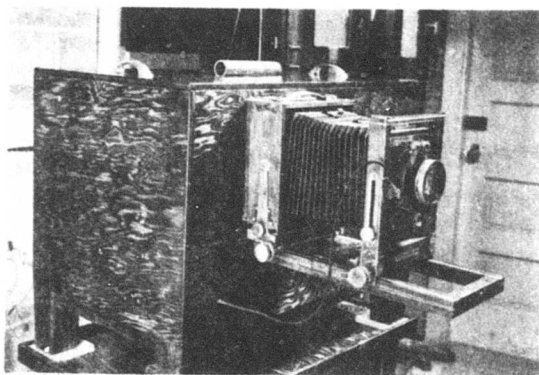


Figure 2.

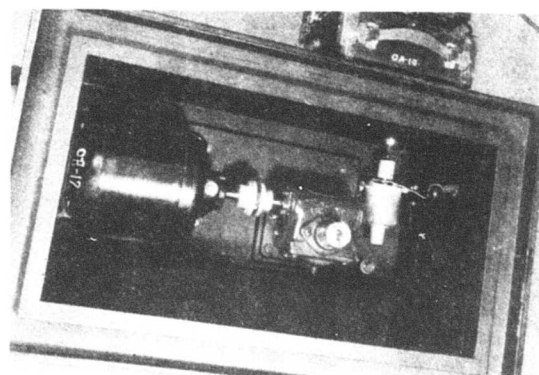


Figure 3.

The camera is a commercial type with a Bausch and Lomb $f/4.5$ lens and a one to 0.01 second shutter. It is attached to a cabinet-box as shown in Figure 2. This cabinet houses a synchronous type, 1800 R.P.M. motor, reduction gears, a rotating drum geared to rotate at 245 R.P.M., and a solenoid for operating the shutter (Figure 3).

The hollow drum, (Figure 4) is 7 inches in diameter, and is fitted with a pin which keys it to the socket on top of the reducing gear casing.

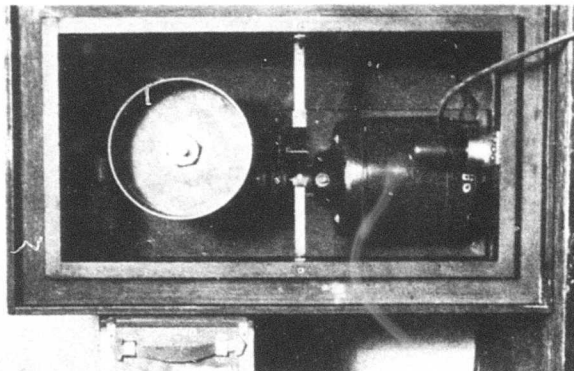


Figure 4.

A light-tight box housing the rotating drum is mounted on the underside of the cover of the cabinet-box (Figure 5).

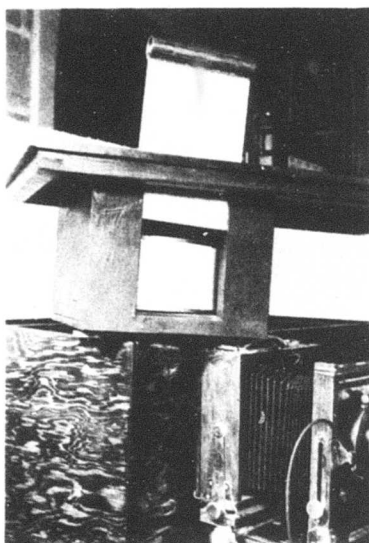


Figure 5.

The front of this box is fitted with a metal slide which makes it possible to load and unload sensitized paper without taking the entire cabinet into the dark room. A hole in the bottom of the small box allows the pin on the under side of the drum to engage the driving socket of the gear casing. During operation, the drum is held clear of the bottom of the box by the socket; and, when the entire cover is removed, the drum seats itself against a piece of felt on the bottom of the box. The modulator tube and lens which are also shown in Figure 4 will be discussed later in detail.

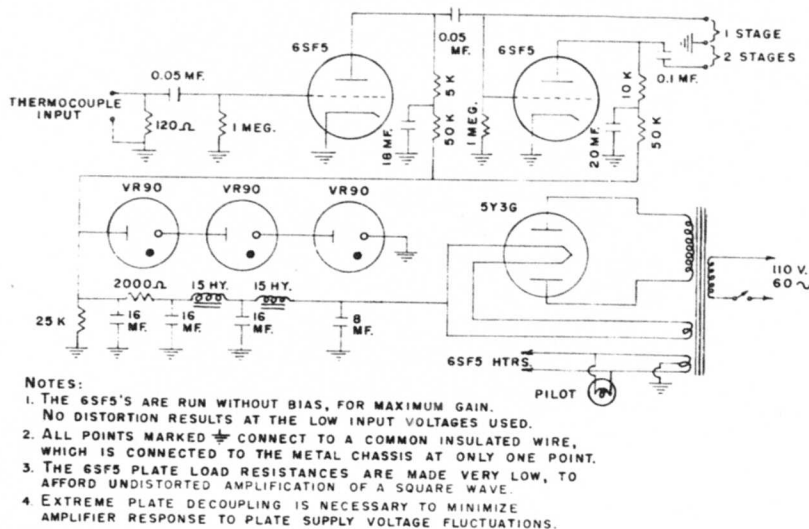


FIG. 6 VOLTAGE AMPLIFIER

Voltage Amplifier.

The amplifier circuit is shown in Figure 6. It has two stages and employs two 6SF5 Hi-Mu triodes. Three Vr-90 tubes are used to stabilize the line voltage. Nearly all the leads within the mounting were shielded to prevent electrostatic pick-up; every lead outside the amplifier was shielded. In addition, all the shields were grounded.

Chopper.

By far the most difficult job to date has been to obtain a suitable device for interrupting the thermocouple voltage. The group of research workers which designed the rotating drum camera also designed a rotary switch capable of interrupting the voltage at a rate 1800 times per second. The switch consisted of a synchronous motor with a disc mounted on the shaft. The disc was made of bakelite with a brass ring around the perimeter and with brass bars extending radially outward from the center as shown in Figure 7.

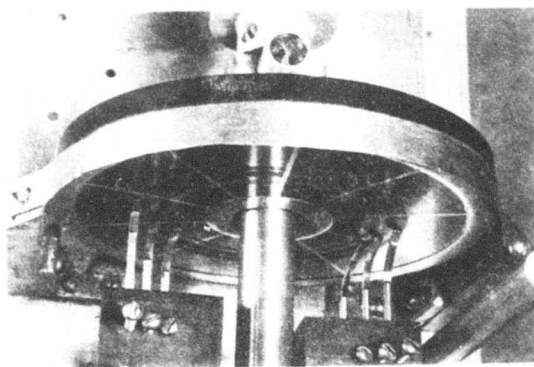


Figure 7.

A copper band was held in contact with the outside brass ring, and brass brushes were held in contact with the disc by means of small phosphor-bronze springs. For a simple switch only one brush need be used. The circuit consists of the copper band, the brass ring, any of the bars, and the brush. Under this system only one side of the thermocouple voltage is interrupted. This switch proved unsatisfactory because of the sliding contact and high speed of rotation. Although several types of brushes were used, none proved better than brass. In each instance an excessive amount of static electricity

is introduced through the sliding contact, and too much maintenance work is required to consistently obtain a square wave.

An electrically-driven tuning fork with a frequency of 70 vibrations per second was then tried. A contact point was mounted on the end of one of the prongs; opposite this, another contact was mounted in a stationary position. The tuning fork was then substituted for the rotary switch in the circuit. Excellent results were obtained by using silver coated points; the points passed substantially a square wave.

The next step would have been to use a tuning fork of higher frequency; but, since no high-frequency fork was available in the laboratory, it was decided to experiment with the driving element from an old style loud speaker unit. A silver-coated point was mounted on the reed of the element and another was mounted directly opposite it. An electronic circuit to drive the element was constructed, and the contact points were placed in the thermocouple circuit. Since it was driven by the audio oscillator, practically any desired frequency could be obtained. The results, however, were not satisfactory because the contact points chattered and a square wave could not be obtained. All efforts to eliminate the chattering proved unsuccessful.

A type "172 Millisec Relay" manufactured by the Stevens-Arnold Company was then installed in the circuit. This relay is designed to operate in one millisecond, and it was hoped that it would serve as an interrupter. However, due to chattering of the contact points, the use of the unit was discontinued.

Finally it was found that the vibrator from a Brown Elektronik temperature recorder, although designed to operate at about 60 vibrations per second, would operate very well at frequencies of 800 to 850 vibrations per second.

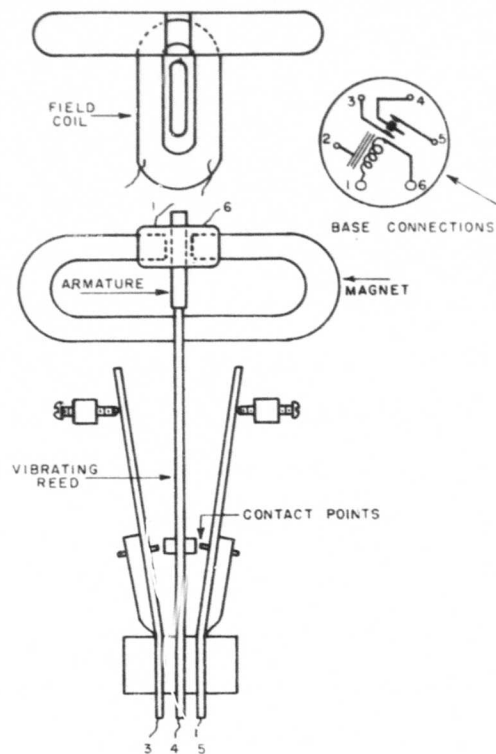


FIG. 8 BROWN VIBRATOR

The vibrator is shown schematically in Figure 8, and the circuit which is used to drive it is shown in Figure 9.

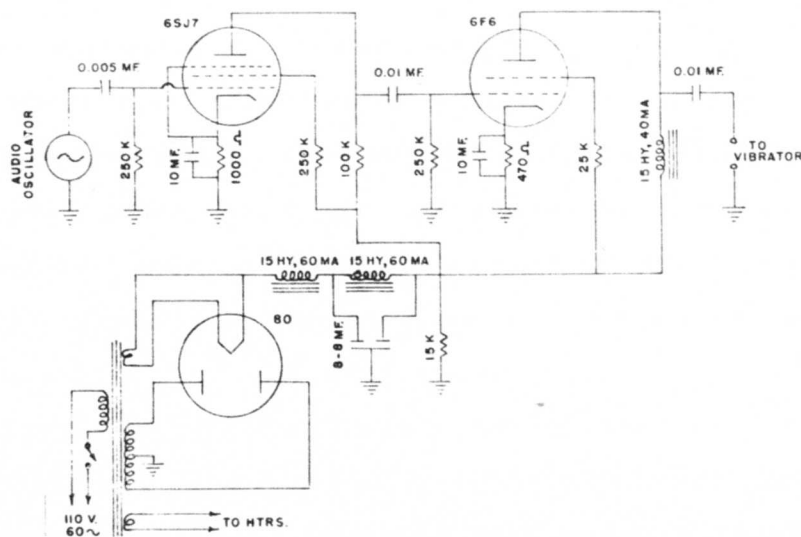


FIG. 9 VIBRATOR DRIVE

EXPERIMENTAL

Various procedures and apparatus were used in the evaluation of the usefulness of the equipment. A system has been developed to provide a variable and intermittent amount of heat for temperature measurement by the thermocouple. The thermocouple is mounted on the end of an arm which moves back and forth through an arc resulting from the action of an electric motor.

(Figure 11)

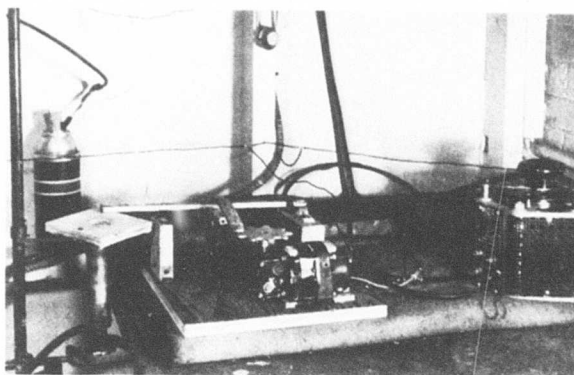


Figure 11.

A Meeker burner is mounted opposite the end of the arm, and an insulating disc is mounted above the burner in order to restrict the size of the flame and to prevent undue radiation to the couple when it is not in the flame. When in operation, the arm moves the thermocouple back and forth through the flame. This apparatus was designed for temporary use and will be replaced by a new unit of improved design.

In order to know the exact time at which the thermocouple enters the flame, the apparatus shown in Figure 12 was developed.

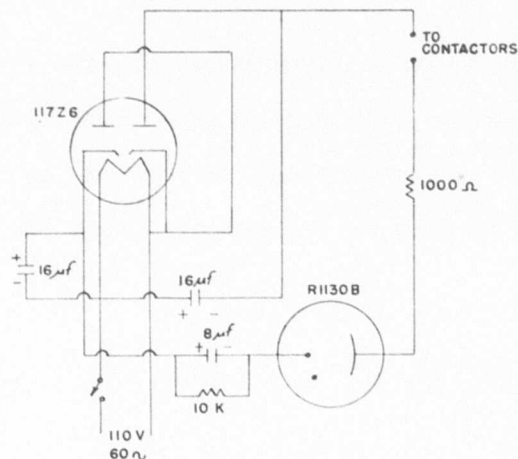


FIG. 12 POSITION MARKER

This circuit employs an R-1130 modulator tube, but it is designed to cause a steady beam of light to be emitted when the switch is closed. The switch in this case is a set of contact points mounted on the arm which carries the couple (See Figure 11). The points are so adjusted that when the couple enters the flame, contact is made resulting in a light flash from the tube. This light is reflected by a mirror directly into the camera lens, as shown in Figure 13.

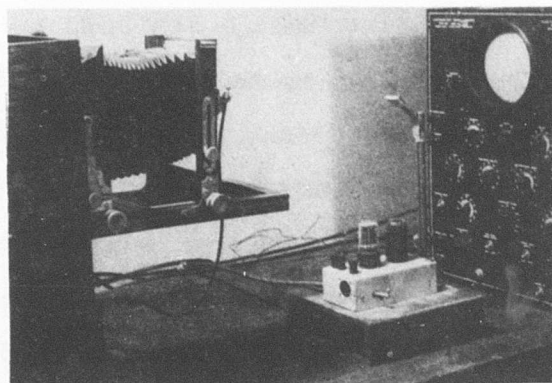


Figure 13.

By aligning the light beam and the oscilloscope trace, it is possible to cause a mark to be made on the recording paper which indicates the exact time the thermocouple enters the flame. A duplicate set of contact points is used to indicate the time the thermocouple leaves the flame.

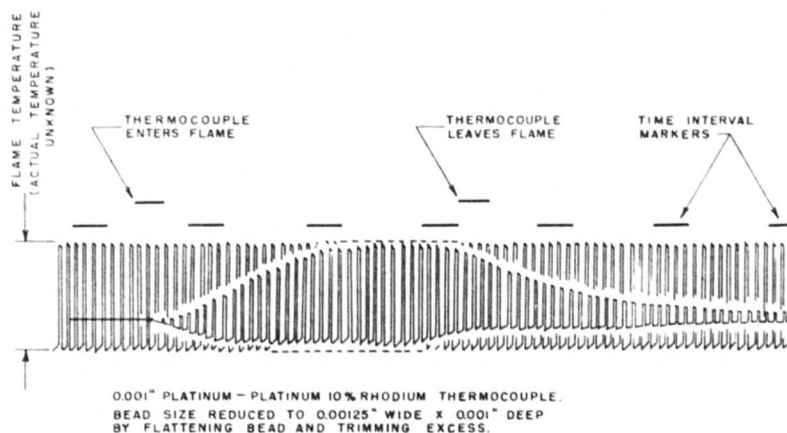


FIG. 14 RECORD OF TEST

Figure 14 is a copy of an actual test record. The thermocouple used was a 0.001 inch diameter Pt-Pt/Rh, 10%, couple with a bead diameter slightly greater than the size of the wire.

The total time lag of the instrument is very small as compared with the response time of the thermocouple. The amplifier and oscilloscope operate almost instantaneously and the persistence time of the oscilloscope screen is of the order of 10^{-4} second. Obviously, the camera can introduce no lag, and since the position marker (indicating when the thermocouple enters and leaves the flame) is operated electrically the greatest time error in the voltage recording system is introduced by the persistence time of the screen.

Thus far the actual flame temperature has not been determined since the main interest has been to determine the percent of maximum rise the thermo-

couple attains during various lengths of time in the flame. Each photograph has superimposed on it, along with the heating curve of the thermocouple, a picture of the oscilloscope screen showing the maximum temperature the thermocouple reaches when held stationary in the flame. Later it will be necessary to determine the actual temperature in order to obtain the effect of the temperature difference between the couple and the flame on the response time of the couple.

The oscilloscope screen has not been calibrated against various y-axis input voltages. However, previous experiments have indicated that a straight line relationship exists between the voltage and the height of the trace on the screen, if the trace is restricted to a height of about 3 inches and is kept in the middle of the screen.

An insufficient number of experiments have been conducted to properly estimate the experimental error. The greatest error will probably be introduced in interpreting the height of the trace on the photographic paper. However, the error should be within 3 percent.

A SHIELDED THERMOCOUPLE FOR GAS TURBINES

by

Andrew I. Dahl and Ernest F. Flock
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Washington, D. C.

Research sponsored by the Bureau of Ships at the National Bureau of Standards on the measurement of gas temperatures has led to the development of a shielded thermocouple suitable for use in gas turbines. In such power plants the gases are normally much hotter than the surrounding metal walls, so that radiation from the sensing instrument to the walls may cause considerable error. The conventional method of shielding by coaxial tubes has the obvious disadvantages of large size with attendant problems of installation, undesirable disturbance of gas flow, and slow response to sudden changes in gas temperature. Even more effective shielding, without these disadvantages, can be obtained by pressing a small shield of silver directly on a junction of base-metal thermoelements.

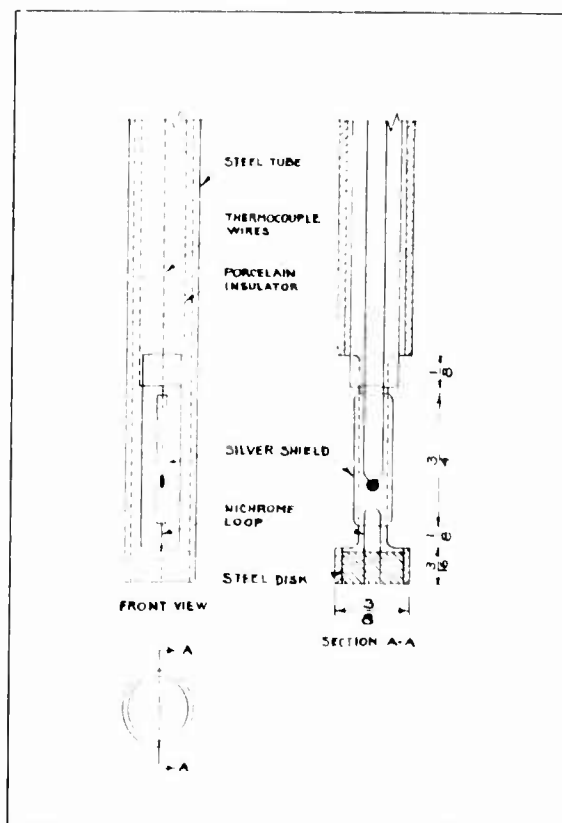


Figure 1

A typical unit of this type is shown in Figure 1. A junction between the base-metal thermoelements is made in a conventional manner, as by autogenous welding, and the resulting bead is dressed to the form of a disk having a thickness about equal to the diameter of the wire. The disk and about 1/2 inch of the adjoining wires are oxidized by heating to a dull red in a mild air-gas flame.

A 3/4 inch length of silver tube, approximately 1/8 inch outside diameter by 0.020 inch thick, is flattened until it slips freely over the disk and wires. The disk and a small loop of nichrome wire of the same diameter as the thermoelements are inserted in the flattened tube approximately as shown.

The flattening of the tube is then completed in a press or vise until the silver clamps all parts firmly. When No. 22 wires are used the shield becomes about 3/16 inch wide and 1/16 inch thick. The free ends of the thermoelements are then inserted in a two-hole porcelain insulator having an external diameter only slightly less than the internal diameter of the metal tube which is to be used for protecting and mounting the unit.

A convenient protecting tube, without influence on the performance of the shielded junction, is also shown in Figure 1. Slots are cut near one end of the tube to permit passage of gas over the entire shield, and a disk drilled to take the free ends of the nichrome loop is fixed in the tube just below the slots. Before the disk is fastened, it must be oriented so that the shield assumes the position indicated with respect to the slots. The junction assembly is then inserted through the open end of the protecting tube to the position shown. Stabilized stainless steel, such as Type 347, is recommended for protecting tubes to be used in gas turbines.

It is convenient to make the pressure seal at the cool end of the protecting tube with an appropriate cement, such as Sauereisen. The head of the unit may consist of a thermal block which provides mechanical backing for the hardened cement.

Tests have shown that the oxide coating on base-metal thermoelements provides adequate electrical insulation between these and the shield. The nichrome loop, which has no significant effect on the temperature attained by the junction, provides mechanical stability which has been found necessary in some applications.

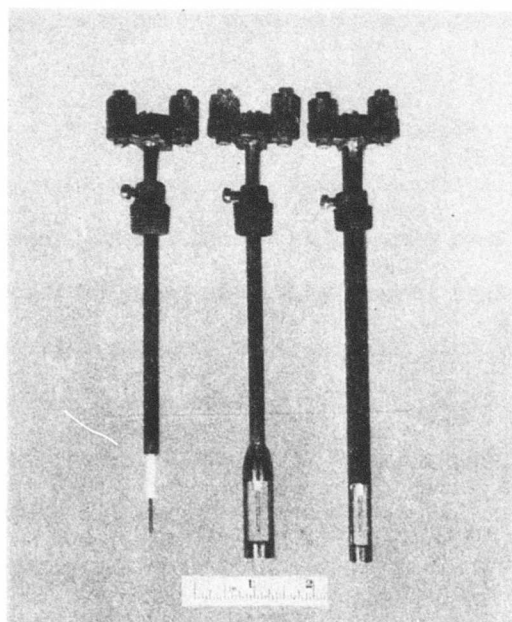


Figure 2

Figure 2 is a photograph of three typical units, none of which has the nichrome loop. Silver is recommended as a shield for service up to 1500°F. For temperatures up to 2000°F platinum-shielded chromel-alumel junctions are recommended. Although the error due to radiation from platinum is about

3.5 times that from silver, it is still only 1/3 that of a bare junction. The use of pressed platinum shields in products of combustion below 1200°F is to be avoided, because reactions at the surface of the platinum raise its temperature above that of the gas.

The effectiveness of various radiation shields can be illustrated by the following typical experimental results:

Pipe Wall Temp.	True Gas Temp.	Ag-Shielded Junction	Pt-Shielded Junction	Temperature Indicated by Junction with Single-Tube Shield	Bare Junction
-----°F-----					
1200	1500	1494	1478	1432	1480

Charts have been developed for evaluating the radiation corrections which remain with both silver- and platinum-shielded junctions over the range of gas and wall temperatures experienced in gas turbines.

Junctions of No. 22 wire with pressed shields of the dimensions stated have a characteristic time of 1.8 seconds at a mass flow rate of 6.8 lb/sec. ft², as compared with 0.8 seconds for the same junction without a shield. Thus the junctions with pressed shields will respond to sudden changes in temperature at a rate which is satisfactory for all purposes except control. For the latter even bare junctions are considered too slow.

The recovery factor of the shielded junctions is about 0.58 in the range of gas velocities from 400 to 700 ft/sec. The broad faces of the shield should be parallel to the direction of gas flow, but they may be rotated as much as 10° without measurable effect on the recovery factor.

A more detailed report on this instrument is being prepared for presentation at the spring meeting of the American Society of Mechanical Engineers in Milwaukee.

A CANTILEVER STRAIN GAGE FOR HIGH TEMPERATURE
TENSILE AND CREEP TESTING OF SHEET MATERIALS

by

Glen Guarnieri and James Miller
Cornell Aeronautical Laboratory
Buffalo 21, New York

In the course of studying the high temperature load-carrying ability of various sheet stock alloys, instrumentation has been developed for conducting tensile, creep, and stress-rupture tests. The objectives of such tests have been concerned primarily with the evaluation of materials for relatively short life applications as encountered in guided missiles, rockets, and jet engines. The variables of common interest to such investigations are stress, temperature, strain, and strain rate. Basic units of equipment have been constructed or assembled for measuring and controlling these variables.

While conventional types of apparatus have been used for loading, heating, and controlling temperature of the specimen, a strain measuring system has been designed and constructed suitable for determination of elastic modulus, proportional limit, yield stress, and creep deformations of sheet stock at temperatures up to 1800 degrees F. This strain measuring device, while of light weight construction, is sufficiently rugged to permit routine and accurate measurement of a 0.00010 inches change in gage length over a range of approximately 0.2 inches (10 percent elongation in 2 inches).

This instrument was originally developed as part of a contract for the Bureau of Ordnance and has been modified and improved for work on Project Squid.

Extensometers

Measurement of the gage length strain is made by transferring this extension outside of the furnace through two pairs of extensometer arms. These arms (made of 310 stainless steel) grip the specimen through knife edges with the outer arms attached to the upper end of the gage length and the inner arms to the lower end. Thus, the strain in the two inch gage length is represented by the relative motion of these arms. Since all tests conducted with this type of extensometer are at constant temperature (maximum variation of ± 3 degrees F.) negligible errors are introduced due to expansion and contraction of the extension arms. Such errors are further minimized by the fact that one pair of arms acts as a reference for the other and tends to cancel out length changes due to temperature variation.

Cantilever Strain Gage

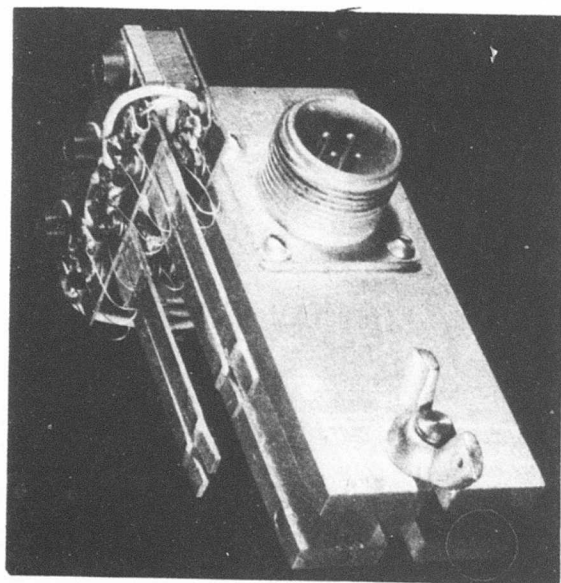


Figure 1

A cantilever beam assembly (Figure 1) which engages the extensometer arms is used to detect their relative motion. SR-4 strain gages attached to both the tension and compression side of each beam near its fixed end, serve to indicate changes in beam deflections due to specimen elongation. When the SR-4 gages are connected as shown in Figure 2, to complete the bridge circuit of a Baldwin-Southwark SR-4 Strain Indicator unit, the amplified unbalanced current in the bridge is a measure of the strain in the specimen gage length.

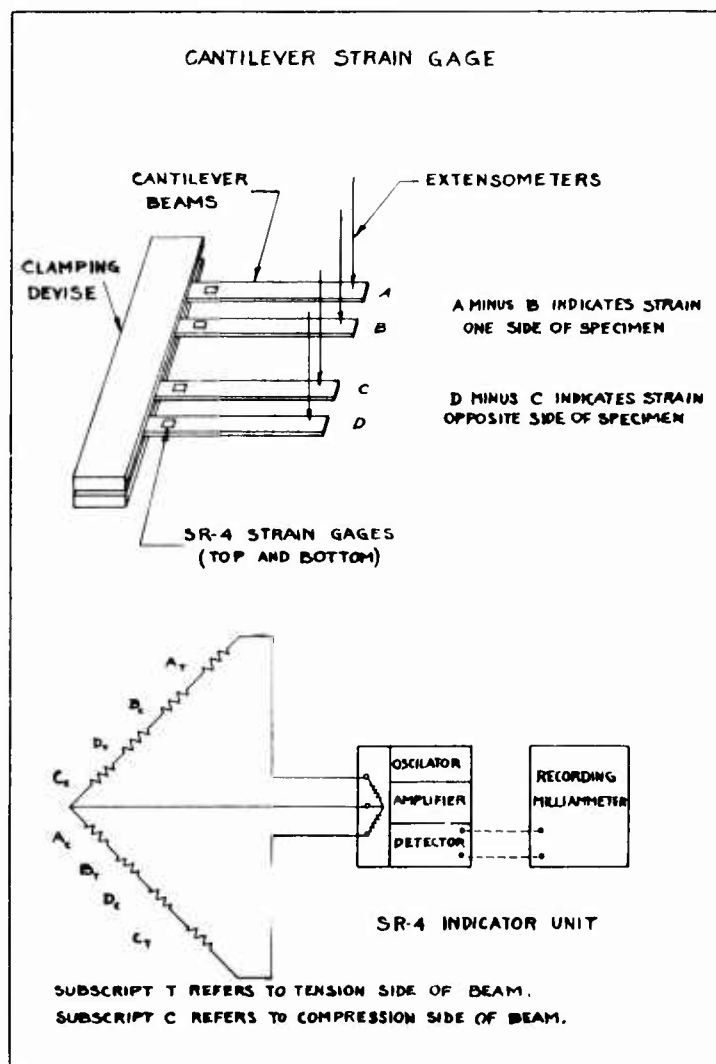


Figure 2

Consideration of the circuit arrangement of the SR-4 wire gages will reveal that the gages on each pair of beams (A and B, or C and D) electrically oppose each other so as to produce a net change in resistance proportional to the difference in deflection of the two beams of each pair and this net change from each pair of beams is electrically added to give a final circuit unbalance that is proportional to the average gage length extension of the specimen. The combined extensometer and cantilever assembly are shown in Figure 3:

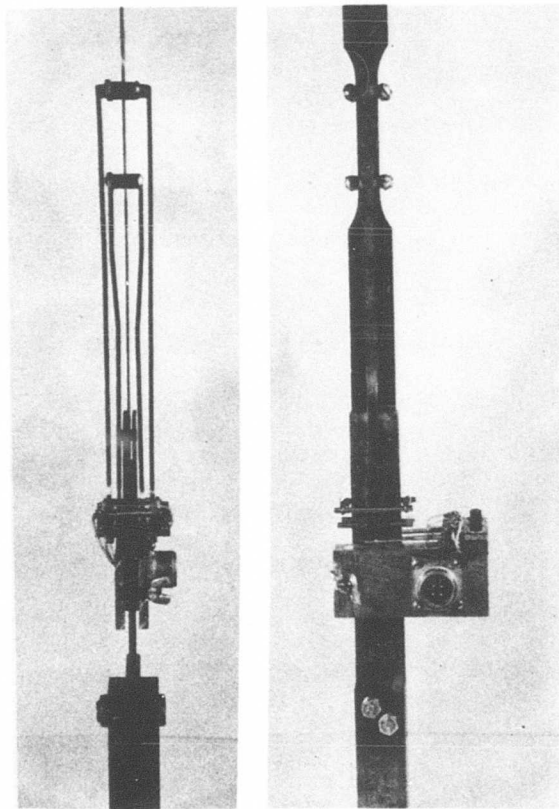


Figure 3

Strain Indicating Systems

A Baldwin-Southwark SR-4 strain indicator, which combines the necessary oscillator, amplifier, detector, and balancing controls in a single portable unit has been used in conjunction with the cantilever strain gage bridge circuit. The unbalanced current output may be read directly on the meter of the strain indicator unit or, as is done for controlled strain rate tension tests, supplied to a recording milliammeter (Esterline-Angus). When using the bridge circuit in its unbalanced condition for recording strain, linearity of output signal vs. specimen strain is limited to about 0.4 percent extension on a 2 inch gage length so that it becomes necessary to rebalance the circuit when this value of strain is reached. Where the bridge is maintained manually in balance, continuous strain readings may be made from the calibrated balancing dial of the SR-4 strain indicator unit up to the limit of the extensometer system.

Calibration of Strain Gage

Determination of the sensitivity factor of the cantilever gage unit (inches of beam deflection per dial division) is accomplished by deflecting the beams known distances with a micrometer and noting the resulting change in meter or dial reading. Close agreement was realized between the experimentally determined value of sensitivity and that calculated according to the cantilever beam formulas (see appendix). In order that the true averaging of both pairs of extensometer arms may be accomplished in the bridge circuit, it is necessary that the individual sensitivity of all four beams be equal. This adjustment is made during assembly of the gage and is controlled by varying the beam span. During the past eight months in which two of these gages have been in use, frequent calibration checks

have revealed their high degree of stability and freedom from change in sensitivity.

In conducting tensile or creep tests at 1800 degrees F., sufficient heat is carried through the specimen holder to the strain gage unit to raise the gage temperature to approximately 150 degrees F. However, no change or drift in sensitivity could be detected by calibration tests conducted on the strain gage while at this higher temperature.

When the system is used for automatic recording of strain, the bridge circuit is operated in its unbalanced condition. With this situation, one precaution must be observed in regard to determination of sensitivity factor. Due to deterioration of the batteries of the SR-4 indicator unit, its oscillator and amplifier outputs will be altered, giving rise to decreased sensitivity (for unbalanced condition only). The actual sensitivity factor is quickly determined by noting the output reading for a standard degree of bridge unbalance as measured by the calibrated balancing dial. Over the useful operating life of the batteries the sensitivity factor will vary from 0.00010 to 0.00013 inches deflection per meter division for unbalanced bridge operation. Where strain measurements are made by maintaining the bridge in its balanced condition, sensitivity is independent of battery condition.

Constant Strain Rate Tension Tests

The cantilever strain gage system has provided a satisfactory means of conducting high temperature tensile tests at controlled rates of strain. By recording the specimen strain on an Esterline-Angus meter, a chart of strain vs. time is obtained. Through the use of an auxiliary margin pen actuated by a solenoid, loads are registered manually on the same paper at selected intervals so that a simultaneous record of load, elongation, and

time is had on the same chart. Figure 4 illustrates the apparatus assembly.

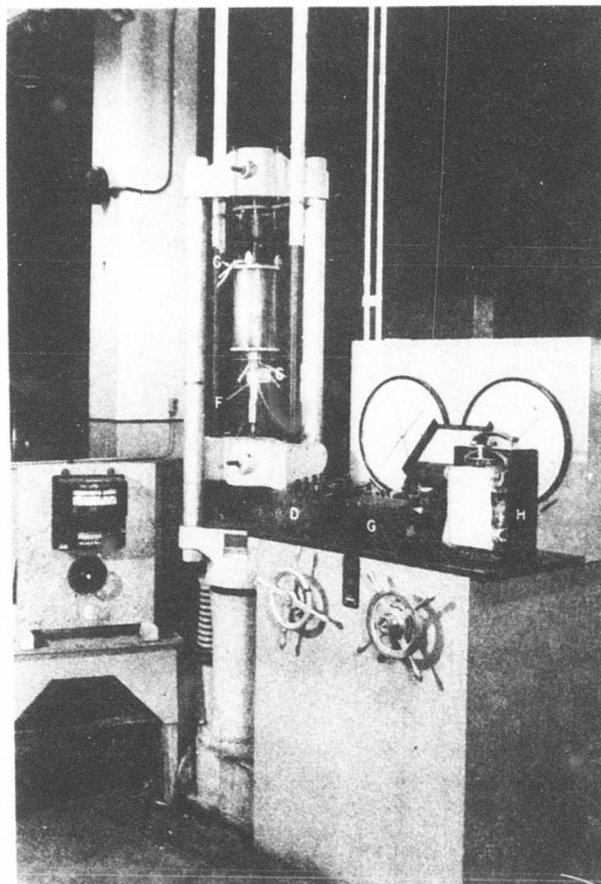


Figure 4.

- A. Tensile Machine
- B. Furnace
- C. Thermocouples
- D. Potentiometer
- E. Temperature Control Panel
- F. Cantilever Strain Gage
- G. SR-4 Bridge and Amplifier
- H. Esterline Angus Recorder

While the specimen is being loaded elastically, a constant strain rate will be maintained on its gage length for a given head speed of the tensile machine. However, as the specimen begins to deform plastically, it becomes necessary to reduce the head speed in order to maintain the same strain rate. The operator accomplishes this by viewing the recording of the time-deformation trace through a plexiglass plate on which are engraved a set of parallel lines adjusted to the slope corresponding to the desired strain rate. Typical stress-strain diagrams plotted from the recorded data for an S-816 sheet material (.042 inch thick) are illustrated in Figure 5.

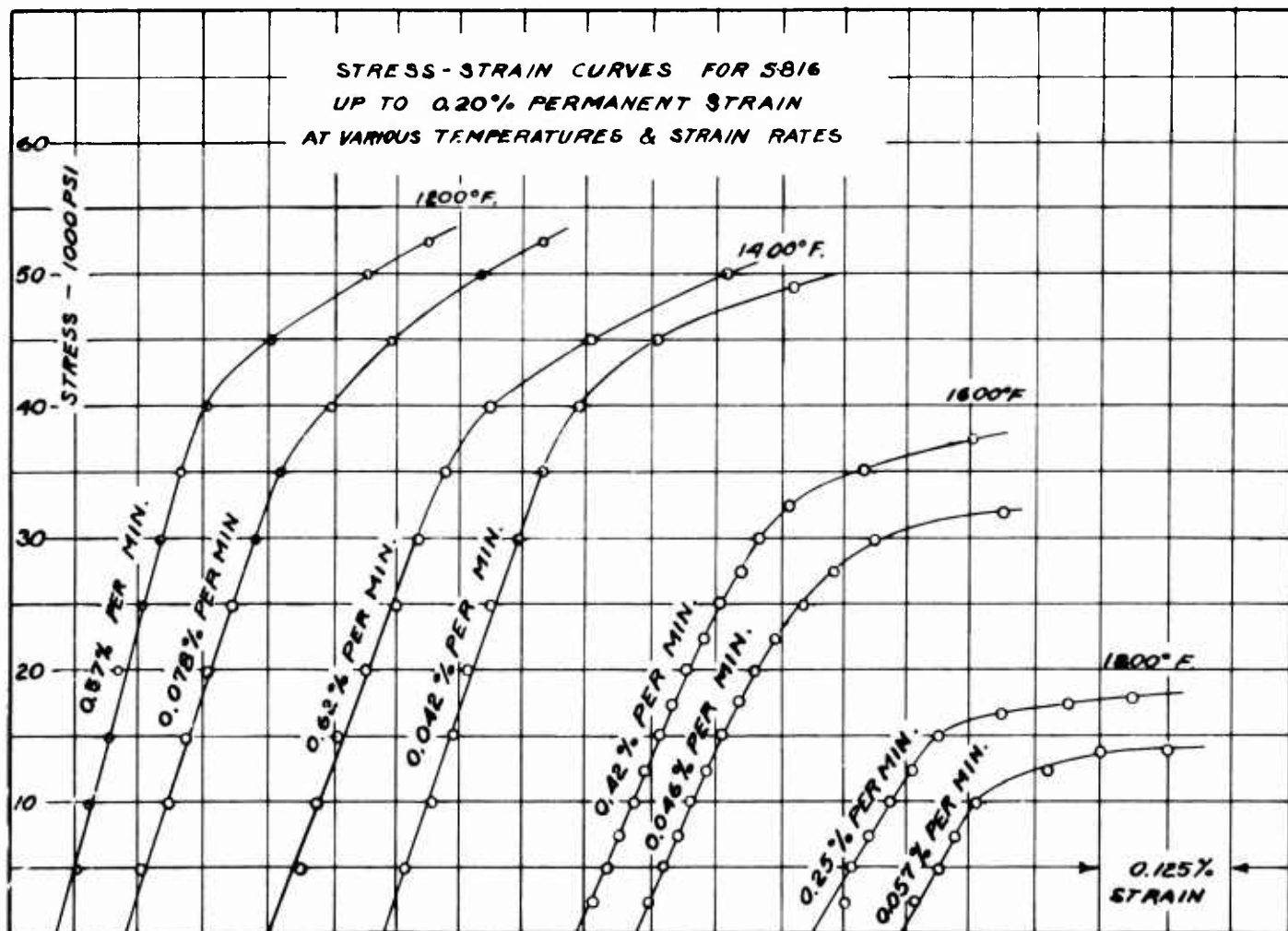


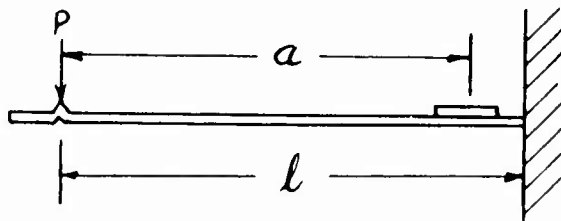
Figure 5.

Creep Tests

The same extensometer system has been used for continuous measurement of strain in constant load high temperature tests of relatively short duration. For the long time creep test, it would be necessary to substitute a regulated D. C. power source for the batteries of the indicator unit if continuous strain recording were required.

APPENDIX

1. Calculation of Sensitivity of Cantilever Strain Gage



Symbols (see diagram):

p = Load from extensometer arm

l = Span of beam

a = Distance between strain gage and point of application of load
(approximate since strain gage has finite length)

t = Thickness of beam

y = Deflection of beam at point of application of load

ϵ = Strain in beam at SR-4 gage

S = Surface fiber stress in beam at SR-4 gage

E = Young's modulus of beam

I = Moment of inertia of beam cross section

Deflection of beam;

$$y = \frac{Pl^3}{3EI} \quad (1)$$

Fiber stress at strain gage

$$S = \frac{Pat}{2I}$$

Since

$$S = Ee, \text{ then}$$

$$e = \frac{Pat}{2EI} \quad (2)$$

Dividing equation (1) by equation (2) gives $\frac{y}{e}$ which is the sensitivity of the system.

$$\text{Sensitivity} = \frac{y}{e} = \frac{2l^3}{3at}$$

In the cantilever strain gages already constructed, the following beam dimensions were used:

$$l = 2.00 \text{ inches}$$

$$a = 1.75 \text{ inches}$$

$$t = 0.040 \text{ inches}$$

These values yield a calculated value for y/e of 76 inches which is reasonably close to the experimental calibration factor of 72 inches deflection per unit strain in the SR-4 strain gage.

Since the SR-4 indicator unit is calibrated in microinches (readings may be estimated to 2 microinches), this permits a cantilever gage sensitivity of 0.00014 inches deflection per dial unit (2 microinches). Where the unbalanced bridge system is used, a slightly greater sensitivity of 0.00010 to 0.00013 inches deflection per meter or paper division is realized.

2. Force Required to Actuate Beams

From equation (1):

$$p = \frac{3EIy}{l^3} \quad (3)$$

$$E = 10.3 \times 10^6 \text{ psi (24-ST aluminum)}$$

$$I = 1/12 bh^3 = .83 \times 10^{-6} \text{ inches}^4$$

$$l = 2.00 \text{ inches}$$

$$\text{Assume maximum deflection } y = 0.25 \text{ inches}$$

Then maximum load required per beam,

$$p = 0.84 \text{ pounds}$$

A DEVICE FOR COMPARING PRESSURE PICK-UPS

By

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When measuring cyclic pressures it is often necessary to evaluate the pressure response and frequency response of the pressure pick-up. Although it is desirable to calibrate the pick-up for various amplitudes and frequencies, calibration is difficult and it is often necessary to resort to a simple comparison of one pick-up with another. For this purpose it is customary to use a pressure wave of some convenient shape with controllable amplitude and frequency.

A device to generate such a pressure wave is described in an article entitled "Dynamic Pressure Transmitter Calibrator," written by Richard D. Meyer, and published in the Laboratory and Shop Notes section of the Review of Scientific Instruments; Vol. 17, No. 5; May 1946. This device provides a source of fluctuating air pressure which may be used as a test signal in the study of pressure pick-ups. It consists of an air passage which exhausts through a series of holes in a rotating wheel. The holes are drilled at an angle so that the air makes the wheel rotate. The opening and closing of the exit causes the pressure to fall and rise in the passage thus producing a modulated pressure wave.

The disadvantage of this particular driving method is that the frequency and amplitude are inter-related. In order to eliminate this an NRL model has a separate air supply which drives the wheel as a turbine. The

advantage is more independent control of the peak-to-peak amplitude and frequency although the exiting gas still has some effect on the speed of the wheel. In addition, more connections were provided so that two or more pick-ups could be used simultaneously.

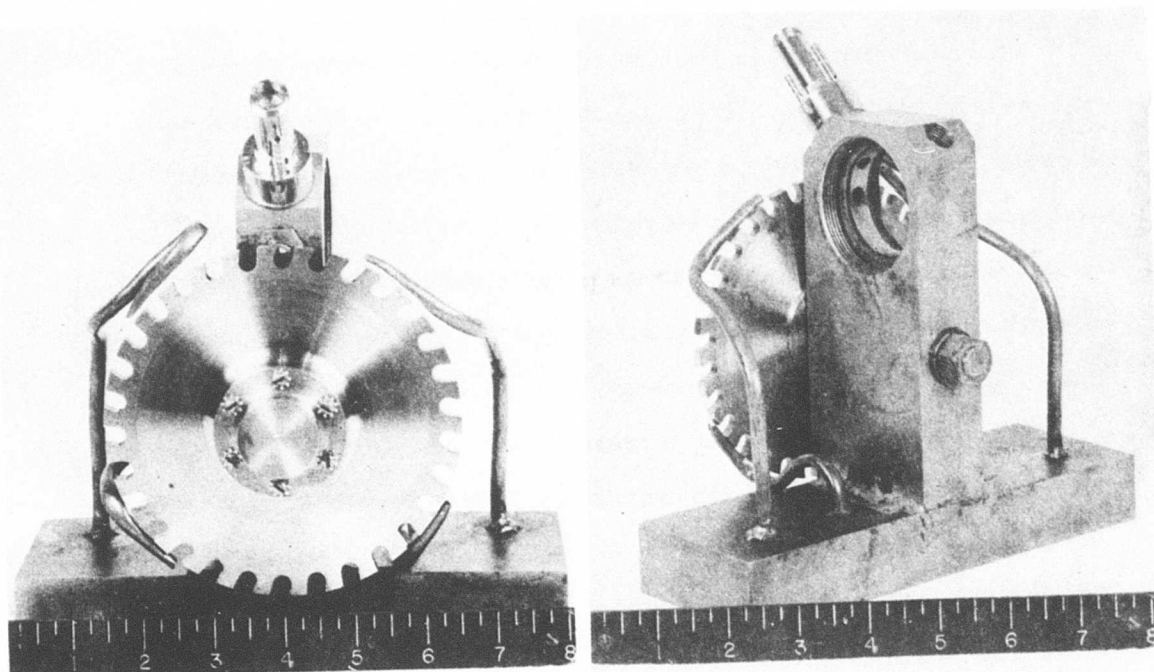


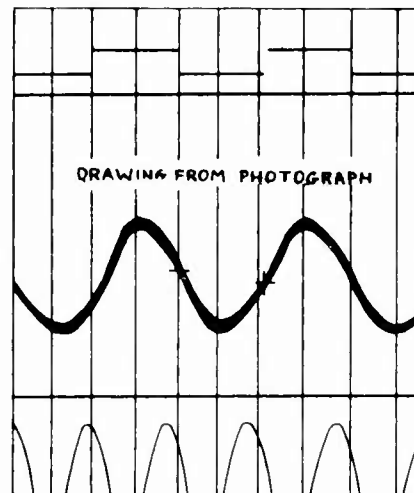
Figure 1 is a photograph illustrating the shape and size of this device. The large openings are tapped with a 2.25 inch - 16 thread for some of the larger pressure pick-ups. The wheel is 5.125 inches in diameter and has 30 slots, each 0.25 inch wide. The circular holes terminating the slots are centered on a 4.75 inch diameter. The steel wheel is 0.375 inch thick at the perimeter. Two sets of ball bearings are mounted inside the wheel. As depicted in the photograph, the slots are milled at an angle

to the radial lines for driving. This particular device has been used at speeds from 20 rpm up to 3,000 rpm. The corresponding pressure frequencies are 10 cps to 1,500 cps. Although higher speeds could be attained by using a larger inlet line or higher pressure air, this particular range was sufficient for studying the pressure pick-ups under consideration.

This pressure generating device is useful for comparing the amplitude and frequency response of two pick-ups. The pressure generator permits study of mechanical inertia, damping, and carrier frequency. Three different types of pressure indicating devices have been compared on this pressure generator. They are an inductance type, a capacitance type, and a balanced diaphragm type. The frequency response of the first two is limited by carrier frequency as well as by mechanical inertia. The particular inductance type pick-up studied has a carrier frequency of 2,200 cps. Since, in an amplitude modulated system, the frequency response is limited to approximately one-fourth the frequency of the carrier, the over-all system is good only up to 550 cps. This is lower than the natural frequency of the pick-up—about 1,000 cps in this case. In any carrier system there is a lag caused by the use of the carrier and, in particular, by the phase shift in each component which is not purely resistive. The demodulation system generally provides the greatest fraction of such phase shift. If the carrier frequency is constant, then the phase shift is of constant time—generally about 3 or 4 cycles of the carrier. For the low frequency carrier used with the inductance pick-up, this amounts to approximately 1.5 milliseconds and is constant over a wide range of signal frequency.

The pressure records made using the turbine-driven pressure generator are exemplified in Figures 2 and 3. Both of these are from the same record

made when the turbine was accelerating. There were two pressure pick-ups mounted in the pressure chamber; one an inductance pick-up and the other a balanced-diaphragm pick-up. The straight lines on the record are reference lines. Time is measured from left to right. Timing lines are at 0.01 second intervals. The bottom sine wave was produced by an audio oscillator adjusted to 50 cps. The top signal (a square wave) was produced by the balanced diaphragm unit with 20 psig pressure applied to the back of the diaphragm. Hence, this signal indicates a reference pressure of 20 psig. The center sinusoidal wave was produced by the inductance pick-up. This particular unit is characterized by an objectionable hum caused by inadequate filtering of the carrier in the demodulation circuit. It is this hum which makes the "hash" on this trace.



The section shown in Figure 2 was taken when the pressure wave had a frequency of 25 cps and illustrates the lag caused by the low frequency carrier. If lines are drawn down from the square wave produced by the balanced diaphragm pick-up, they should intersect the pressure-time diagram at points representing 20 psig. The pressures at these points should be

the same whether the pressure is rising or falling. However, the lines drawn on this record give two points which are not on the same level of pressure. The first indicated pressure is 21.5 psig, the second is 18.8 psig, and the average is 20.15 psig. This agrees closely with the reference pressure (20 psig) applied to the back of the diaphragm. Because of the direction of the difference it seems as though the inductance pick-up did not respond fast enough. This lag has been found to be not in the pick-up itself but in the electronic system.

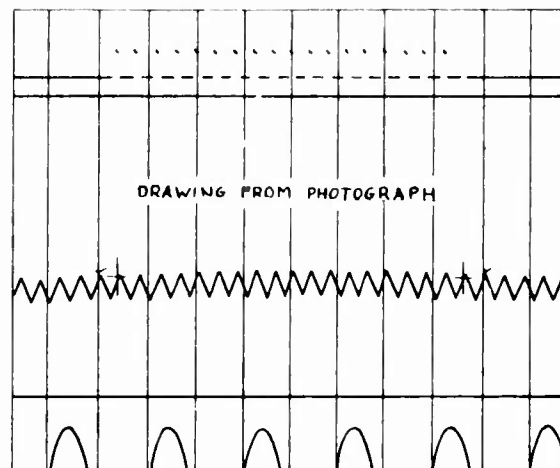


Figure 3 is another section from the same record and illustrates the effect of a slight misalignment of the turbine wheel. Since the leakage between the nozzle and the openings in the wheel varied, the average pressure in the chamber rose and fell slightly throughout each revolution as demonstrated by the record from the inductance pick-up. In this case there are 18 cycles in which the pressure was above the reference point as determined by the back pressure on the balanced diaphragm unit and indicated by the pips in the top trace of the oscillographic record. The peaks corresponding to the first and last pip indicate a dynamic pressure of just

20 psig. This agrees exactly with the reference pressure of 20 psig impressed upon the balanced diaphragm unit. Hence, the misalignment provides a method of comparing these two types of pressure pick-ups with complete disregard of the lag. The frequency for this particular record is computed for the cycles extending from the two small check marks. Since there are approximately 20 pressure cycles for 8 of the timing lines, the frequency of the pressure wave was 250 cps.

These records illustrate the results which can be obtained with the turbine driven pressure generator, and show some of the techniques by which pressure pick-ups may be investigated. The wave shape is nearly sinusoidal and is quite useful in determining the response of pressure indicating devices over a wide range of pressure amplitude and frequency. The air drive is particularly convenient for obtaining a wide speed-range without any belts, pulleys, or gears. In addition, the possibility of having two or more pick-ups exposed to the same pressure wave is a convenience since it permits an immediate observation of phase shift or of variance in indicated amplitude of one in relation to the other.

A COMPARISON OF THE SODIUM LINE REVERSAL AND INFRA-RED
EMISSION SPECTRA METHODS OF
FLAME TEMPERATURE DETERMINATION

by

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Richmond, Virginia

SUMMARY

Flame temperature surveys in a Meker type burner carried out by means of both sodium line reversal and water rotational emission spectra techniques are presented. Pertinent data comparing the two methods are included.

INTRODUCTION

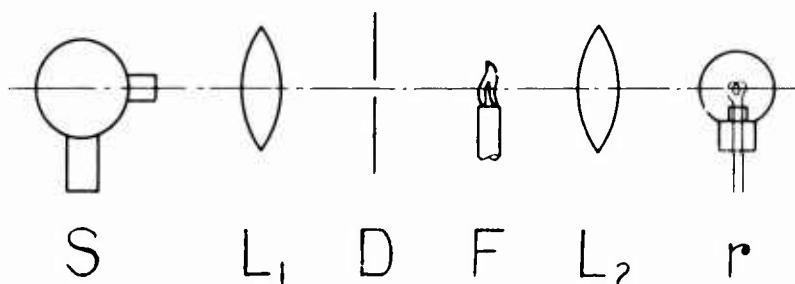
The desirability of using optical methods of temperature measurement in high velocity air streams has been indicated in a previous report (1). Two such methods which appear to have possibilities in this connection are the sodium line reversal method, and infra-red photography of the water rotational emission spectra. It was decided to evaluate these methods through temperature studies of a flame of very simple geometry, and consequently, temperature traverses of the flame from a Meker type burner have been carried out under various conditions. The Meker burner was chosen for study because it offers a flat flame front, corresponding to some of the requirements of the infra-red photographic technique, and its large grid offers an opportunity for selective coloration of the flame in sodium line reversal studies. It was hoped that the data obtained would yield valuable information as to the effectiveness of each method and would enable an accurate comparison of the two procedures.

A. SODIUM LINE REVERSAL STUDIES

1. Theory:

The sodium line reversal method consists of matching the apparent brightness of a radiating body with that of sodium vapor in a flame through which the radiator is viewed at the characteristic wave length of sodium. The theory of the method has been described on numerous occasions in the literature. (2), (3), (4), (5).

The apparatus was arranged on an optical bench as follows:



S = Prism Spectrometer

L₁, L₂ = biconvex lenses

D = Diaphragm

F = Sodium colored flame being investigated

r = comparison radiator (General Electric
6 volt, 18 amperes tungsten strip
filament lamp)

Light from the comparison radiator is focused through the lens L₁, on a colored portion of the flame. This image

and the flame serve as the object for the lens, L_2 . The compound image from L_2 is then focused upon the slit of the spectrometer. Viewed through the spectrometer the sodium lines appear to be superimposed on the continuous spectrum from the comparison lamp. At reversal the sodium lines will disappear in this continuous background instead of appearing bright (when lamp is at low intensity), or dark (when lamp is at high intensity).

2. Experimental Part:

The strip filament lamp was calibrated in terms of the current passing through it, using an optical pyrometer. Another lamp calibrated by the National Bureau of Standards served as a standard for checking the calibration.

A lens correction is necessary for L_1 , since only the light from r passes through this lens. However, both the radiation from r and the radiation from F pass through lens L_2 so no correction need be made in the latter case. The correction for L_1 was obtained by measuring the temperature of the lamp filament with lens L_1 between it and the pyrometer, and measuring the temperature without the lens. A color correction must also be made, since r is calibrated with the pyrometer in terms of red brightness temperature whereas the comparison with the colored flame is made in the yellow spectral region. A calibration curve including these corrections is shown in Figure 1.

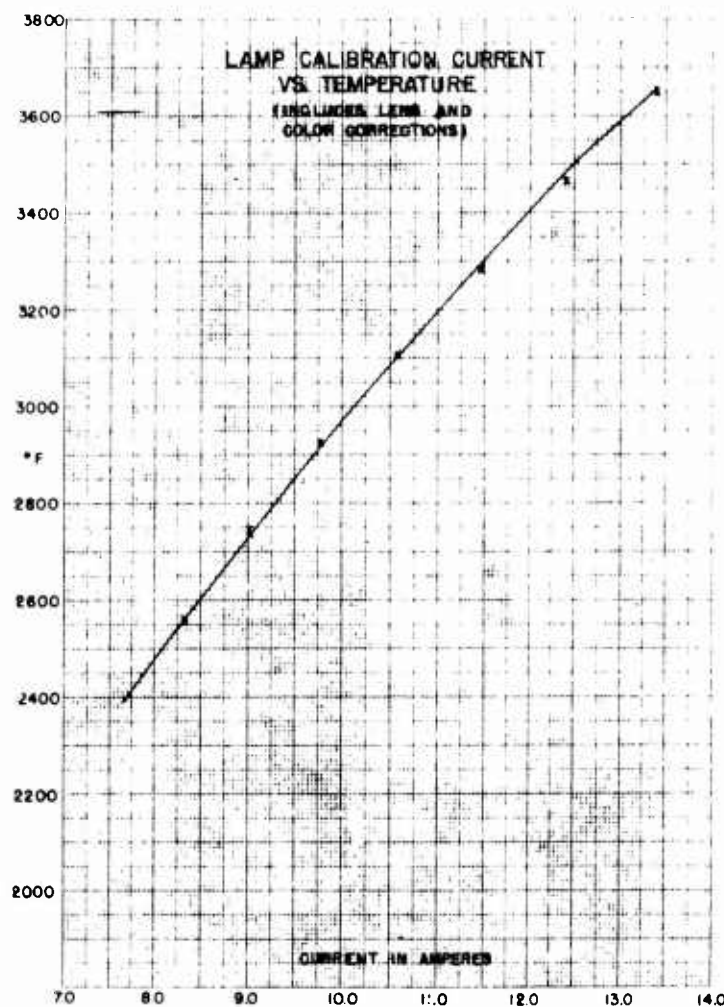


Figure 1

Butane (tech. grade) was used as the fuel and (as well as the air) was metered before entering the Meker burner. The flame was colored with sodium chloride which was ground to a powder, mixed with a little collodion and formed into small pieces. These could then be placed on the grid of the burner in the proper place to give local coloring to the desired portion of the flame.

Temperatures were obtained by the following steps:

- (a) The reversal point was approached from low-lamp intensity and the current through the lamp measured.
- (b) The reversal point was approached from high-lamp intensity and the current through the lamp measured.
- (c) After averaging a and b, the corrected temperature was obtained from the calibration curve.
- (d) Repeated a, b, and c.
- (e) Obtained an average value for the two temperatures of c and d. A series of readings which were taken to determine the overall "repeatability" of the system is given in Table 1. Between pairs of values the optical bench was moved with respect to the flame and reset to the original position, air flow changed and reset, gas flow changed and reset, sodium chloride removed and replaced and the lamp switched off and on. It may be seen from the table that the values obtained had a spread of only 25°F , while the average of pairs taken at the same setting had a spread of only 12°F .

Table 1.

Series of values taken at the same point to determine the repeatability of the system (local coloring used).

Setting No.	Temp (°F)	Average (°F)
1	3285 3295	3290
2	3305 3280	3293
3	3290 3305	3298
4	3295 3305	3300
5	3295 3290	3292
6	3300 3305	3302
7	3280 3295	3288
8	3305 3295	3300
9	3305 3295	3300
10	3295 3305	3300

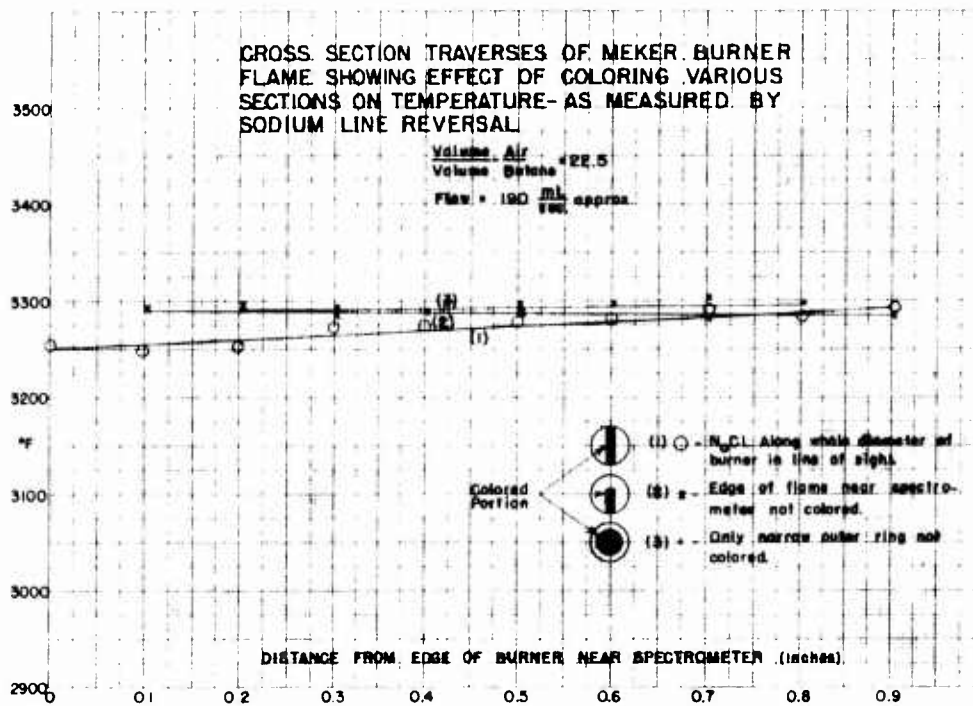


Figure 2.

It was of interest to investigate the effect of location of color in the flame on the observed temperatures. Figure 2 shows temperature curves obtained for same flame colored in different places, as follows:

- (a) Colored entire diameter along the line of sight-35°F lower temperature on edge near spectrometer, attributed to the heavier weight of the cold edge near the spectrometer.
- (b) Colored diameter along the line of sight except the edge near the spectrometer - "edge effect" of (a) was eliminated indicating that a cold edge away from the spectroscopy has little effect on the observed temperatures.
- (c) Colored entire flame except narrow ring around outer edge - constant temperature values similar to (b) were observed.

In the above tests, the position of the filament image was varied along the line of sight through the flame. An additional series of tests was run in which sodium chloride was placed at various points on the burner grid. The location of coloring and the results (average of several values) obtained for a constant flame with the image kept at the center were as follows:

- (a) Very small center section colored - 3335°F .
- (b) Edge near lamp colored - 3330°F .
- (c) Edge near spectrometer colored - 3225°F .
- (d) Both edges-(b) and (c) colored - 3240°F .
- (e) Both edges and center-(a),(b), and (c) colored - 3260°F .

When the image was moved to the same point as the colored section, the results obtained were similar:

- (a) Center section - 3335°F .
- (b) Edge near lamp - 3320°F .
- (c) Edge near spectrometer - 3200°F .

The results show that only a very small section of the flame should be colored, preferably only the point at which the temperature is desired. It is also observed that the edge of the colored flame near the spectrometer bears much more weight in the average value obtained than the opposite edge. In Figure 2 the constant temperature value obtained is quite noticeable. This may be attributed to the fact that the rays from the lamp must pass through the same colored section, whether they are focused at the center or off center, in the same optical path. Temperature traverses for various air-fuel ratios are included in Figures 3 and 4.

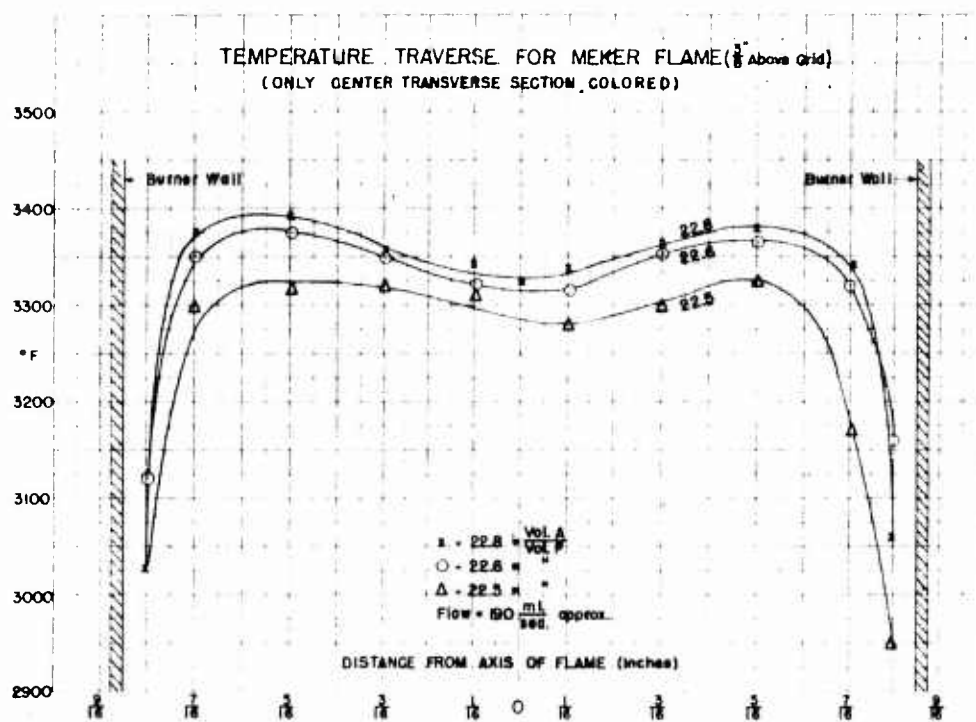


Figure 3.

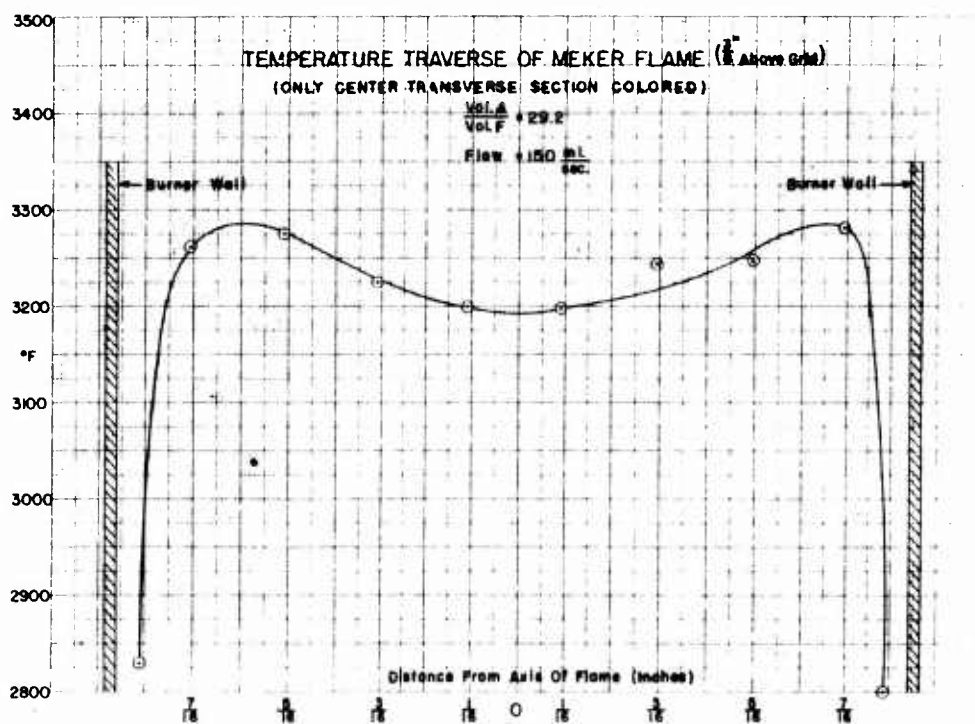


Figure 4.

These traverses were made transverse to the optical axis and $3/8$ inch above the burner grid with only a narrow section of the flame colored in order to avoid the effect of a cold edge. One of these traverses is compared with a corresponding traverse by means of infrared measurements in Figure 5.

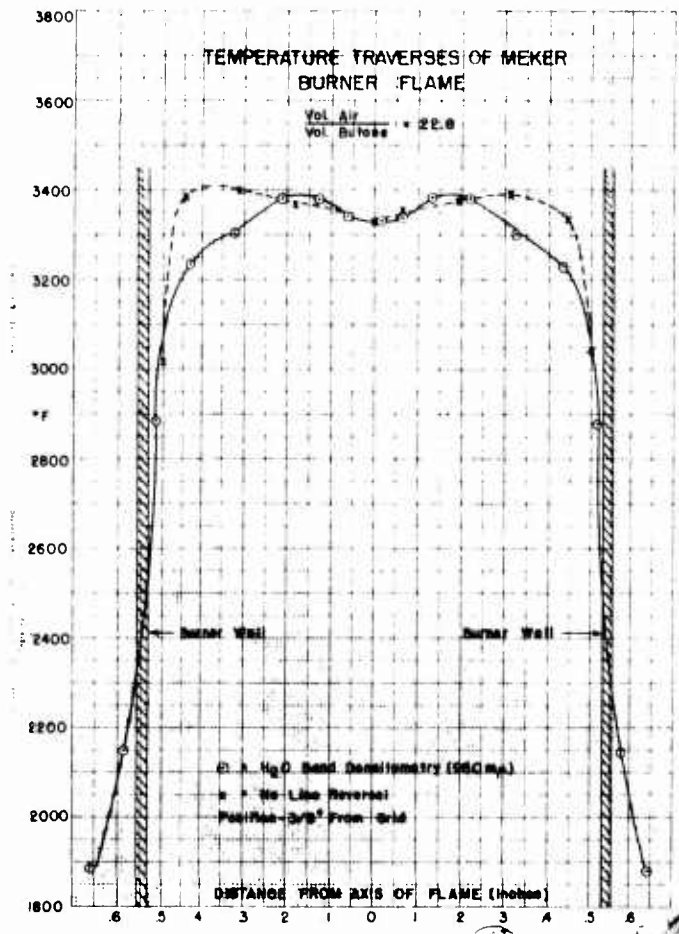


Figure 5.

The actual temperature measured and the coloring effects observed in this investigation are in line with the results that were to be expected from descriptions of this method as found in the literature (2),(6),(7). It is believed that a Meker type burner used in the above manner, constitutes the most practical device for illustrating the requirements for proper sodium line reversal technique.

B. INFRA-RED PHOTOGRAPHIC TEMPERATURE MEASUREMENT

1. Theory:

Available data (8) indicates that the relaxation time of the H_2O molecule at flame temperatures is less than $2.1 \cdot 10^{-8}$ seconds. This, coupled with the fact that it is an end product in combustion, makes H_2O a desirable species for the measurement of thermal emission. Assuming equipartition of energy, the intensities of H_2O rotational emission spectra, in the near infra-red, are proportional to temperature and concentration. In certain flames a first approximation may be to assume reasonably constant H_2O concentration transverse to the direction of major propagation of the flame. It further appears that small variations in water concentration have little effect on H_2O emission. Hence, by photographic recording of radiation densities, plates can be obtained in which density and temperatures are related.

Since it appears that certain anomalies are present in Frieser's report (9) describing the application of these principles to symmetric flames, a modified analysis is herewith presented.

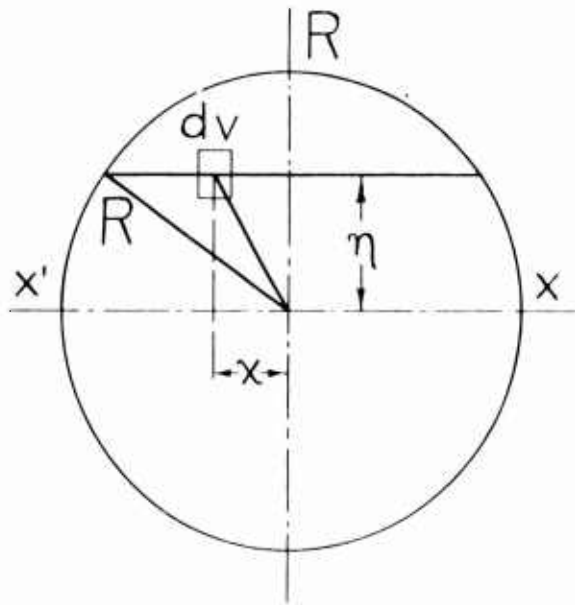


Figure 6.

In Figure 6, let the circle represent a section of the flame transverse to the direction of propagation. R is the radius at which the radiation density on a photograph becomes zero. Since the image of the flame (taken from the direction $X-X$) is a projection, it follows that:

$$(a) \quad \bar{I}(\eta) = 2 \int_{x=0}^{x=\sqrt{R^2-\eta^2}} I(x) dx$$

where $\bar{I}(r)$ is the sum of the radiation densities per unit volume along a chord at a distance r from the axis of the flame. Then since $x = \sqrt{\rho^2 - \eta^2}$ it follows that;

$$(b) \quad \bar{I}(\eta) = 2 \int_{\rho=\eta}^{\rho=R} I(\rho) \frac{\rho}{\sqrt{\rho^2 - \eta^2}} d\rho$$

where $I(\rho)$ is the radiation density per unit volume at distance ρ from the flame axis. The solution of the foregoing integral equation, as given in Frieser's report, is

$$(c) \quad I(\rho) = -\frac{1}{\pi} \int_{\eta=\rho}^{\eta=R} \frac{d\bar{I}(\eta)}{d\eta} \frac{d\eta}{\sqrt{\eta^2 - \rho^2}}$$

Unless the function $\bar{I}(r)$ involves something less than a 5th order polynomial, it appears most economical to carry out a graphical integration. This involves determination of $d\bar{I}(r)/dr$ by a suitable means (graphical, electronic, etc.). Due to a discontinuity at $r = \rho$, it is advisable to employ the following relation:

$$(d) \quad \int \frac{d\eta}{\sqrt{\eta^2 - \rho^2}} = \text{Log}(\eta + \sqrt{\eta^2 - \rho^2})$$

With values of $\log(\eta + \sqrt{\eta^2 - \rho^2})$ as abscissae and marked off in values of $\eta/\rho \geq 1$, $d\bar{I}(\eta)/d\eta$ is plotted. A different division of abscissae is used for each value of ρ for which $I(\rho)$ is to be determined. The net area, after subtraction of negative values, is the $I(\rho)$.

Relative values of $I(\rho)$ suffice for the determination of point temperatures if an independently determined temperature at

some point is used as a reference. From Wien's law:

$$(e) \quad I = \frac{C_1}{\lambda^5} e^{-\frac{C_2}{\lambda T}} \alpha$$

or taking the Napierian log of both sides;

$$(f) \quad \text{Log } I + k = \frac{0.4343 C_2}{\lambda T}$$

If λ is in $m\mu$, $C_2 = 1.433 \cdot 10^7 m\mu$ degrees.

Knowing I (ρ) and T for a given point in the flame, k may be determined and the course of the temperature plotted throughout that region in which α may be assumed reasonably constant.

2. Experimental Part.

A dichromatic camera enabling exposures in both the blue violet* and infra-red regions, was constructed along lines shown diagrammatically in Figure 7.

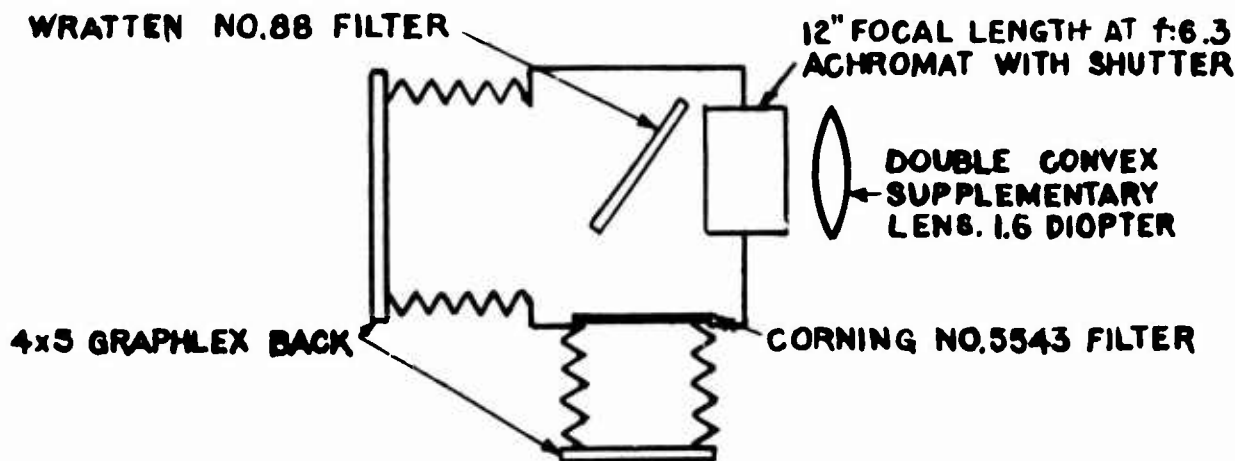


FIGURE 7

The resultant focal length is approximately 9.5 inches at f. 5.

* While simultaneous photographs were taken in the infra-red and blue-violet, only those pertinent to this paper, i.e. in the infra-red region, are discussed; the other photographs and their evaluation will comprise material for a later communication.

Since the requisite blue violet exposure is far less than the infra-red, satisfactory densities were obtained relying entirely on energy reflected off the incident face of the Wratten 88 filter. The infra-red filter has a plateau maximum from 750 to over 950 $m\mu$. This coupled with an Eastman Spectroscopic plate M (peaking at 930 $m\mu$) gave a maximum sensitivity at 930 $m\mu$. The Corning #5543 filter (fairly flat from 420-440 $m\mu$) coupled with an Eastman process plate (having a maximum at 420 $m\mu$) gave a peak sensitivity at 420 $m\mu$. For Super Panchro Press plates this maximum shifted to 440 $m\mu$. These data are from published characteristics.

For sensitometric calibration of the films a Wratten neutral density wedge was used having a density range of 4.75 in 5 $31/32$ inches. The wedge illuminator, shown in Figure 8, provided a strip light source of even illumination. Exposure times to wedge and films were kept comparable to cancel out "reciprocity law failure" effects.

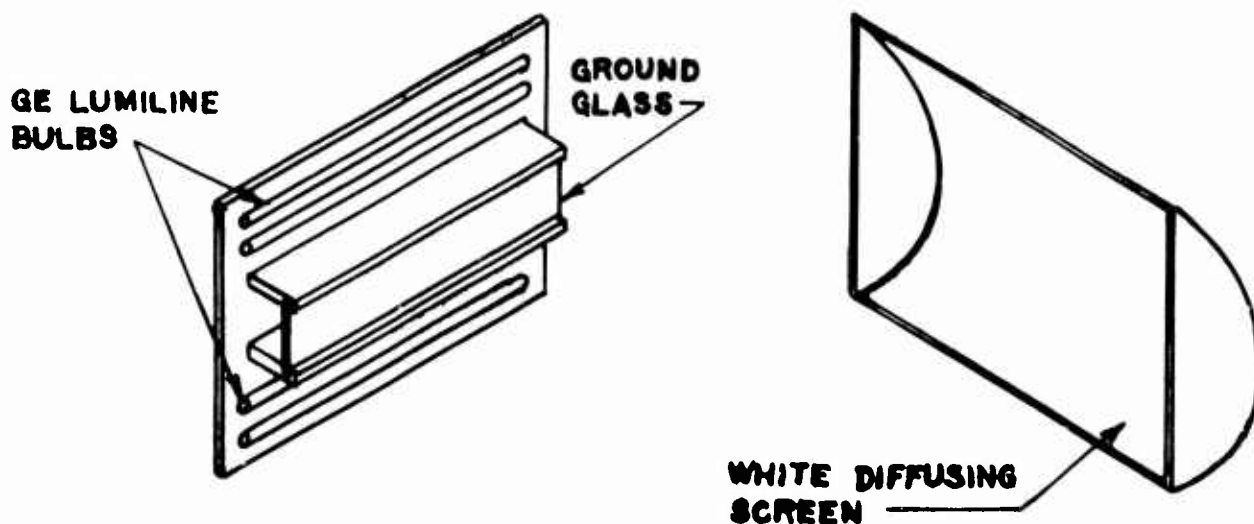
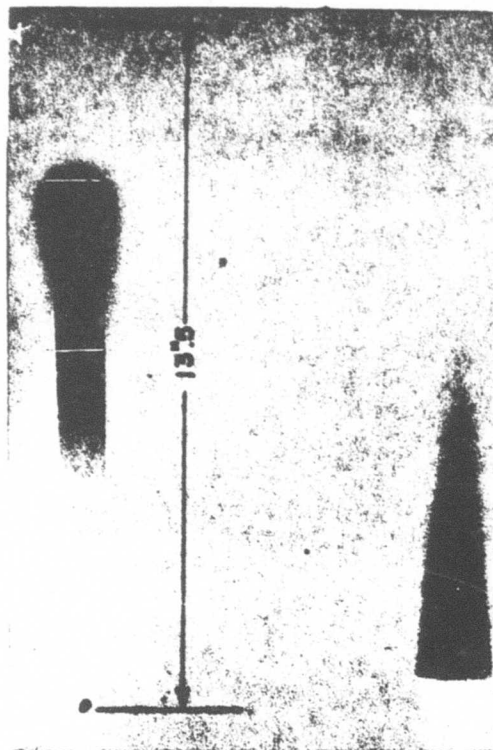


FIGURE 8

Densitometry was accomplished by means of a microdensitometer constructed in this laboratory from available parts. A 931-A multiplier phototube was used as the detecting element. Resolution of the order of 0.01 inches was provided by a microscope with supplementary negative lenses. With this system a hybrid density somewhere between spectral and diffuse is measured; subsequent work will incorporate a collimator to more nearly approach spectral density, as assumed in the relation $T = 10^{-D}$. Using a motor driven micrometer stage and a recording potentiometer, the density traverses resulted in a curve of μ amperes vs. inches from the center of the flame. From densitometry on the copy of the wedge this curve was translated to $\bar{I}(r)$. This curve approached but in fact was never symmetric about the flame center for transverse sections. Accordingly, ordinates were averaged for corresponding values of r , in the interest of rotational symmetry. The smoothed curve of $\bar{I}(r)$ was differentiated graphically and the mathematical procedure outlined above followed. Areas were determined by planimetry.

The flame chosen for this initial study was that produced by a 1 1/16 inch Meker type burner using an air-butane mixture in which the volume ratio was 22.8. Such a burner satisfied the requirement of rotational symmetry, in addition to affording a reasonably flat flame front to approach the requirements of constant water concentration and density. The density traverse was made on the infra-red plate (Figure 9) along a line perpendicular to the flame axis and representing a distance 3/8 inch from the burner tip, corresponding to a traverse under the same conditions by sodium line reversal.



N D. WEDGE
30 SEC

MEKER BURNER
FLAME- 4 MIN.

Figure 9.

From the center temperature, as determined by sodium line reversal, and $I(\rho)$ at $\rho = 0$ the k in (f) was determined. Temperatures for other values of $I(\rho)$ were then calculated. The resulting temperature course transverse to the flame as determined by the two methods is plotted in Figure 5.

CONCLUSIONS

The requirements for proper sodium line reversal technique are best illustrated by studies of a Meker type burner, in which the location of the colored portion of the flame can be varied at will. In this manner, it is shown that the influence of a cold edge upon the reversal temperature depends upon which side of a hot-cold interface is toward the observer. Thus, application of principles of rotational symmetry to flames whose temperatures are determined by the sodium line reversal method becomes complicated.

A comparison of temperatures measured by the line reversal technique, and by photography of the water rotational emission spectra for a flame of simple geometry indicates good agreement. It is concluded, therefore, that the assumptions involved in the photographic method are justified in the case of the Meker type flame employed as a test medium, and that application of this method to other flames is now in order.

SYMBOLS

dv = elemental volume in the flame

α = monochromatic emissivity

λ = wave length under investigation

(For the "980 band" this was chosen as 930, inasmuch as the photographic plates employed gave maximum sensitivity at this point, and also since the wave length of maximum energy shifts toward lower values with increase in temperature).

C_1, C_2 = universal radiation constants

D = photographic spectral density

T = absolute temperature

T = percentage transmission (in the expression $T = 10^{-D}$)

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SPARK LIGHT SOURCE OF SHORT DURATION

by

J. W. Beams, A. R. Kuhlthau, A. C. Lapsley,
J. E. McQueen, L. B. Snoddy, and W. D. Whitehead, Jr.
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Charlottesville, Virginia

A simple spark-gap light source together with an associated pulsing circuit has been utilized to produce light flashes of approximately 10^{-7} -sec. duration suitable for the study of shock waves produced by high speed bullets and for the photography of shock and turbulent disturbances in supersonic air streams. Included are sample photographs and circuit diagrams.

Journal of The Optical Society of America
Volume 37, Number 10, Page 868
October, 1947

PRECEDING PAGE BLANK-NOT FILMED

TWO USEFUL ELECTROMAGNETIC GAUGES

By

E. B. Brown
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In both gages the displacement to be measured moves an iron armature modifying the emf of two differentially connected transformers. In the first described, which is direct-reading, the resultant output of the transformers actuates the moving coil of the indicator, which is a separately excited iron-cored dynamometer instrument graduated to read the displacement directly. The analytical theory of the direct-reading gage is given. The second gage described uses an identical gage head and dynamometer instrument, but the latter is used only as a null indicator, the displacement being indicated by a pointer attached to a coil which can slide along an iron rod, near the ends of which are fixed two coils of opposite polarity connected in series with the gage primary circuits, the sliding coil being connected in series with the gage secondaries and moving coil of the indicator. If the gage armature be moved from its central position, emf is set up displacing the indicator from zero. This emf may be balanced by the emf in the sliding coil caused by moving it from its central position, so that the indicator is restored to zero. The pointer attached to the moving coil then indicates the displacement of the gage armature on a very enlarged scale, which is closely linear. The sliding-coil principle of this instrument has been adapted to make a recorder in which the sliding coil replaces the ordinary slide wire with the advantage of having no moving contacts.

Journal of Scientific Instruments
January, 1948

AIR JETS - THEIR CHARACTERISTICS FOR GAGING DEVICES

by

R. S. Elberty

The operation and characteristics of air jets as used for ultra-sensitive gages are discussed. An illustration is presented that shows the basic circuit for an air gage in which pressure is used for indication. Factors governing the sensitivity of various jets are reviewed. Greater sensitivity is obtained with large-diameter jets, sensitivity being roughly proportional to jet diameter. Pressure drop across an air jet varies as the square of the velocity of air through the jet; sensitivity of a pressure-type air gage varies directly as the initial pressure; and sensitivity of an air jet varies directly as the diameter of the jet. The operating principle of a few pressure regulators is included. Analysis is presented of a Wheatstone-bridge circuit for connecting a combination of jets to reduce effect of pressure variations in air-gaging operations.

Machine Design
January 1948

A STUDY OF THE CONTROLLED SPECTROGRAPHIC SPARK SOURCE

by

J. H. Ems and R. A. Wolfe
University of Michigan

The stability of spectrographic spark sources when controlled by a synchronous (Feussner) interrupter or an auxiliary air-gap interrupter was investigated. The purely electrical features were analyzed to show that the total electrical energy input into each transient discharge can be maintained constant from spark to spark. To obtain a constant breakdown voltage pattern for the air-interrupter source, the factors affecting this breaking voltage were localized to the interrupter gap itself. Replacing the tungsten electrodes with magnesium pins showed that the nature of the air flow was not so critical, and the air-interrupter is capable of stable operation even at one spark per half cycle. Study of the circuit elements for the discharge cycle, in particular the several air gaps, indicates that the decay is more linear than exponential.

American Society for Testing Materials Preprint
1948

FINE WIRES CAN BE WELDED

by

R. S. Gillette

Technique of resistance-welding fine wires ranging from 0.0005 to 0.060 inches is discussed. Copper, iron, silver, gold, platinum, tantalum, tungsten, molybdenum, iridium, nickel, palladium, binary and ternary alloys may be welded as fine wires. Equipment needed for wires up to about 0.015 is a motor-operated, bench-type spot welder. The electrode-force range is about 4 ounces to approximately 50 pounds and is obtained by using three sizes of pressure springs; current range, 25 to 2500 amperes. Welders should be designed and built for specific jobs. Wires of from 0.003 to 0.010 or 0.015 may be butt-welded. A self-contained welder with automatic welding control, annealing station, wire cutters, magnifying glass and all necessary instruments is recommended for this type of welding.

General Electric Company
Welding Engineer
December, 1947

THE ABSORPTION-EMISSION PYROMETER

by

Donald H. Jacobs and S. Scholnick

This report discusses a photoelectric method of measuring rocket flame temperatures, utilizing the absorptive and emissive properties of particles in the flame. A theory is derived from fundamental laws of radiation. Several possible arrangements of the Tungsten lamps and photo-cells are presented and discussed with diagrams included. Various electrical circuits are suggested with schematic diagrams shown. The sensitivity requirements of the instrument are mechanically developed.

North America Aviation, Inc.
Aerophysics Laboratory Report AL-100
Inglewood, California
January 21, 1947

AN ELECTRIC FLOW METER

by

J. H. Laub

A metering system is described which measures the rate of flow as well as the total flow of a fluid. A metal tube is inserted into the fluid line on which are wound a heater coil and the downstream resistance thermometer. The upstream thermometer is wound on the outside wall of the fluid line. The thermometer resistors form two arms of a Wheatstone bridge, the circuit is completed by two fixed, thermoconstant resistors, and by a Null indicator. In series with the heater coil are a current regulator, a wattmeter to read the rate of flow, and a watt-hour meter to register totalized flow. The system thus obtained has all the measuring elements arranged outside of the fluid, does not require conversion into electrical signals, and permits the rate of flow to be read on an instrument with a uniform infinite scale.

Electrical Engineering
December, 1947

INSTRUMENTATION FOR DEVELOPMENT OF AIRCRAFT
POWERPLANT COMPONENTS INVOLVING FLUID FLOW

by

S. J. Markowski,
Pratt & Whitney Aircraft

and

E. M. Moffatt,
Airflo Instrument Company

Presented in this article is a detailed discussion of the measurement requirements of general fluid flow; the design and operational problems of temperature, pressure, and miscellaneous measuring devices; and the development and calibration of various instruments. The complications added to the instrument problem by distorted and unsteady flow are described. The authors analyze temperature probes to show how their accuracy is affected by radiation, conduction, and gas velocity. A design chart indicates, for various temperature velocity combinations, which of these sources of error is most serious and what materials are most satisfactory for probes.

Society of Automotive Engineers
Quarterly Transactions
January, 1948

HIGH-RANGE TRUE AIR-SPEED INDICATOR

by

R. D. Munnikhuisen
Equipment Laboratory
Engineering Division
Air Materiel Command

An air speed indicator has been developed to measure accurately air speeds throughout the subsonic, transonic, and supersonic ranges. Much experiment has produced a laboratory unit composed of the following elements.

(1) A spark gap controlled in breakdown frequency by a combination of a master oscillator, spark-initiating circuit, and spark source. The spark gap is positioned in a region of relatively undisturbed air, and at a fixed distance down stream from it is located (2) an ion detector. The detected signal is amplified and shaped by the combination of the ion-detector amplifier and shaper amplifier. A visual speed indicator is provided by the (3) synchroscope speed indicator. The latter instrument is essentially a time-measuring device, whose circular sweep frequency is determined by the combination of a master oscillator and the sweep generator in such a manner that a complete circular sweep corresponds to one millisecond of time.

The article contains a theoretical analysis of the operating principles and a detailed description of the elements of the instrument.

Technical Data Digest
Volume 13, No. 5, 1 March 1948

A HOT-WIRE ANEMOMETER
FOR LOW WIND SPEEDS

by

R. G. Parr

The apparatus described will measure wind speeds from 0.2 to 2.0 miles per hour at normal temperatures and pressures with an accuracy of 2 percent. The anemometer head is designed to cause minimum disturbance to the air flow. Provision is made for screwing it into a calibrating apparatus, which is described. Compensation for variation in ambient temperature has been provided.

British Electrical and Allied Industries Research Association
Journal of Scientific Instruments
December, 1947

REPORT ON THE MEASUREMENT OF SPECTRAL
AND TOTAL RADIATION EMITTED BY JET ENGINES

(Final Report on Contract NOa(s)-8472)

by

C. M. Wolfe

This report contains a detailed discussion of instruments used in the measurement of spectral and total radiation of jet and rocket motors. Special reference is placed on measurement of radiation in the infrared region. An over-all discussion of the program with detailed sections on the apparatus is included. Some of the major topics of interest to instrumentation are:

- (1) Calibration of Black Body Sources.
- (2) Calibration of Radiometer for Intensity of Total Radiation.
- (3) Calibration for Infrared Spectral Intensity of Black Body Standard.
- (4) Calculations of the Black Body Equivalent Temperature for Jet Engine Flames.

Various photographs, diagrams, electrical circuits and calculations describe the above topics.

Aerojet Engineering Corporation
Report No. R-82, September 30, 1947
Azusa, California
RESTRICTED

LIQUID ROCKET MOTOR TESTING

by

R. Youngquist

Some problems involved in the testing of liquid rocket engines are discussed. Problems which differentiate rocket testing from other engineering tests arise from the presence, in combination, of high-pressures, temperatures, velocities, noise levels, flow rates, heat-transfer rates, forces, design stresses, and dangerous working fluids. The importance of the location of the test facility is analysed. A description is given of test structures necessary for rocket power-plant testing equipment, and instrumentation. The method of testing should be carefully worked out and a rigorous safety procedure should be enforced. In obtaining reliable data, close collaboration between the designer and the tester is essential.

Glenn L. Martin Company
American Rocket Society
December, 1947

PROBE FOR RECORDING CONSUMPTION OF
ROCKET PROPELLANTS

A probe has been designed to record with extreme precision the rate of consumption of self-igniting rocket propellants. The design makes use of the electric conductivity of the fluid under test. Eight pairs of electrodes, connected in parallel by insulated wires, are fastened at different levels of the measuring vessel. As soon as the level of the fluid falls below or rises above one of the electrodes, the conductivity of the whole device changes sharply.

The design for the electrodes and methods of mounting and calibrating them are also included.

Technical Report No. 38
War Department
Office of the Chief of Ordnance
Research and Development Division
Sub Office Rocket
Fort Bliss, Texas

FLOW CALORIMETER MEASURES
SPECIFIC HEATS OF GASES

A new flow calorimeter for more accurate measurement of the specific heat of gases has been developed. The entire calorimeter is immersed in a constant-temperature bath. The gas whose specific heat is to be measured enters the system through a copper helix, in which it is brought to the temperature of the bath. It then flows into the calorimeter proper, whier it traverses a labyrinth surrounding a constantan heater, and leaves the calorimeter through a throttle valve. The temperature rise within the calorimeter is determined by appropriately placed thermocouple junctions. The precision of the new instrument is chiefly due to the almost complete elimination of heat leaks by various features of design. With this instrument more thorough knowledge of thermodynamic properties of petroleum material may be obtained.

Petroleum Engineering
December, 1947

SHIELDING PRINCIPLE PROVIDES
ELECTRONIC MICROMETER

The electronic micrometer utilizes the fact that the RF energy radiated from a coil is at zero at the surface of a perfectly conducting shield adjacent to that coil. As the distance between the shield and a secondary coil increases, the field set up by the currents of the shield becomes weaker. When the micrometer is held at some distance from any metallic object, the field from the radiating coil includes voltage in the secondary, or pick-up coil, and this induced voltage is measured either on an oscilloscope or by an AC meter. The linear indication of the change in distance between the micrometer and the metal background is indicated. The uses of this principle as applied to measuring the displacement of a turbine shaft in its journal, photograph and microphone pick-up, and the tachometer are discussed.

Journal of The Franklin Institute
October, 1947

THE ABSOLUTE CALIBRATION
OF VIBRATION PICKUPS

To make the quantitative data obtained from the vibration pickup useful, it is necessary to know the proportionality factor between the mechanical quantity under observation and the electrical output of the pickup. This poses the problem of calibration. A method of calibration is given in this article which uses two reversible-velocity pickups. Expressions are derived for the calibration constants of the pickups, and the experimental results obtained are presented graphically. It is shown that the measurement of three electrical ratios and a measurement of mass are sufficient to perform the calibration.

National Bureau of Standards
Technical News Bulletin
January, 1948

NOTES AND ANTIDOTES

THERMOCOUPLE-WELDING TECHNIQUES

By

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The objective in the development of thermocouple-welding techniques is to produce couples capable of following very closely the temperature changes in a gas that is fluctuating at a rate of 120 times per second. This requirement will limit the mass of the thermocouple to an extremely low value. Several attempts were made before a satisfactory welding technique was devised.

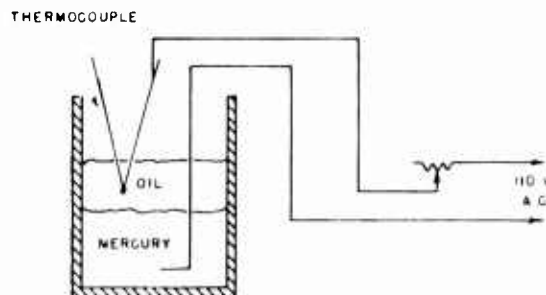


FIGURE 1

The first attempt to weld the couple was by means of an electric arc. One side of a battery was connected to one of the thermocouple wires, and the other side was connected to a pool of mercury as shown in Figure 1. When the wire approached the surface of the mercury, an arc occurred and a bead

was formed at the end of the wires. A layer of oil was placed over the mercury to prevent oxidation during welding. Before welding, it was necessary to twist the ends of the wires together to hold them in contact with each other. Since a thermocouple is formed wherever the wires touch, it was necessary to untwist the wires after welding so that the only junction would be the welded tip. Many failures occurred during the untwisting operation. In later experiments the wires were held on the outside of a glass tube with Scotch Tape, one wire on either side of the tube and parallel to its axis. The ends protruded beyond the end of the tube and were bent to touch each other. The welding operation was carried out as before by approaching the surface of the mercury with the wires until an arc passed between the wires and the mercury. In this way the wires were held in position without twisting, and the untwisting operation was eliminated. It was also possible to connect the power lead to either or both thermocouple wires. When connected to only one wire, the higher melting point wire was used. This method proved unsatisfactory for fine wires since a slight fluctuation in the voltage was sufficient to burn off the entire bead.

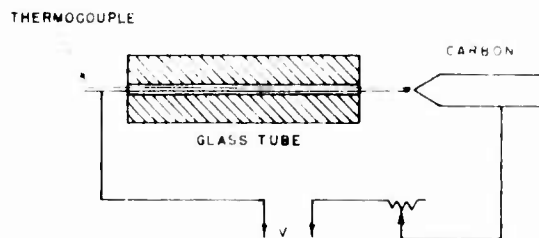


FIGURE 2

In a second attempt to weld a small bead, the wires were placed in a glass capillary tube as shown in Figure 2 and a carbon electrode was brought close to the ends of the wires. As before, one terminal of a battery was

connected to the wires and the other to the carbon electrode. As the electrode approached the wires, an arc discharged across the gap and a bead was formed. This method was also proven to be unsatisfactory, since a separate bead was formed on each wire.

Spot welding by crossing the wires and welding at the junction proved unsatisfactory because the electrodes could not be made flat and smooth enough to insure that the current would pass through the wire. Instead, the contacts touched each other, rather than the wires, and a bead was seldom formed.

Wires were then welded in a "glass-blower's-flame" by holding them crossed and melting the free ends down to the junction. This formed a large bead, two or three times the diameter of the wire. By hammering the bead down to a thickness equal to the wire diameter and cutting off the excess metal at the sides a useable thermocouple was produced. All work was, of necessity, done under a magnifying glass. The dimensions of the bead after trimming were 0.001 inch by 0.00125 inch using wires 0.001 inch in diameter. This method was very time consuming.

An attempt was made to butt weld the 0.001 inch wires in a channel between mica sheets assembled as shown in Figure 3. It was hoped that the bead size could thus be held to small limits. In operation, an arc occurred as the wires approach each other from opposite ends of the channel. However, instead of welding the wires together, the arc usually caused a separate bead to form on each of the wires; the method was discarded for this reason.

Some of the thermocouples were reduced in size by boiling in a solution of one part concentrated nitric acid and three parts concentrated hydrochloric acid, but in each case the platinum-rhodium wire broke prematurely, next to the bead.

A successful method of welding the wires was by melting them between carbon electrodes as shown in Figure 4.

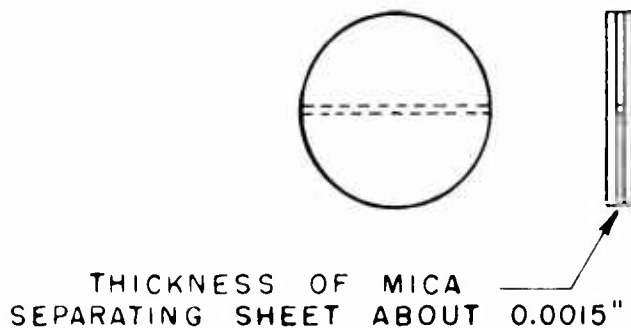


FIGURE 3



FIGURE 4

The electrodes, shaped in a pencil sharpener with the ends about 1/16 inch in diameter, were connected to a source of alternating current and their tips dressed with emery paper. The wires were crossed and held in position between the electrodes while the latter were brought together. A voltage of 2.75 volts was applied for about 10 seconds, a time interval sufficient for the tips of the electrodes to become hot enough to soften the platinum. Applying a slight amount of pressure to the softened electrodes, an excellent weld was obtained. Later, the excess wire was trimmed off and a bead only slightly larger than the wire was obtained. This method is very satisfactory and requires but little time per operation.

SCALE FORMATION IN WATER-COOLED GAS-SAMPLING PROBES

By

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Difficulty in maintaining stainless-steel water-cooled probes for withdrawing samples of gas from within high-intensity combustors has been attributed principally to excessive thermal gradients through the film inside the tube. When it was realized that two-phase heat transfer might be occurring within this film because of the high rates of heat transfer, attempts were made to decrease the development of a steam film by operating the probe at high internal pressures. Despite these precautions, probes continued to fail without any assured reason.

Finally, a probe which had failed unpredictably was sectioned adjacent to the point where the metal had fused as the result of inadequate cooling, and a layer of white scale was noted on the inner surface. This scale was about 0.001 inch thick and appeared to be similar to the scale formed in boiler tubes when raw water is used. Normally, such scales form slowly in boilers, often not becoming objectionable until after several weeks or months of continuous operation, but the rate of heat transfer in these boilers may not exceed 35,000 Btu per hour per square foot. For a probe inserted in a high-intensity combustor the rate of heat transfer may be as much as 10,000,000 Btu per hour per square foot, so that the accumulation of scale is accelerated tremendously. Actually an objectionable layer of scale has developed with raw water in less than one minute of operation.

As a measure of the effect of this scale, assuming a thermal conductivity of 1.3 Btu per hour per square foot with a gradient of one degree F per foot of thickness, the thermal gradient through the layer of scale would be 64 F for 1,000,000 Btu transferred per hour per square foot. In the case of these probes, where the heat transfer rate commonly is 10,000,000 Btu per hour per square foot, the thermal gradient through the scale alone may amount to 640 F. It is obvious that this gradient, when added to that through the metal and through the coolant film, can cause overheating of the metal. In other words, a probe having a clean internal surface when operated under maximum heat transfer rates, might fail quickly if such a deposit of scale formed.

To prevent further trouble from scale formation, distilled water was used in subsequent tests. No scale was formed and successful cooling of the probes was achieved. An alternate method, which would be necessary for probes of larger size or for extended operation, might include an ion-exchange softener using zeolite. The addition of phosphates or other water-treating chemicals to modify the nature of the scale regarding adherence also might be used.

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ABSTRACT:

The apparatus for measurement of gas temperatures under transient conditions is described. A discussion of a shielded thermocouple for gas turbines and a device for comparing pressure pick-ups is given. The principles and operations of a cantilever strain gage for high temperature tensile and creep tension of sheer materials are reviewed. A comparison is made of the sodium line reversal and infrared emission spectra methods of flame temperature determination. Numerous abstracts of articles and papers pertaining to instrumentation are included. Thermocouple welding techniques and scale formations in water-cooled gas-sampling probes are analyzed.

DISTRIBUTION: Request copies of this report only from Air Materiel Command; Attn: MCREON

DIVISION: Power Plants, Jet and Turbine (5)
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SUBJECT HEADINGS:

Gas temperatures - Measurement (44050); Thermocouples (93886)

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May '48	Restr.	U.S.	Eng.	81	photos, diagrs, graphs

ABSTRACT:

The material covered by Project Squid during this period deals with the techniques and instrumentation in the field of jet and rocket propulsion. Papers are contributed by scientists and engineers, working in this field throughout the country. The items covered are instruments for measuring gas temperatures under transient conditions; a shielded thermocouple for gas turbines; a cantilever strain gage for high temperature tensile and creep tension of sheet materials; a device for comparing pressure pick-ups; a comparison of the sodium line reversal and infra-red emission spectra methods of flame temperature determination. Other information is presented on thermocouple-welding techniques, and scale formation in water-cooled gas-sampling probes.

See also ATI 26604

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