TO: KSI/Scientific & Technical Information Division
   Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,832,903

Government or Corporate Employee

Supplementary Corporate Source (if applicable)

NASA Patent Case No. : LAR-11139-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES ☒ NO ☐

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Bonnie L. Woerner

Enclosure
ABSTRACT

A method and apparatus for measuring the stagnation pressure of supersonic velocity gas streams without the generation of shock waves which interfere with such measurements. The technique is insensitive to type of gas and Mach number and is therefore particularly useful in the study of jet engine exhausts.

15 Claims, 4 Drawing Figures
FIG. 1

FIG. 2
FIG. 3

FIG. 4
STAGNATION PRESSURE PROBE

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 STAT. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

This invention relates generally to measurements of gas streams of supersonic velocity and more specifically to the measurement of the stagnation pressure of such a gas stream.

The measurement of stagnation pressure is a requirement of investigations in aeronautics. Knowledge of this parameter is required in testing of both aerodynamic surfaces and engines. Stagnation pressure is essentially the static pressure resulting when the flow of a gas stream is brought to rest isentropically. It varies with the kind of gas, the Mach number and the static pressure. The phrase total pressure is sometimes used in the same sense as stagnation pressure and the term recovered pressure meets the same requirements in an ideal system where there are no losses in the conversion of the kinetic energy of the moving gas to the pressure energy of the gas at rest.

Heretofore the only available means of evaluating stagnation pressure has been the use of pitot tubes and similar devices to secure a measurement of pressure which is adjusted by factors previously studied to arrive at a value for stagnation pressure. In gas streams flowing at supersonic velocities, however, the shock waves which accompany the pitot tube and any other surface, including the surface being investigated, drastically affect the reading of such a pitot tube. Moreover, the effect of the shock waves varies with the type of gas and the Mach number so that in certain situations, such as the study of a jet engine exhaust, irregular variations of gas and Mach number make computation of the adjustment factors hazardous. The dependability of the stagnation pressure computation suffers accordingly. Moreover, in some investigations the stagnation pressure measurement is required to compute the Mach number of the gas. In such a case one of the prime factors used to adjust a pitot tube reading, the Mach number is the very unknown being studied leaving the investigator heavily dependent on theoretical computations rather than actual measured parameters.

SUMMARY OF THE INVENTION

It is the primary purpose of this invention to provide a means for the direct measurement of stagnation pressure of a supersonic gas stream. This direct technique is independent of adjustment factors which may vary with the conditions under which the measurements are taken. It is accomplished by isentropically decelerating a part of the gas stream and reading the pressure of that portion with conventional devices such as pitot tubes. The deceleration and compression of the gas stream is caused by a curved surface placed in the gas stream. This surface is placed with its leading edge approximately parallel to the direction of flow of the gas and it consists of a gradual curve into the flow such that it does not generate a shock wave sufficient to interfere with a measurement taken at its downstream end. A pitot tube or other pressure measuring device is mounted so that it is near the downstream end of the curved surface, but it is placed far enough off the surface to be clear of any boundary layer which could interfere with the measurement. The supersonic air stream is thus decelerated and compressed isentropically by the curved surface and the pitot tube measures the pressure without any shock wave interfering with the technique. This enables investigators to take direct measurements of stagnation pressure in such situations as the path of a jet engine exhaust where the type of gas and the velocity are continuously changing.

Although the greatest benefit from the invention is in the study of supersonic gas streams, it is not limited to that velocity range. The invention is also convenient to use and accurate in both the sonic and subsonic range.

A secondary function of the invention is served by pressure monitoring orifices positioned along the deflecting surface. The pressures from these orifices are used to operate instruments which indicate the orientation of the surface in the gas stream. The relative pressures of such orifices aligned along axes parallel and perpendicular to the gas stream are sensed and changes in these pressures are used as aids in maintaining the orientation of the surface in the gas stream. Such a system can also be used to determine the orientation of supersonic aircraft flying in atmosphere.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross section view of the invention in the plane described by the gas stream which it deflects, showing only the leading edge of the surface;

FIG. 2 is a top plan view of the invention;

FIG. 3 is a perspective view of the invention;

FIG. 4 is a cross section view of two deflecting surfaces placed in series in a gas stream showing only the leading edges of the surfaces.

DETAILED DESCRIPTION OF THE INVENTION

The specific embodiment of the invention selected for illustration is shown in simplified cross section form in FIG. 1 which shows the cross section of the leading edge 10 of the stagnation pressure probe. Leading edge 10 is that line of the surface 9 which first meets the gas stream. FIGS. 2 and 3 show other views of the same configuration. The same numbers indicate the same parts in all views. FIG. 2 is a top plan view and FIG. 3 is a perspective view of the invention. The curve of the leading edge 10 as seen in FIG. 1 is a smooth curve about an axis 25 perpendicular to the axis of the flow of the supersonic gas. A typical streamline 11 of the sampled part of the supersonic gas stream is shown being deflected toward pitot tube 12 by deflecting surface 9. The supersonic gas stream impinging on deflecting surface 9 forms a compression fan 13 ahead of the leading edge 10 of the deflecting surface 9. This compression fan 13 merges into shock wave 14 and down stream from the shock wave lies an area 8 of lower velocity compressed gas undisturbed by the shock wave 14. In this undisturbed area is placed a conventional pitot tube 12 which transmits the static pressure of the gas.
3,832,903

immediately adjacent to its upstream end to a pressure measuring device 7. Pitot tube 12 is placed at the down
stream end of the leading edge 10 sufficiently far from the surface 9 to be unaffected by the boundary layer
flowing along the surface. Since the gas stream in area 8 has been decelerated to the near sonic range, any
shock wave generated in this area immediately up-
stream from the pitot tube 12 is of minor nature and
does not interfere with the desired pressure measure-
ment.

The shape of surface 9 in the direction transverse to
the gas flow can have many variations. It may be a cir-
cular cross section as shown in FIG. 3 at top edge 23,
an ellipse, or a simple rectangular sheet with no signifi-
cant depth dimension. The circular and elliptical sur-
faces may be open or close upon themselves and be ei-
ther solid or hollow. A critical aspect of the surface is
that the width in the direction transverse to the gas flow
is limited so as to limit the growth of the boundary
layer. The surface 9 must be narrow enough to allow
the boundary layer to spill off the edges of the surface
thus relieving the boundary layer and preventing sepa-
ration of the layer of creation of a disturbance up-
stream from the pitot tube. The forward tip 24 of the
deflecting surface 9 is tapered to minimize the shock
wave in both its width as seen in FIG. 3 and in the sur-
face thickness as seen in FIG. 1.

The deflecting surface 9 of the stagnation pressure
probe-contains two patterns of pressure orifices which
allow verification and correction, if required, of the ori-
entation of the probe within the gas stream. Pressure
orifices 15, 17 and 19 form a line parallel to the typical
flowline 11 of the gas. Accuracy of the probe is en-
hanced by aligning the leading edge 10 of deflecting sur-
face 9 as it approaches tip 24 into a parallel rela-
tionship with the axis of gas flow. While the probe is toler-
ant of misalignment up to the order of 10°, the ratios of
the pressures indicated at pressure orifices 15, 17
and 19 are used to perfect this alignment. The pres-
sures along the surface 9 at the orifices 15, 17 and 19 are
read by pressure measuring devices 27, 28 and 29
attached by tubes 16, 18 and 20, respectively. The ra-
tios of these pressure readings are used to indicate the
relative position of the probe and changes in these ra-
tios indicate deviations from the original orientation of
the probe in the plane of deflection of the gas stream.
In a similar manner the pressure orifices 21 and 22 are
used to indicate the orientation of deflecting surface 9
relative to the planes transverse to the axis of flow of
the gas.

The preferred embodiment of the stagnation pressure
probe described above consists of a cylindrical member
of .372 inch diameter cross section at the top edge 23.
The member is curved about an axis 25 such that lead-
ing edge 10 nearest the axis has a 2 1/4 inch radius of cur-
vature for an angular sweep of 55°. The curve at the
forward tip 24 of the surface 9 is placed approximately
parallel to the direction of gas flow and the cross sec-
tion 30 formed by cutting the cylinder at forward tip 24
forms a 7° angle with the tangent of leading edge 10. A
.02 inch inside diameter, .04 inch outside diameter
pitot tube 12 protrudes .27 inch into the area of de-
fecting surface 9 described by the 55° angle at the down-
stream end of the deflecting surface. The pitot tube 12 is
mounted flush against leading edge 10 since the bound-
ary layer effect in this region is less than the wall thickness of the pitot tube. The pressure orifices
15, 17, 19, 21 and 22 in deflecting surface 9 are .02
inch diameter holes drilled flush with the surface. This
embodiment of the stagnation pressure probe demon-
strates a true reading of stagnation pressure within 1
percent error in gas stream velocities in the supersonic
range and down to subsonic velocities.

While the embodiment described above yields excel-
ient results in the supersonic range other embodiments
are used to measure stagnation pressures in higher ve-
locity gas streams. These variations consist of a plural-
ity of deflecting surfaces placed in series progressing
downstream. FIG. 4 shows one of these variations with
only two deflecting surfaces. Leading edge 10 here is
similar to that described in the embodiment using one
surface. Leading edge 26 is similar to, but smaller than,
edge 10 and is placed in the position 8 comparable to
the pitot tube of the previously described embodiment
where neither the shock wave nor the boundary layer
affect the measurement. At this position at the down-
stream end of the first deflection surface the typical
flowline 11 of the gas stream which has been deflected
by the first surface is picked up by the smaller deflec-
tion surface which then deflects flowline 11 to pitot
tube 12. Pitot tube 12 is oriented toward the second de-
fecting surface in the same manner as the pitot tube is
positioned in a single stage embodiment shown in FIG.
1. Each surface in the multistage technique contributes
to the deceleration and compression of the sampled
part of the gas stream so that in total the velocity is de-
creased more than in the single stage arrangement. This
is accomplished without breaking up the boundary
layer since the smaller second deflecting surface allows
the spill-off described above to relieve the boundary
layer growth.

It is to be understood that the forms of the invention
herein described are to be taken as preferred embodi-
ments. Various changes may be made in the shape, size
and arrangements of parts. For instance, the deflecting
surface may be flat or cylindrical, may have other
smooth configurations or may be tapered in any of its
dimensions. Also, the number, length and position of
the deflecting surfaces may be varied with the velocity
of the air stream studied. The embodiment described
includes five pressure orifices in a particular pattern of
straight lines. However, a nonlinear configuration of
pressure orifices or a greater or lesser number of holes
could be used without departing from the invention.

What is claimed as new and desired to be secured by
Letters Patent of the United States is:

1. A method of directly measuring stagnation pres-
sure of a gas stream having an upstream, downstream
and boundary layer of supersonic, subsonic, or sonic
velocity by decelerating said gas stream comprising the
steps of:
directing the gas stream in a manner whereby a
nearly isentropic deceleration and compression re-
sults, thereby rendering the gas stream incapable of
forming an interference shock wave; and
placing a pressure measuring means in the deceler-
ated part of said gas stream, clear of any adverse
boundary layer and shock wave effects; and di-
rectly measuring the stagnation pressure.

2. A method of directly measuring stagnation pres-
sure of a gas stream according to claim 1 wherein said
method includes the further step of:

deflecting said gas stream by means of a deflecting
surface means to decelerate and compress said gas
stream and boundary layer of supersonic, subsonic or sonic velocity by decelerating said gas stream with a de-
pressure of a gas stream having an upstream, down-
said deflecting surface means begins approximately pressure of a gas stream according to claim 4 wherein said method includes the further step of:
placing a plurality of deflecting surface means in a series arrangement progressing downstream whereby each deflecting surface means contributes to the deceleration and compression of the air stream thereby rendering said gas stream incapable of forming an interfering shock wave; whereby said pressure measuring means is placed near the downstream portion of the last deflecting surface means in the series and outside of the boundary layer.

4. An apparatus for directly, measuring stagnation pressure of a gas stream having an upstream, down-
stream and boundary layer of supersonic, subsonic or sonic velocity by decelerating said gas stream with a deflecting surface comprising:
deflecting surface means to deflect part of said gas stream from its original direction of flow to a direction angularly displaced from the direction of the balance of the gas stream thereby compressing and decelerating said part of the gas stream to near-sonic velocity rendering said gas stream incapable of forming an interfering shock wave; and pressure-measuring means located within said decelerated part of the gas stream near the downstream end of said deflecting surface means and clear of the boundary layer on said surface, and below any interfering shock wave, said pressure-measuring means directly measuring stagnation pressure.

5. An apparatus for directly measuring stagnation pressure of a gas stream according to claim 4 wherein said deflecting surface means is tapered such that part of the gas stream farthest forward into the gas stream is the narrowest part of said surface.

6. An apparatus for directly measuring stagnation pressure of a gas stream according to claim 5 wherein said deflecting surface means is comprised of a plurality of curved surface means in a series arrangement progressing downstream each contributing to the deceleration and compression of said part of the gas stream and wherein said pressure measuring means is placed near the downstream end of the last curved surface means.

7. An apparatus for directly measuring stagnation pressure of a gas stream according to claim 5 wherein said deflecting surface means is tapered such that part of said surface farthest forward into the gas stream is the narrowest part of said surface.