NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF:

July 27, 1970

TO: USI/Scientific & Technical Information Division
          Attention: 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 contained in the Code GP
to Code USI memorandum on this subject, dated June 8, 1970,
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.   : 3,201,980

        Corporate Source   : Hughes Aircraft Company

        Supplementary
        Corporate Source   : _____

        NASA Patent Case No.: XLE-00702

Please note that this patent covers an invention made by an
employee of a NASA contractor. 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. . . ."

Gayle Parker

Enclosure:
Copy of Patent

N70-40203

FACILITY FORM 602

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Aug. 24, 1965

JAMES E. WEBB
ADMINISTRATOR OF THE NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
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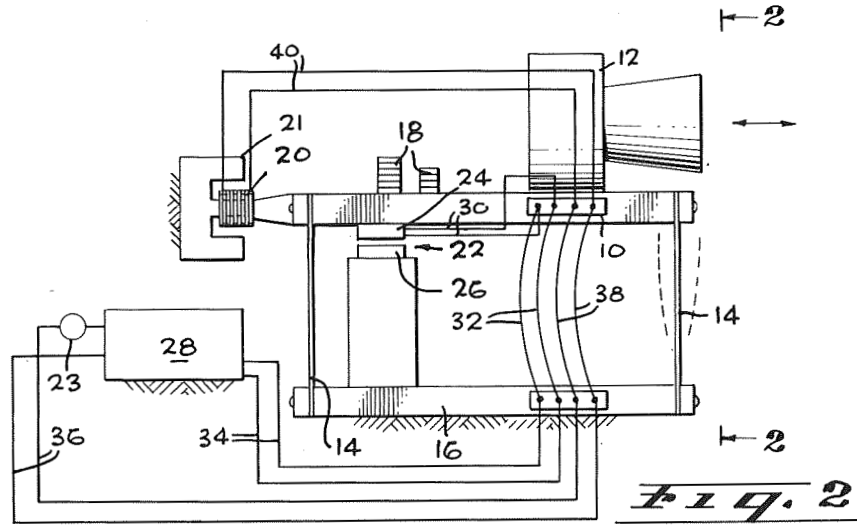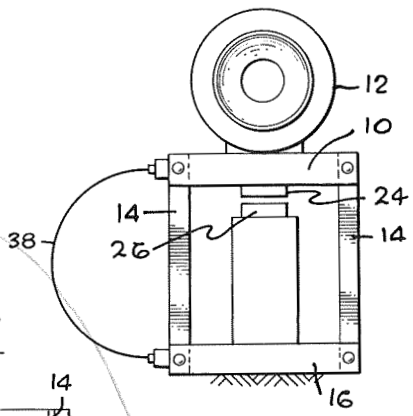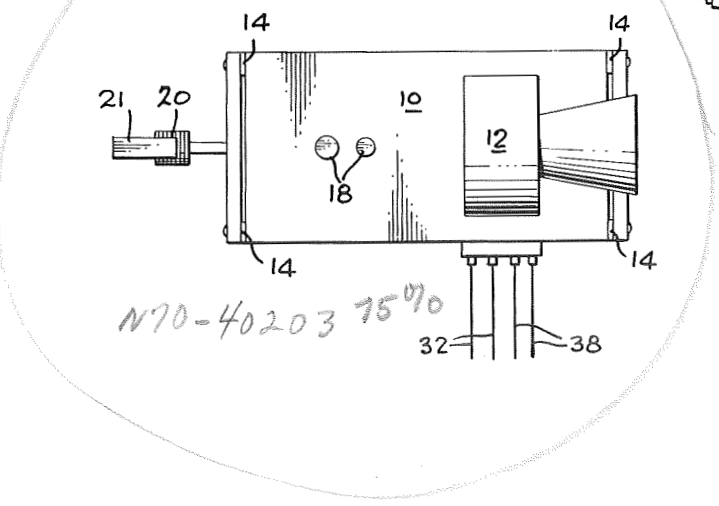Filed Feb. 15, 1963

3,201,980

Fig. 1

Fig. 2

Fig. 3

N70-40203 75%

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BY

ATTORNEYS

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1

The invention described herein may be manufactured
and used by or for the Government of the United States
of America for governmental purposes without the pay-
ment of any royalties thereon or therefor.

This invention relates to apparatus for accurately meas-
uring thrust forces and more particularly the invention
relates to apparatus for precisely measuring the thrust
produced by an ion reaction engine.

The relatively recently developed means of obtaining
propulsion for space ships by expelling a high momentum
stream of ions and electrons from a combustion chamber
is defined as ion propulsion. The scheme, presently, is
intended for propulsion in gravitationless space where a
microforce thrust might be operated over a long period of
time to yield extremely high vehicular velocities. The
processes for obtaining the stream of ions and electrons
to produce an ion engine are molecular disassociation,
nuclear fission, nuclear fusion and the like. Presently ex-
isting thrust measuring instruments are not capable of
accurately determining the amount of microforce thrust
being acquired by expelling ions and electrons from the
combustion chamber.

Thus, it is an object of this invention to provide a thrust
dynamometer which will accurately and precisely measure
microforce thrust produced by an ion engine.

This and other objects of the invention will become
more apparent from a consideration of the description
which follows, taken in conjunction with the drawings.

FIG. 1 is a schematic, side elevational view embodying
the present invention.

FIG. 2 is an end elevational view taken on line 2—2 of
FIG. 1.

FIG. 3 is a plan view illustrating the present invention.

The invention embodies a substantially level, horizon-
tally movable rectangular platform 10. Mounted pref-
errably on the upper surface of platform 10 is an ion en-
gine 12 which develops very low thrust forces that are in
the order of ten to one thousand micropounds, and it is
this thrust which is to be measured. An alternative man-
ner of mounting ion engine 12 is to suspend it from the
lower surface of the platform.

Supporting platform 10 is a plurality of elongated leaf
springs 14, there being a leaf spring fastened to each
corner of the platform. Leaf springs 14 are in turn fas-
tened to and supported by a flat stationary base 16 which
is substantially parallel to platform 10. Initially the
rigidity of leaf springs 14 is more than adequate to sup-
port platform 10 and ion engine 12.

To neutralize the rigidity of leaf springs 14, or to re-
duce the spring constant whereby it approaches zero or
balance is achieved, a determinable quantity of weights
18 are placed on the upper surface of platform 10. The
quantity of weights to be added is determined by the
rigidity of springs 14. It might be supposed that the
condition for reducing the aforementioned spring constant
or to achieve balance requires a weight load that would be
close to collapsing springs 14. Such is not the case, how-
ever, for it has been determined that for relatively any
size of leaf spring the load for collapse is four times the
load required to achieve balance.

The principle of the suspension or supporting of plat-
form 10 is that of columnar instability. The moment due
to bending of support springs 14 can be almost exactly
compensated by the moment due to eccentric support of

2

the weight of platform 10 and its load over quite an ap-
preciable range of motion. Once condition for balance
has been achieved, springs 14 tend to flex and assume
either one of the configurations shown in dotted lines in
FIG. 1. In this condition platform 10 tends to move hori-
zontally under the influence of any added force which
occurs such as that produced by the thrust of ion engine
12. It is necessary to provide for the measurement of this
movement produced by the reaction thrust force which is
accomplished by a servo feedback system which includes
a movable coil permanent magnet 20 as a motor to de-
velop a counterthrust equal and opposite to that of the
engine. The movable coil 20 is preferably connected to
and located at the left end of platform 10, as illustrated
in FIG. 1, remote from the stream of ions and electrons
discharged from the combustion chamber of ion engine 12.

The servo system also includes an electromagnetic sen-
sor 22 which as represented in FIGS. 1 and 2 is divided
into two portions, an upper portion 24 which is fastened
to the underside of platform 10 and therefore movable
with the platform, and a lower portion 26 which is
mounted on and fastened to stationary base 16.

Movement of platform 10 either to the right or left,
as viewed in FIG. 1, is detected by sensor 22 which relays
a signal to movable coil 20 through a servo amplifier 28.
Movable coil 20 unattached to but influenced by magnet
21 then produces the aforementioned counterthrust to
counteract the movement of platform 10, and it is this
counterthrust which is measured by a D.C. meter 23 so
as to determine the thrust of engine 12. Instead of coil
20 being connected to platform 10 as aforementioned,
magnet 21 may be connected to the platform. The results
achieved would be substantially identical.

The movement of platform 10 is, as aforementioned,
detected by sensor 22. The signal generated by sensor 22
is carried by conductors 30 to conductors 32 of a family
of U-shaped loop conductors, each of which is insulated
from the others and each of which bridges the distance
between platform 10 and base 16. From loop conduc-
tors 32, the signal is delivered to amplifier 28 through
conductors 34, and from amplifier 28 the signal is trans-
mitted to meter 23. The amplified signal is transmitted
from meter 23 via conductors 36 to conductors 38 of the
loop conductors where the signal is transmitted to coil 20
through conductors 40.

Although the preceding method is the preferred manner
of measuring thrust, it is to be understood that other
means are available for achieving substantially the same
results.

The manner of supporting engine 12 on platform 10 en-
ables sensor 22 to easily detect the deflection of the plat-
form produced by the thrust of the engine, and it has been
determined that the sensor is capable of detecting a deflec-
tion of platform 10 created by ion engine thrust of about
one micropound.

While the present invention has been described herein in
what is considered to be a preferred embodiment thereof,
it should be recognized that departures may be made there-
from within the scope of the invention, and it should
therefore not be limited to the details of the aforemen-
tioned disclosure, but should be accorded the full scope
of the appended claims.

What is claimed is:

1. A dynamometer for measuring the thrust of an ion
propulsion system comprising:

(a) a platform for supporting an ion engine;
(b) means for adjusting the weight of said platform;
(c) a base plate disposed adjacent to said platform in
    a spaced and parallel relationship with respect thereto;
(d) a plurality of spring members connected between
    said platform and base plate, said spring members
    having a spring constant whose magnitude is such

that by slight adjustment of the weight of said plat-
form the spring constant can be made to approach
zero, whereby, the platform is balanced and a very
small thrust force applied thereto by an ion engine
mounted thereon will result in deflection thereof with 5
respect to said base plate;

(e) motor means attached to one end of said platform
for applying a counterforce thereto which is equal
and opposite to the force applied thereto by the ion
engine; 10

(f) servo means for sensing the deflection of said plat-
form means and actuating said motor means, and

(g) means connected to the motor means for indicating
the force exerted by said motor means.

2. A dynamometer for measuring the thrust of a reac- 15
tion motor comprising:

(a) a platform on which the reaction motor is mounted;

(b) a base disposed below said platform;

(c) a plurality of leaf springs connected between said
platform and said base for resiliently supporting said 20
platform;

(d) means for adjusting the weight of said platform
so as to preload said leaf springs to a point where
their spring constant approaches zero, whereby said
platform is balanced on said base and a very small 25
thrust output from the reaction motor, in the range
of 10 to 100 micropounds, will result in displace-
ment thereof with respect to said base;

(e) sensor means attached to said platform and said

base for detecting movement of said platform with
respect to said base and generating an electric signal
in response to such movement;

(f) motor means actuated by the electric signal from
said sensor means for applying a counterforce to said
platform that is equal and opposite to the force ap-
plied to said platform by the reaction motor, and

(g) means electrically connected to the motor means
for indicating the force exerted by said motor means
and thereby also indicating the force exerted by said
reaction motor since the forces are equal in mag-
nitude.

3. The dynamometer recited in claim 2 wherein said
motor means comprises:

(a) a coil connected to one end of said platform, and

(b) a magnet disposed closely adjacent to said coil
and extending into and around said coil.

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