THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
8621 GEORGIA AVENUE
SILVER SPRING, MARYLAND 20910

TELEPHONE
776-7100
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October 24, 1969

Defense Supply Agency
Defense Documentation Center
Cameron Station
Alexandria, Virginia 22314

Attention: Mr. Herbert Rehbock
Director of Documentation

Reference: (a) DDC-TCA 043068-8-0960 dtd 30 April 1968

Gentlemen:

In reply to your recent tracer, I regret that the original request for my memorandum SDO-1134 never reached my office. I am happy to forward herewith a copy of the memo, "A Controllable Heat Pipe Experiment", my supply being limited, and I am sorry that a more comprehensive formal report has not been written.

This work was sponsored by the U. S. Department of the Navy under Contract NOw-62-0604-c.

This document has been approved for public release and sale; its distribution is unlimited.

Very truly yours,

Theodore Wyatt

Theodore Wyatt

TW/lb
Enc. (1) - APL/JHU Memo SDO-1134 dtd 9 Mar 1965

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IN REPLY REFER TO DDC-TCA 043068-8-0960 20 April 1968 Telephone 274-6847

SUBJECT: Request for Scientific and Technical Reports

TO:

Johns Hopkins University
Applied Physics Lab (CPIA)
8621 Georgia Avenue
Silver Spring, Maryland 20910

AD695433

1. This is a tracer on the request cited below. No reply has been received to date. Please notify DDC by return mail of the action taken.

2. The report referenced below is believed to be a DoD-funded document. It has not been located in the Defense Documentation Center (DDC) collection.

3. DoD Instruction 5100.38 of 29 March 1965 requires twenty (20) copies of each report be forwarded to DDC. At least one (1) copy should be black printing on white background (or if typed, the ribbon copy) suitable for reproduction by photographic techniques.

4. Documents should be marked with an appropriate distribution statement according to DoD Directive 5200.20 of 29 March 1965, and Change 2 dated 8 May 1967 (AFR 310-2, AR 70-31, NAVMATINST 4000.17). This includes information on the releasability of unclassified, unlimited documents for sale to the general public by the Clearinghouse for Federal Scientific and Technical Information (CFSTI) of the Department of Commerce. These distribution statements are found on the reverse of this letter.

5. Return the copy of this letter as your reply marking the reverse accordingly, i.e.:
   a. When reports are forwarded, or have previously been forwarded, check and fill in statements opposite A or B as applicable, or
   b. If the document is not releasable to DDC, indicate the category of exception by checking the applicable statement under C.

6. Enclosed is a DDC Form 50 for your use, if you wish to be notified of the DDC accession number (AD number). A mailing frank is also enclosed to use for shipment of documents.

FOR THE ADMINISTRATOR:

Herbert Rehbock
HERBERT REHBOCK
Director of Documentation

2 Encl
1. DDC Form 50
2. Franked label

043.58-8-0960

Johns Hopkins University - Silver Spring, Maryland
Applied Physics Laboratory

Controllable Heat Pipe Experiment by T. Wyatt

SDO-1134 - March 1965

Note: If this report is DoD sponsored, DDC would like it for their collection.

GMR 05763

FL-88
Nov 67

SDO-1134
March 9, 1965

To: C. J. Swet and R. E. Fischell

From: T. Wyatt

Subject: A Controllable Heat Pipe Experiment for the 5E-4 Satellite

Since you have both expressed an interest in performing a controllable heat pipe experiment in the 5E-4 satellite I wish to suggest a device of this type for you to employ.

A somewhat unexpected and intriguing observation was made during early heat pipe trials. Purely by accident an unwanted "non-condensible" gas (in the sense used by steam plant engineers) was present in a heat pipe and it was observed that the non-condensible gas (hydrogen) was concentrated at the heat-output end of the pipe and that the amount of heat liberated over the intended output area was proportional to the amount of non-condensible gas present. This experimental finding seems to be susceptible to the following logical explanation. Assume that initially the hydrogen was uniformly distributed throughout the pipe. As heat is put into the device the working fluid (sodium) is boiled off and the resulting gas flows from the heat-input end to the heat-output end. The sodium gas flow sweeps the hydrogen to the heat-output end; as long as the heat pipe is operated any hydrogen molecules tending to migrate from the output end are returned by the continuing sodium gas flow. The equilibrium situation thus created is illustrated in Fig. 1. Visual observation of high temperature heat pipes and temperature measurements indicate that the two gases are highly segregated, that a sharp interface exists between the working fluid gas and the non-condensible gas, and that thermal transport of the heat pipe's working mode does not occur in the zone occupied by non-condensible gas.

We thus can control the thermal flow through a heat pipe by varying the amount of non-condensible gas present. Fig. 2 illustrates one way of introducing and withdrawing a non-condensible "control" gas so as to modulate thermal conductance. Fig. 3 is an extension of Fig. 2 with some auxiliary provisions which may prove desirable in some applications.

Although various manual or automatic means might be used to adjust the position of the bellows and hence the heat flow through the pipe the "Vernatherm" manufactured by American-Standard, Controls Division, of the American Radiator and Standard Sanitary Corporation, would seem particularly straightforward for satellite temperature control. An example is a satellite with internal heat dissipation (from electrical loads or nuclear decay) sufficiently large compared to the solar input that regulation of the flow of this internal heat to radiating surfaces substantially shielded from the sun, e.g., the base plate of a gravity stabilized satellite, would permit maintenance of a desired nearly constant internal temperature. A possible arrangement is illustrated schematically in Fig. 4. An increase in temperature causes the "Vernatherm" to extend in length; this motion through a linkage extends the bellows, thereby withdrawing non-condensible "control" gas from the heat pipe and increasing the thermal output of the pipe by allowing more fin area to radiate heat. Since more heat is radiated the tendency to increase in temperature is limited to the response characteristic of the "Vernatherm", as multiplied by the ratio of the linkage.

Another application for satellite temperature control in conjunction with heat from nuclear decay might be as sketched in Fig. 5. In this case the "Vernatherm" actuator moves the bellows directly or through a motion-multiplying linkage to admit heat from the nuclear source in inverse proportion to the temperature within the satellite. An effect similar to that of the motion-multiplying linkage can be obtained by increasing the diameter of the bellows so that a given linear motion involves a greater volumetric displacement as shown in Fig. 6.

It is evident that the reliability of a radio-active isotope thermoelectric power supply is primarily a function of the reliability of the thermoelectric devices, including their electrical and thermal connections. This observation leads one to consideration of redundant thermoelectrics with provision to transmit the heat from the nuclear source to either set of thermoelectrics. This might be accomplished as illustrated in Fig. 7.

T. Wyatt

TW:lb
Distribution attached

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THE JOHNS HOPKINS UNIVERSITY

No. FIG. 1

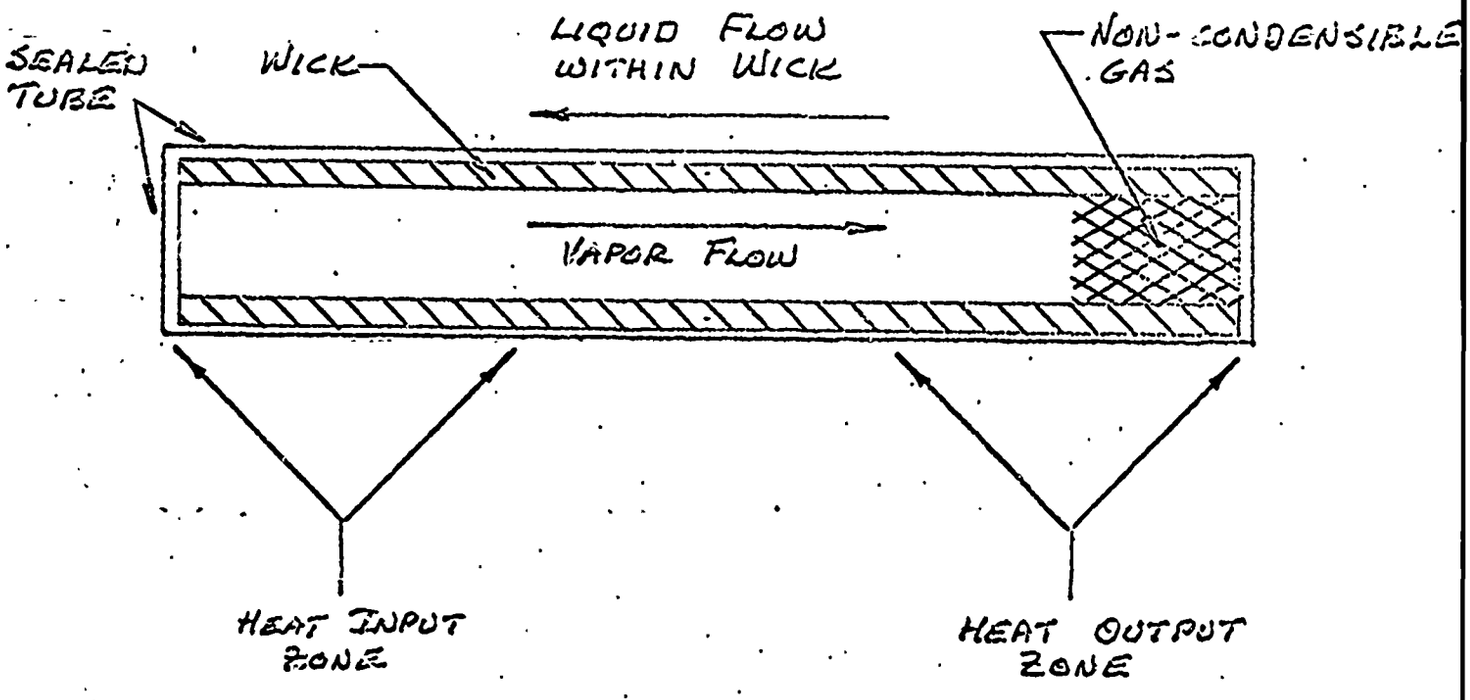
ENGINEERING NOTES

SDO-1134

SUBJECT: EQUILIBRIUM WITHIN HEAT PIPE CONTAINING NON-CONDENSIBLE GAS

DATE 9 MAR 65

BY TWYATT



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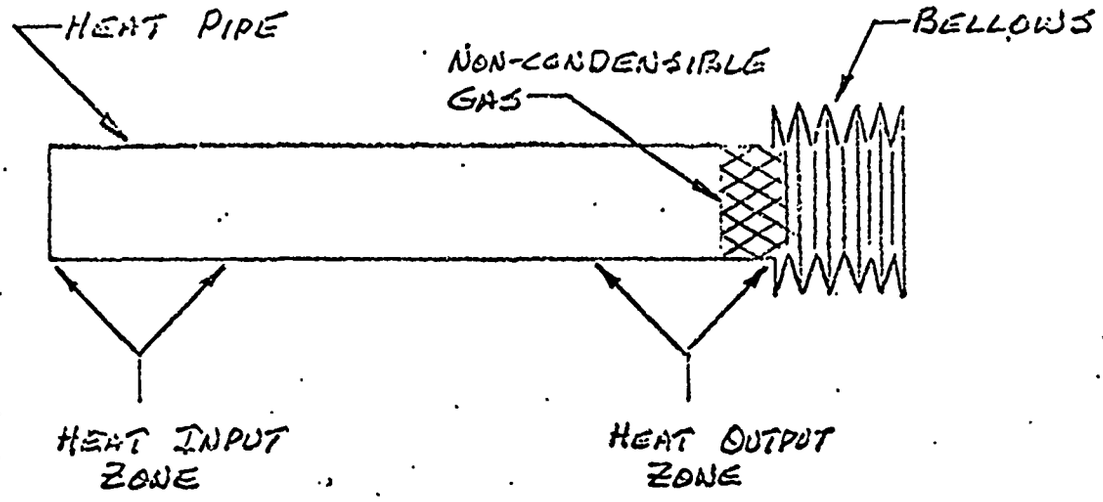
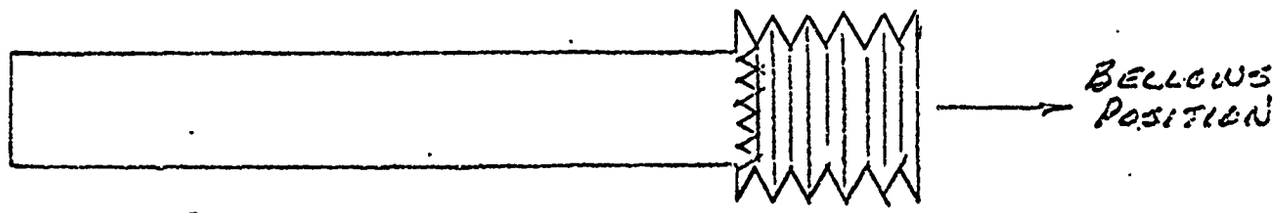
No. Fig. 2
SDO-1134

ENGINEERING NOTES

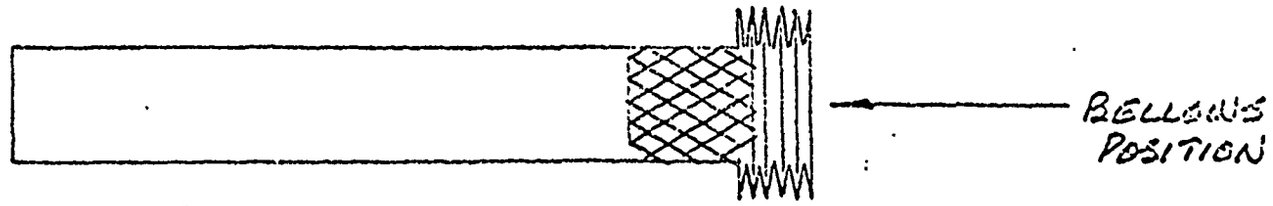
SUBJECT: SCHEMATIC OF CONTROLLABLE HEAT PIPE

DATE 9 MAR 65
BY TWypatt





HEAT PIPE OPERATING AT MAXIMUM CONDUCTION



HEAT PIPE OPERATING AT MINIMUM CONDUCTION

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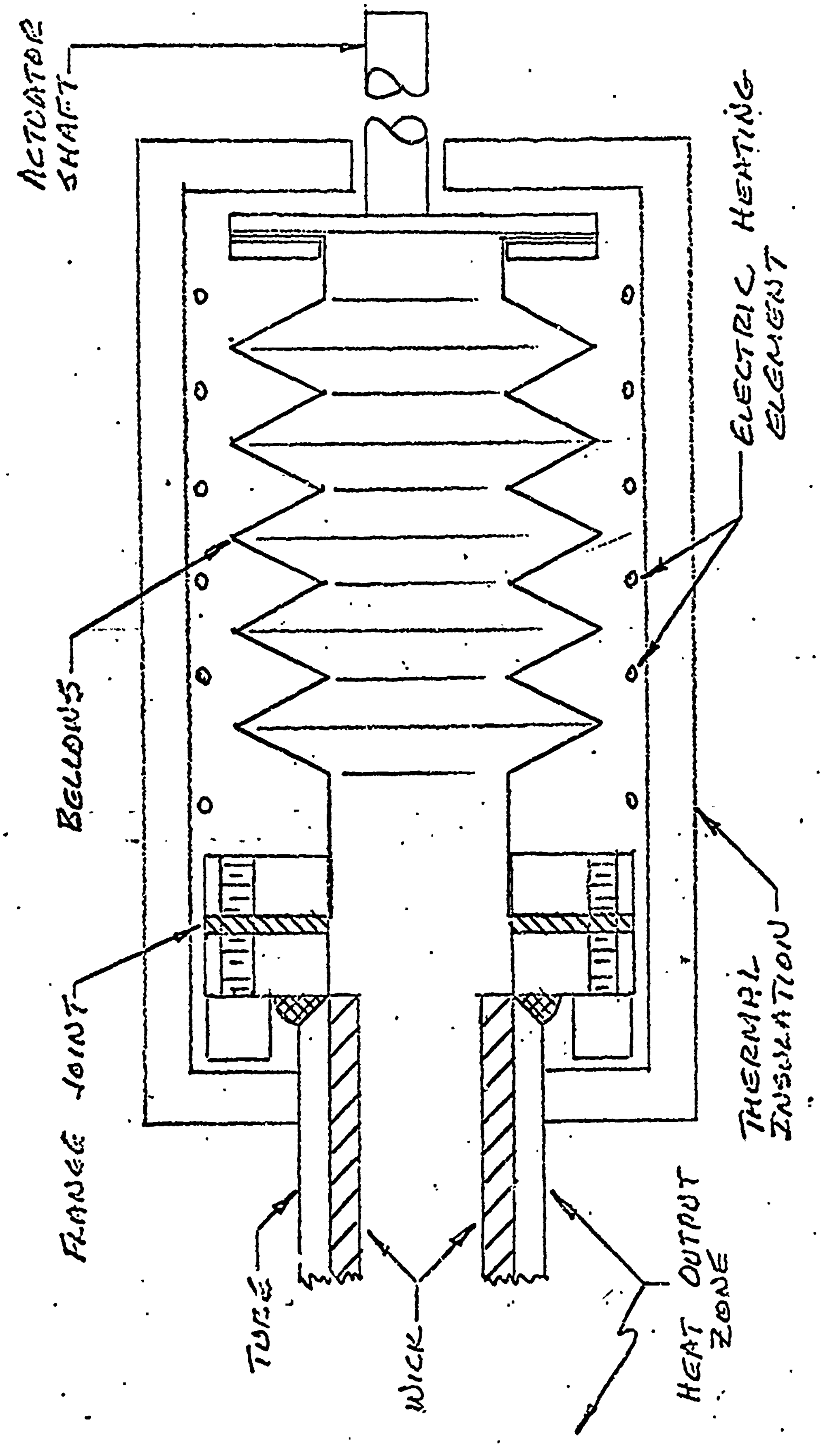
No. FIG. 5
SDO-1134

ENGINEERING NOTES

SUBJECT: OPTIMAL PROVISIONS FOR CONTROLLABLE HEAT PIPE

DATE 9 MAR 65

BY [illegible]



NOTE: INSULATION & LOCAL HEATING PROVIDED TO MAINTAIN BELLOWS A TRIFLE (~1°F ?) ABOVE HEAT OUTPUT ZONE SO AS TO ASSURE THAT STRAY MOLECULES OF WORKING FLUID VAPOR WILL NOT CONDENSE IN BELLOWS.

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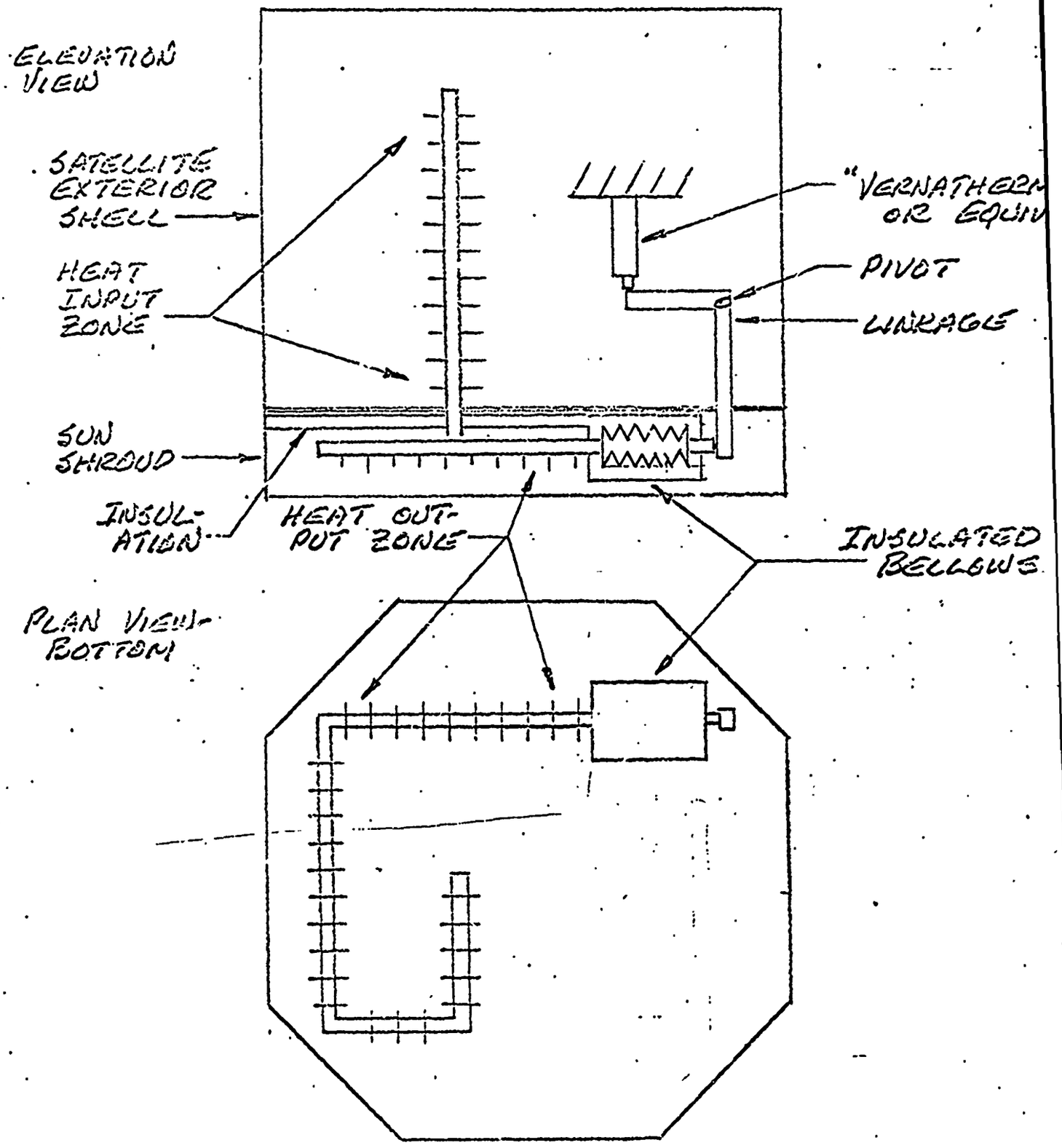
No. Fig. 4

ENGINEERING NOTES

SUBJECT: SATELLITE TEMPERATURE REGULATION THROUGH CONTROLLED HEAT RELEASE AT BASE RADIATOR

DATE 17 MARCH 65

BY T WYATT



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No. Fig. 5

ENGINEERING NOTES

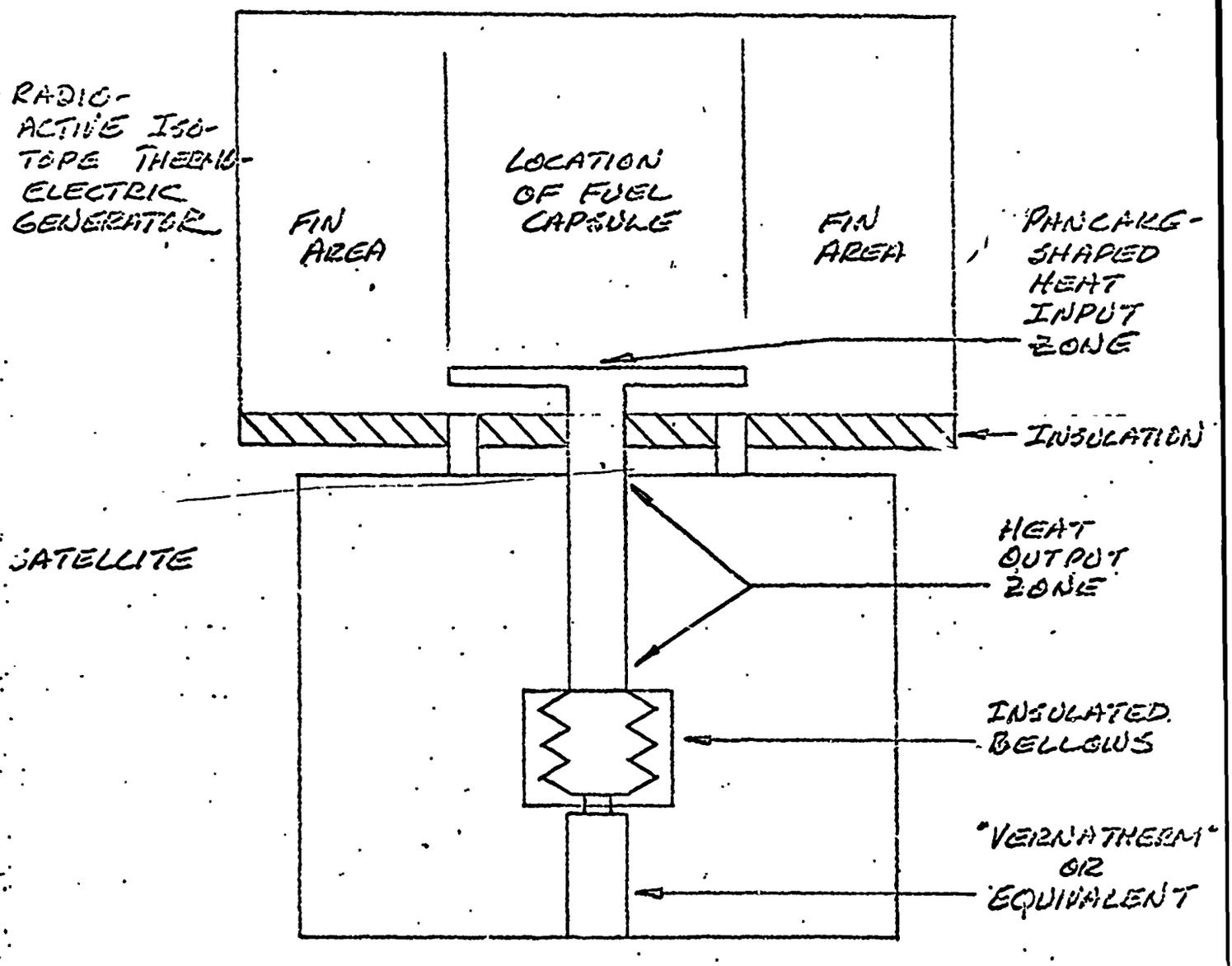
SDO-1134

SUBJECT: SATELLITE TEMPERATURE REGULATION THROUGH CONTROLLED HEAT FLOW FROM NUCLEAR SOURCE

DATE 17 MARCH 65

BY TWIGHT

ELEVATION VIEW



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No. Fig. 6

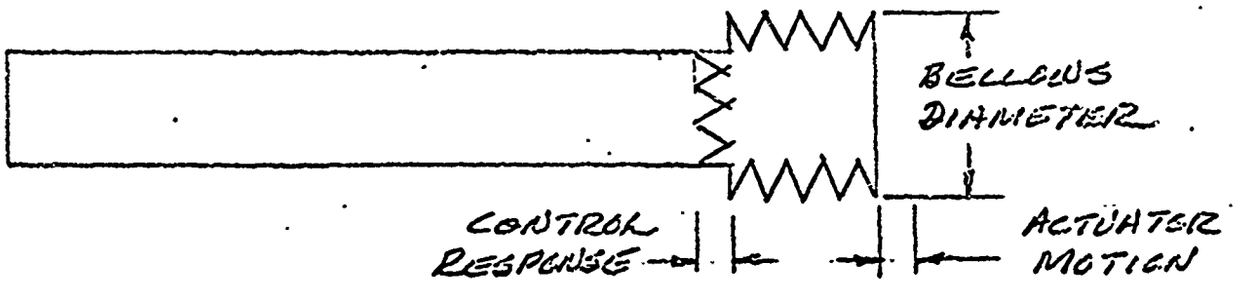
SDO-1134

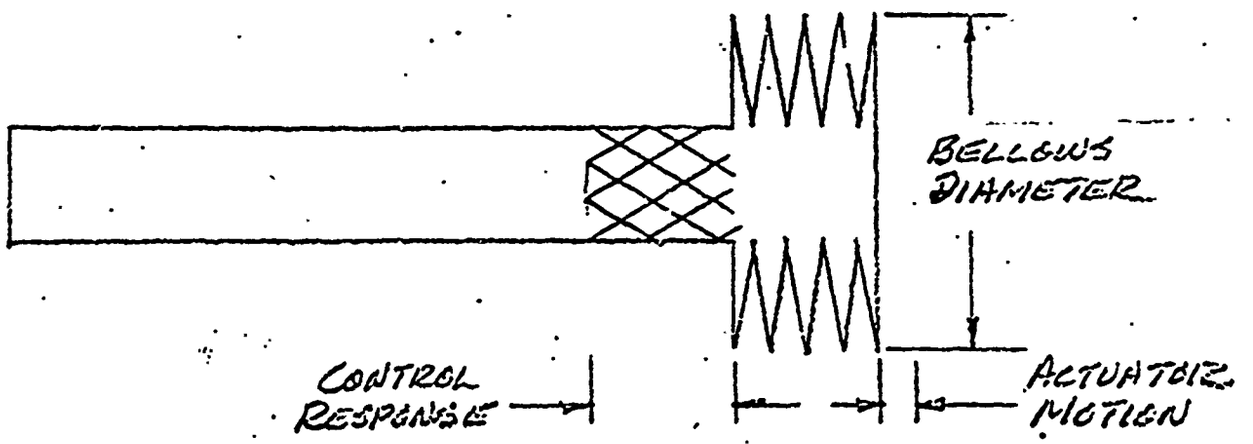
ENGINEERING NOTES

SUBJECT: CONTROL RESPONSE VS A FUNCTION OF BELLOWS SIZE

DATE 17 MARCH 65

BY T. Wyatt





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No. Fig. 7

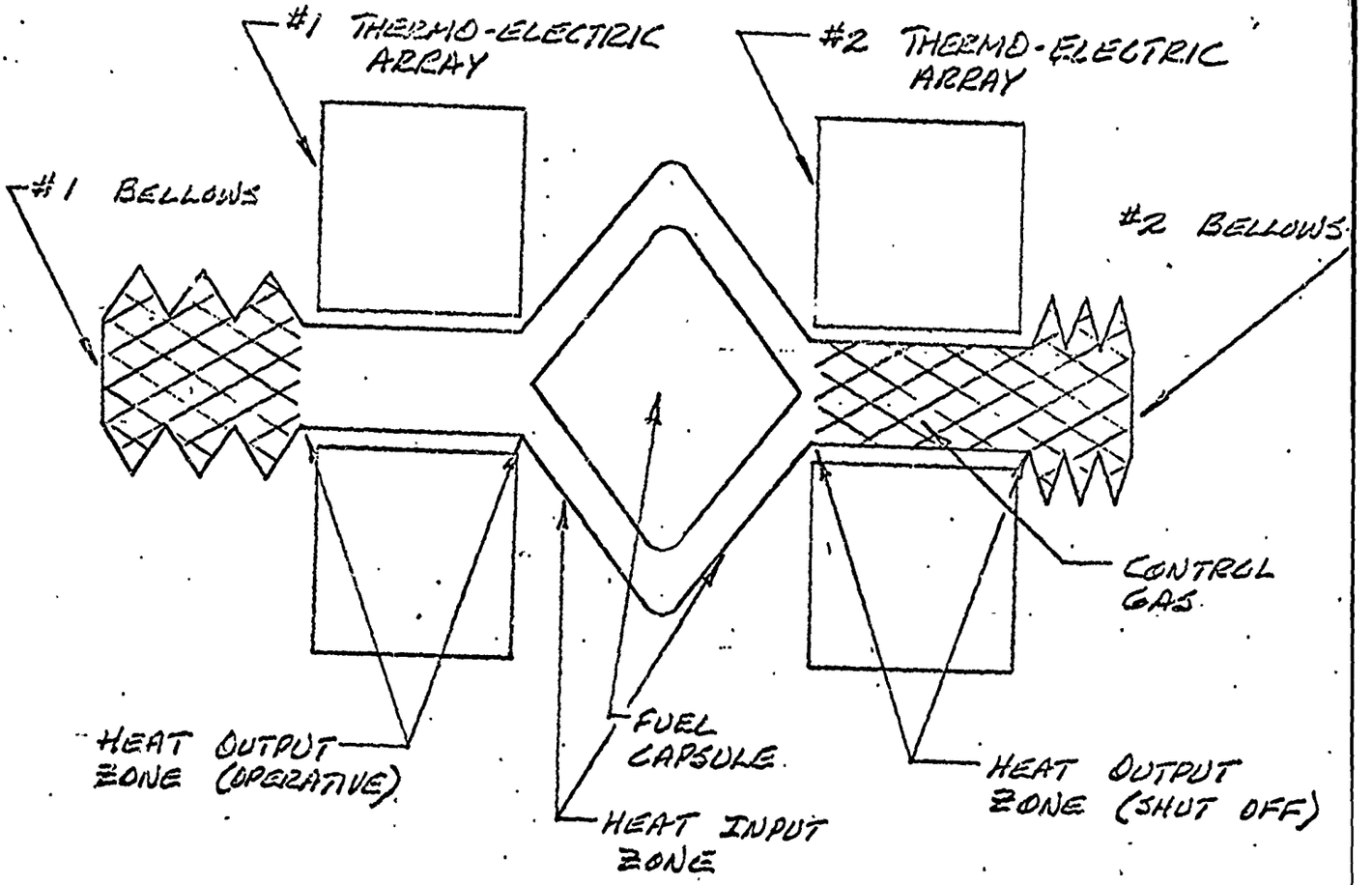
ENGINEERING NOTES

SDO-1134

SUBJECT: "SNAP" GENERATOR WITH SWITCHABLE REDUNDANT THERMO-ELECTRIC ARRAYS

DATE 22 MARCH 65

BY TWyatt



NOTE: CAPILLARY WICK & INSULATION NOT SHOW

Method of Operation - The two bellows are connected by a linkage to an actuator such that either #1 bellows is fully opened and #2 bellows is fully closed (as shown) or #2 is fully opened and #1 is fully closed. By this means the heat output of the radio-active isotope fuel capsule can be switched to either thermoelectric array, with the other array on inoperative standby. The actuation considered is a combination of solenoid holding or latching and spring loading; command operation is also being considered.