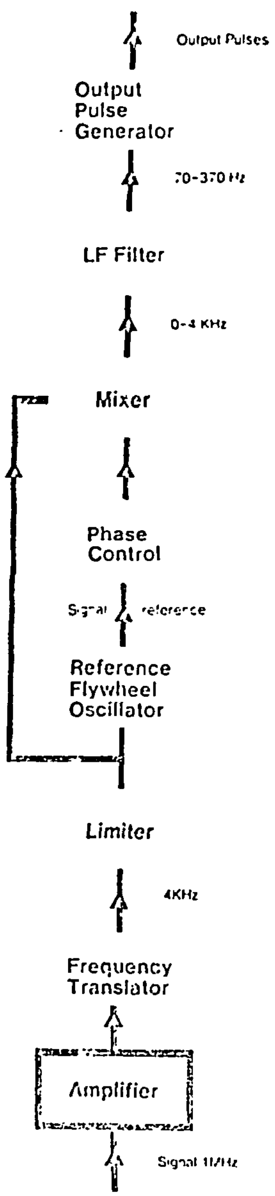
THE REML ULTRASONIC DOPPLER SCATTERING GAS DETECTOR



The output consists of one pulse for each bubble detected The amplitude of the pulse is proportional to bubble radius

The pulses originate as broad band impulses centred on the doppler shift frequency. The actual filter band is selected for minimum noise and may not include the actual doppler frequency.

Low frequency impulses are obtained by mixing the signal with a reference at the sending frequency.

The phase of the mixed signal is adjusted to 0 or 180°. The system is then insensitive to phase modulations caused by the complex structure of the sodium loop.

The reference is derived from the signal itself to eliminate phase drift due to the wave guide temperatures.

A limiter is used to eliminate amplitude disturbances to the signal. The use of a limiter modifies the performance considerably. Doppler signals are detected only by the transient phase changes caused by discrete bubbles.

A frequency translater converts the signal to a convenient low frequency which is independant of the sending frequency

16 " NERATOOM Work on Pump Development ", C.J. HOORNWEG, NERATOOM, Holland.

Summary

The prototype pump has been manufactured by Stork Engineerings Works at Hengelo in 1969. The full-scale test on water has been carried out as part of the procedures of acceptance. Tests on sodium have been carried out in the pumptestfacility of Interatcm at Bensberg (W.Germany); these tests started in March 1971 and were finished in October 1972. During that period nearly 6000 hours of pump testing were accomplished, of which 150 hours the pump was subjected to cavitation. During 30 hours the pump was subjected to a cavitation intensity of more then 3% loss of delivery head. At some occasions the loss of delivery head was 7%.

The measured NPSH with the tests on sodium was 10 m, whereas the NPSH obtained with the tests on water was 9 m. Attempts have been made to account for this difference of NPSH-setting on the two liquids concerned.

At the end of the tests on sodium (that is after the excecution of the cavitation tests) the delivery head of the pump was 2 m.l.c. less than the rated value. After dismantling the pump it appeared that the surface of the impeller vanes was roughened, especially at those parts where the original sand cast surface had not been polished.

Based on the testresults and not being contradicted by calculation-results so far, our opinion is that cavitation in sodium of reactor temperature (550°C) most probably is of the same order of magnitude as it is in water of roomtemperature under the same conditions of NPSH, provided the same pump operates in systems that are exact replica of one another.

Introduction

As reported previously at the Cavitation Conference at Edinburgh (1974) [1], Neratoom participates in a joint venture with Germany and Belgium in the construction of a LMFBR with a capacity of 300 MW_e (called the SNR-300) to be built at Kalkar. It is of the loop-type design with three primary loops and three secondary loops. Before starting the design of the original pumps to be built for

the SNR-300, it was decided to design, to manufacture and to test a prototype pump with a capacity of 5000 m^3/h and a delivery head of 85 m.l.c. The NPSH-required was specified as 10 m.l.c. and the rotative speed in the point of operation was 960 rev/min.
Fig. 1 gives a sketch of the proto type pump.

An abstract of the above mentioned paper [1] reads as follows:
The prototype of the SNR-300 primary pump was tested with water of roomtemperature (about 20°C) at the premises of the manufacturer Stork Engineering Works at Hengelo in 1969. It is worth mentioning that during the designing stages of the prototype pump a half scale model of the impeller was tested with water in order to check on the hydrodynamic design. At that occasion the cavitation behaviour of that model impeller was determined by several means, including:

a) an acoustic detection system; comprising a hydrophone coupled to a frequency spectrometer was mounted at the suction of the pump. The analysis of the sound spectrum was carried out from 12.5 to 40,000 Hz in one third octave band.
b) the observation of visible forms of cavitation bubbles.
c) the determination of the loss in delivery head.

Tests of prototype pump on water

Prior to the sodium tests of the full scale prototype pump it was tested on water. The purpose of the tests on water was not only to check on the hydraulic performance of the pump, but also to acquire test data on water in order to compare them with those obtained on sodium.
With the tests on water the hydraulic characteristics, were obtained. They are given in fig.2.

The measurements to account for the cavitation behaviour of the full-scale prototype pump running on water were executed in a similar manner, including:

a) besides a hydrophone, accelerometers;
b) measuring the decrease in delivery head up to 3% (see fig. 2);
c) the use of acrylic resin, as a means of locating traces of cavitation erosion.
   By applying layers of different colour of acrylic resin to the impeller blade surface an indication of the intensity of the erosion can be established.

After carrying out the normal performance test and a cavitation test up to conditions of 3% loss of delivery head, some damage to the acrylic resin was ascertained, of such a mild nature, that the conclusion was made that no dangerous form of cavitational attack had to be feared at rated conditions of operation.
After a new layer of resin had been applied two tests of longer duration (3 hours) were carried out, one at a capacity of 4000 m^3/h, the other at 4500 m^3/h, at conditions up to 3% loss of delivery head.
After accomplishing each of these tests, the impeller was inspected and some effect of cavitational attack could be established, mainly at the shroud of the impeller. The traces of cavitation erosion to the resin layer was of such a mild nature that the conclusion was drawn that even with tests of longer duration no dangerous form of cavitation would occur.

Tests of prototype pump on sodium

The tests of the prototype pump on sodium were carried out in the APB-test facility of the partner Interatom at Bensberg. These tests started at March 1971 and were finished at October 1972. During this period almost 6000 hours of pump testing were accomplished of which the pump was operated during 150 hours under such conditions of suction head, that cavitation could be established.

During 30 hours the pump was operated at conditions of a loss of discharge pressure exceeding 3% occasionally a discharge pressure decrease up to 7%. The specified delivery (= 5000 m^3/h) and head (85 m.l.c.) was reached, were measured at the normal tests. Remarkable is, however, that after carrying out the cavitation tests the delivery head was 2 m.l.c. less, than before (H= 83 m.l.c. in stead of 85 m.l.c.). The NPSH corresponding to that affected delivery head was established as 10 m.l.c., see fig.3. For this sodium-test acoustic measurements have been done, see fig. 6,7.

Discrepancy of NPSH-values (water versus sodium)

The explanation for the discrepancy found in NPSH-setting of the pump has been accounted for in referring to the differences in lay-out between the water-circuit and the sodium test loop

[1]. The design of the water circuit having been more optimal than the sodium test loop, since the latter was influenced by restrictions of space of the testfacility, fig. 8.
An analysis has been made to the extent of comparing the velocity distribution at pump-suction in either case, leading to the conclusion that the discrepancy most probably can be accounted for by this comparison. In fig. 4 the characteristics of the results of test in both liquids are given for easy comparison.

Applying the thermodynamic concept of Stepanoff for the NPSH-Adjustment [3], on water of roomtemperature and sodium of 580^{o}C, the difference in NPSH-setting should be negligible (NPSH-adjustment is less than 1 mm).
In fig. 5 a comparison is made between the results of the full size impeller and the model impeller.

The condition of the impeller after the tests

The pump was dismounted when the test program was terminated. At the inspection of the impeller it was found that the surface of the impeller blades had roughened. Chemical technological investigation of the material at the upper skin of the damaged area lead to the conclusion that this damage was mainly to be observed at areas where the original sand-cast surface had not been polished.

The traces of sand found imbedded in the blades surface (after an operation of abt. 4300 hours) indicated that cleaning after the sand casting process had not been adequately. The cavitation tests must have accelerated a phenomena of washing out of the sand particles.
That cavitation was not to blame in having caused the rough impeller surface, was explained by the fact, that the location of the damage was not typical for cavitation erosion damage.
The fact that the delivery head was 2 m less than the rated value after the tests were terminated, was probably caused by the roughening of the surface of the impeller blades.

Conclusions

To our opinion - based on our test results, the cavitation characteristics of a pump measured in testfacilities - being exact replica of one another - with sodium at 580^{o}C or water at roomtemperature, should be of the same magnitude. The matter of possible differences in erosion caused by cavitation is in our opinion not yet fully investigated and hence not treated in this contribution.

Appendix A

Quantification of cavitation erosion

Attemps are made by Neratoom to compare cavitation erosion properties of water and sodium by quantifying the implosion energy exerted on the material.
The radius of the bubble is therefore calculated with the Rayleigh-Plesset equation:

$$\rho(R\ddot{R}+\frac{3}{2}\dot{R}^2) = (P_{\infty_o}-P_v+\frac{2\sigma}{R_o})(\frac{R_o}{R})^{3n} + P_v-P_\infty(t)-\frac{2\sigma}{R}-4\frac{\mu\dot{R}}{R}$$

It appears that cavitation bubbles in sodium have a 20-times bigger diameter than those in water under the same circumstances, since k = the thermal transmission coëfficient of sodium is 100x that of water and since a= $k/\rho_L C$ is the value of the thermal penetration depth of a bubble (= $\sqrt{at}$)in sodium about 20 times that in water; hence with the same ratio of $R/\sqrt{at}$ is the bubble in sodium 20 times as big as it is in water.
However there are reasons to assume, that the number of bubbles in sodium is far less than in water (about 10^{-4} times); it works out in that way that according to the model and under certain assumptions, that the erosion of cavitation in sodium is of the same order of magnitude than it is in water.
It is, however, advisable to carry-on with tests comparing especially the effects of cavitation-erosion in the liquids mentioned.

Appendix b

LIST OF REFERENCES

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[2] R.H. Fakkel, C.J. Hoornweg, W.K. Mendte, W. Jansing, H.J. Lambris, J.P. Vroom, H.W. Heslenfeld.
"Development, design, construction and full scale sodium testing of a prototype sodium pump for a LMFBR-Power Plant".
Proc. Conf. on Reactor Pumps, Institution of Mech. Engineers, Bath, England, 1974 April, p. 197-205.
(Paper C 108/74).

[3] R.H. Fakkel.
"Sodium pump development". Paper IAEA/SM 130/23 Monaco March 1970.
Intern. Atomic Energy Agency, Vienna.

[4] Mendte W.K., Reimann H., Tsu D., Fakkel R.H.
"Kavitations- und Schwingungsuntersuchungen an einer Prototyp-Pumpe für den SNR 300". Reaktortagung 1973 des Deutschen Atomforum/KTG in Karlsruhe.

[5] Société Hydrotechnique de France, 12-ièmes journées de l'Hydraulique Paris 6-8 Juin 1972, Compte rendu des Séances et des discussions II pages 7 & 8.
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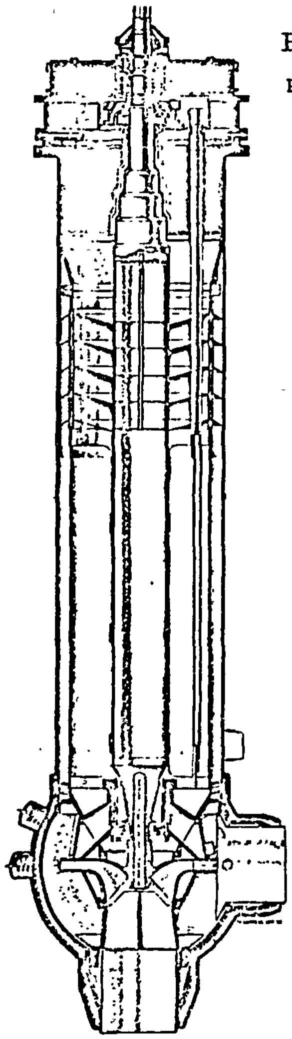


FIG. 1.
Prototype sodiumpump

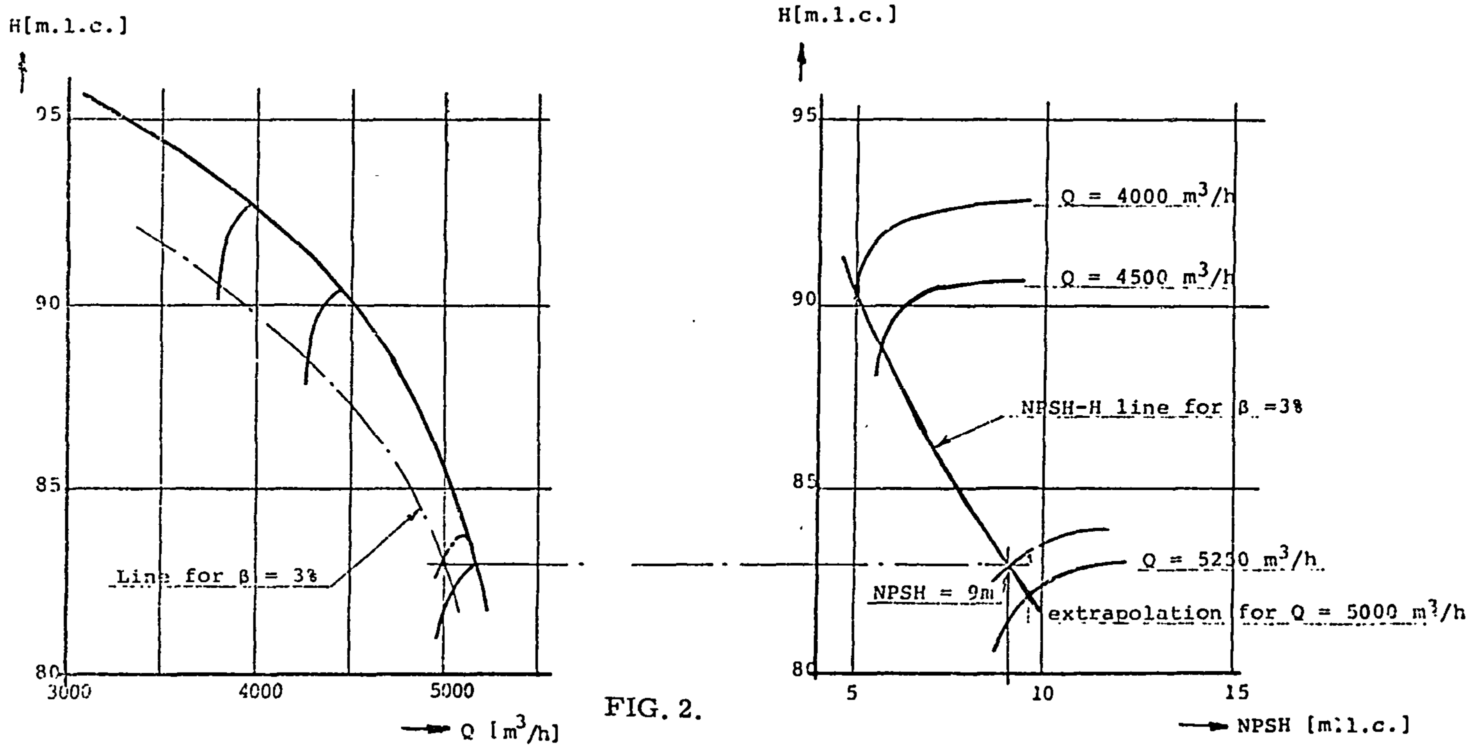


FIG. 2.

Q-H and NPSH-H characteristic obtained on water.
n = 960 rev/min.

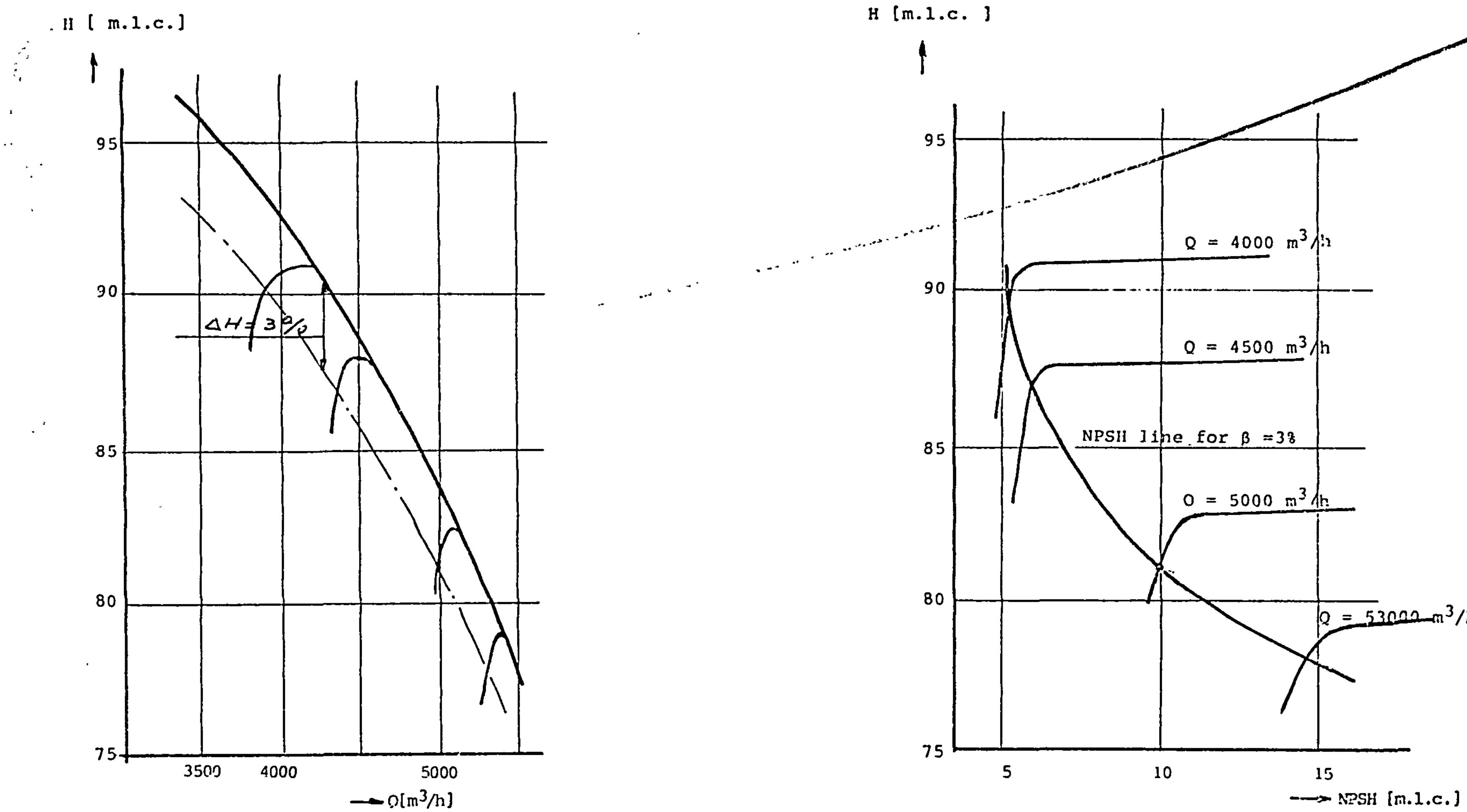


FIG. 3.

Q-H and NPSH-H characteristic obtained on sodium of 580°C.
n = 960 rev/min.

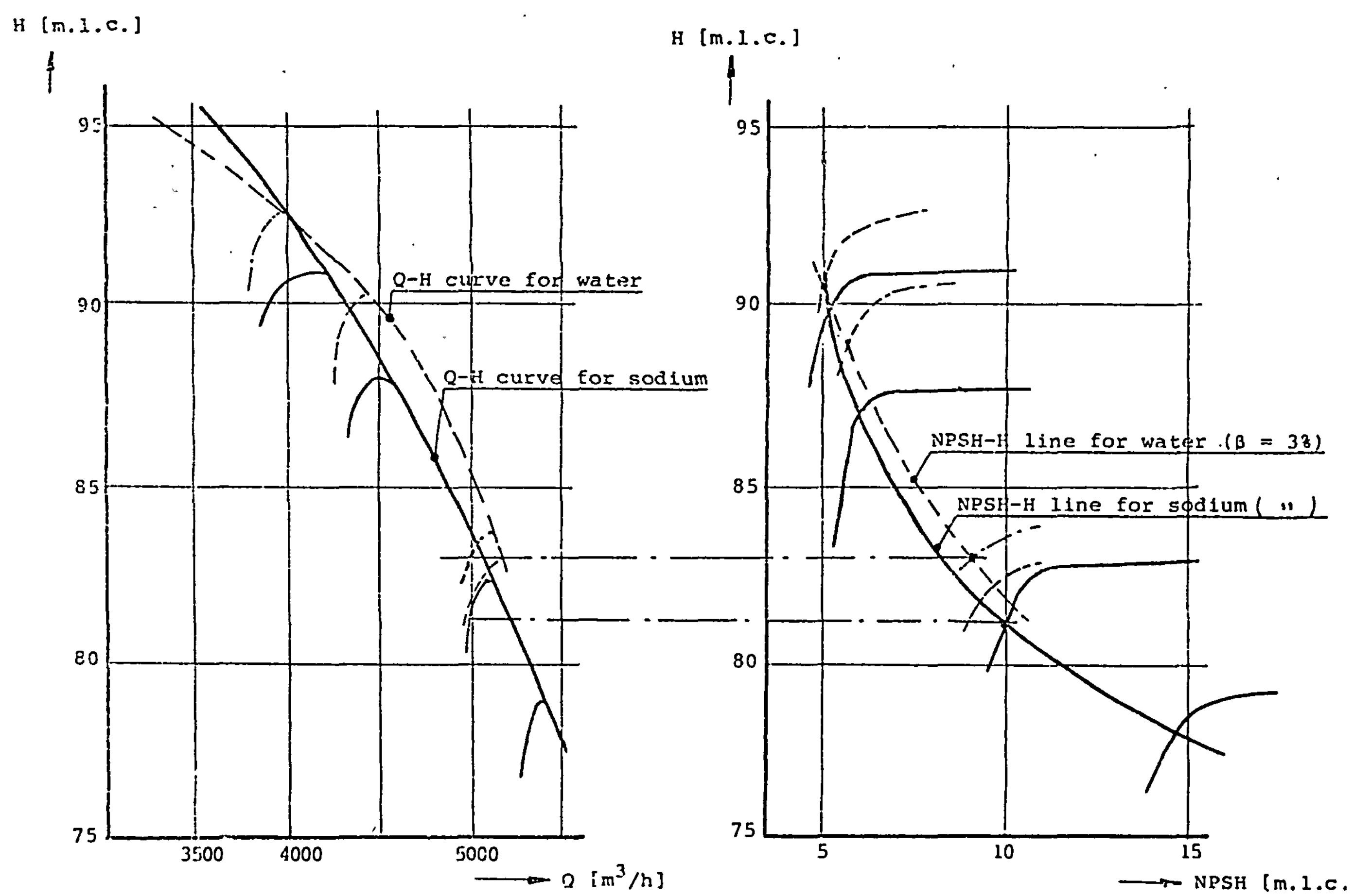


FIG. 4.

Comparison of testresults (water versus sodium of 580 deg. C)

FIG. 5.

NPSH = f (Q$_{rel.}$) for 3% pressure drop
(model impeller versus prototype impeller)

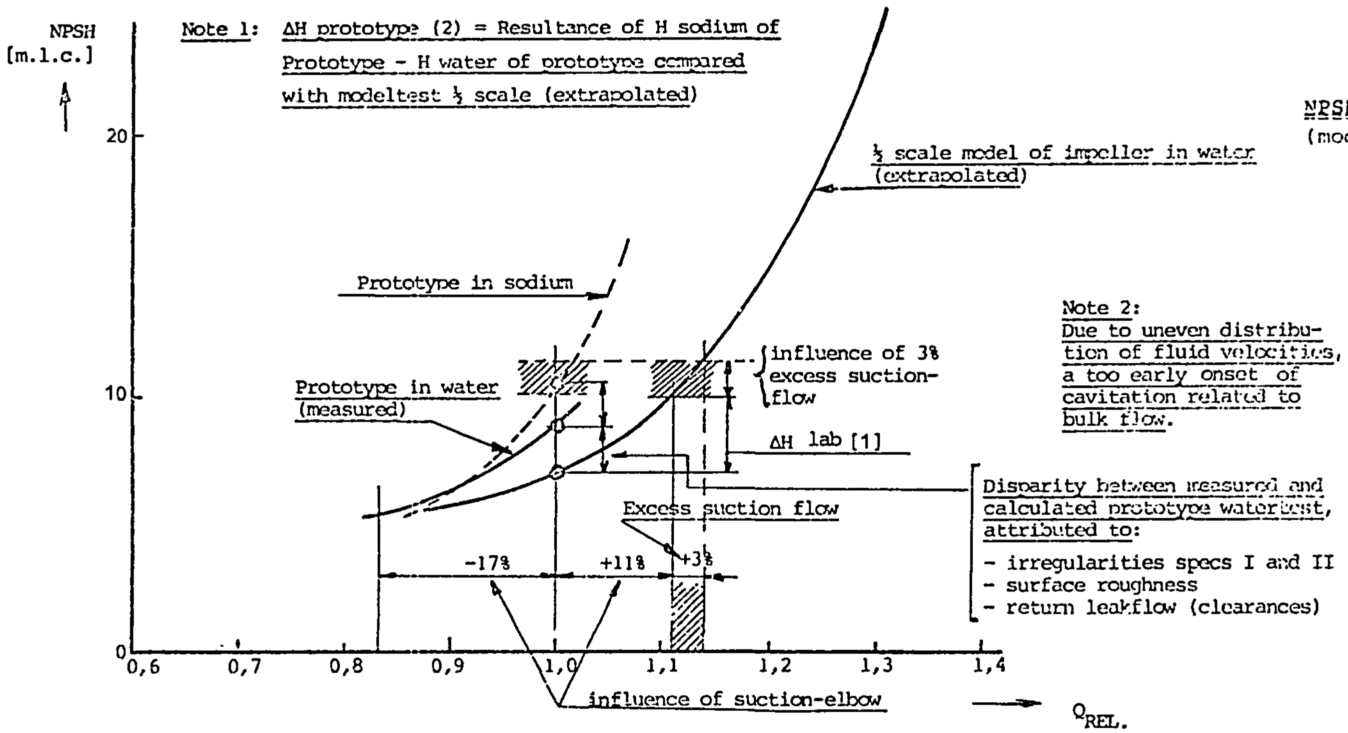


FIG. 6.

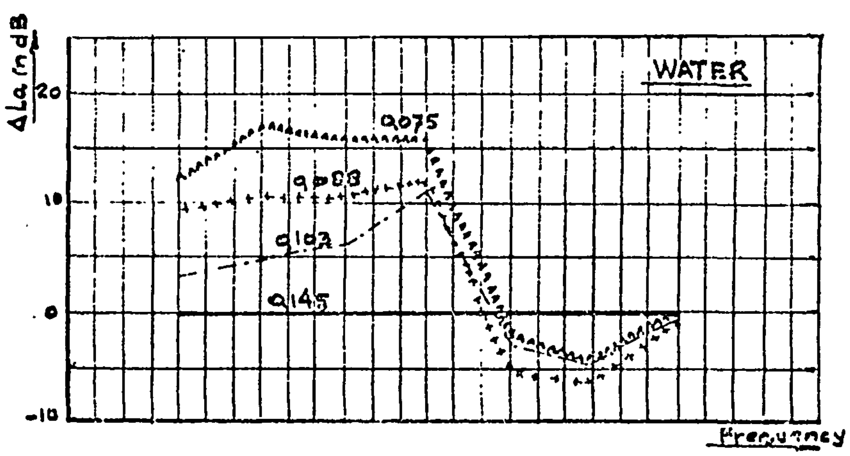


Figure: Water at roomtemperature

Water and sodium comparison (illustrative)

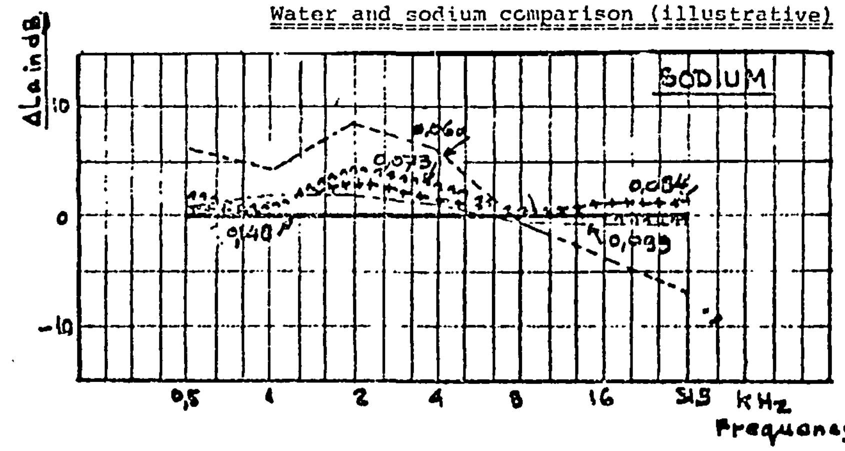


Figure: Liquid sodium at 375°C; n = 960 rpm.

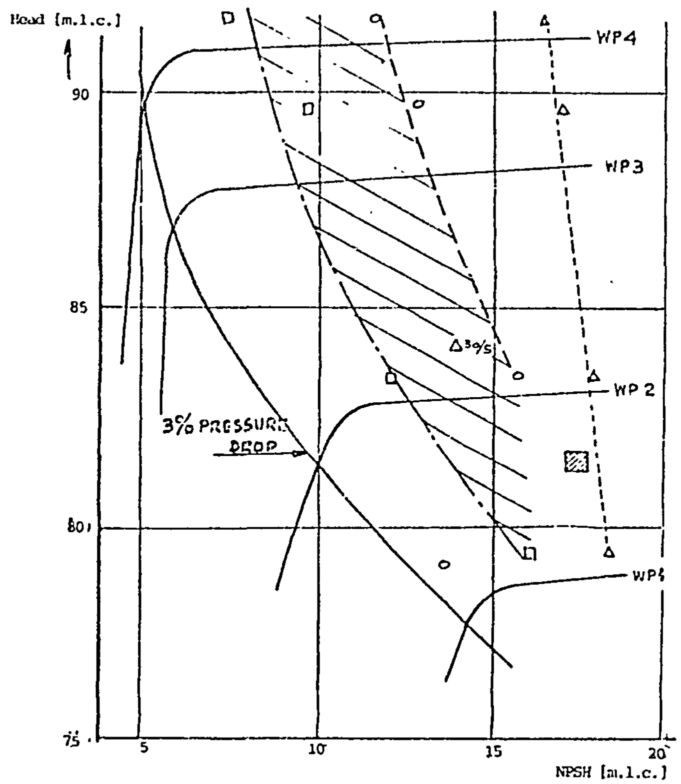
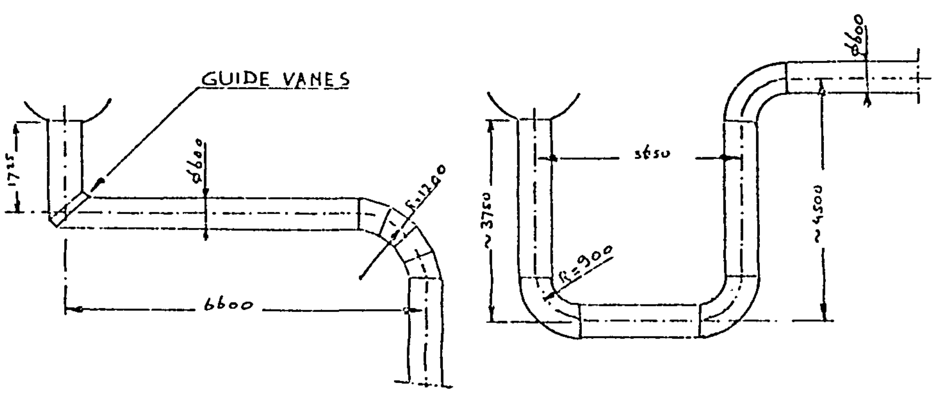


FIG. 7. Cavitation inception measured acoustically.



Water circuit

Sodium circuit

FIG. 8. Suction piping lay-out.

17 " Sodium Cavitation Test in Vibratory Facility ", F.G. HAMMITT, Univ. of Michigan, P. Courbière, C.E.A., France.

ABSTRACT :

With financial support provided by C.E.A./Cadarache Professor F.G. HAMMITT has reported cavitation data from tests on sodium with a vibratory facility (20 kHz, 51 μm double amplitude) over the temperature range 300-500°C at a suppression pressure of 3 bar on a reference material 316 L stainless steel.

The tests were designed to compare :

1°) The effects of sodium temperature variation over the range 300°C, 500°C on cavitation erosion.

2°) The cavitation erosion resistance in liquid sodium of special materials such as stellite 6-B, Colmonoy 6, Hard Chrome, and Carborundom LW-5 with the standard reference material Stainless Steel type 316 L.

1 - *INTRODUCTION*

Cavitation erosion tests in sodium have been conducted under the terms of a contrat for the "Commissariat à l'Energie Atomique" by Prof. F.G. HAMMITT of the University of Michigan.

The purpose of these tests was :

- To determine the influence of temperature on cavitation erosion in liquid sodium.

- To compare the erosion cavitation resistance in liquid sodium of special materials with the standard reference material, stainless steel type 316 L.