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THE UNIVERSITY OF MICHIGAN
College of Engineering
Mechanical Engineering Department
Cavitation and Multiphase Flow Laboratory

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IMPROVEMENT OF STEAM TUNNEL OPERATION AND EFFICIENCY

(In partial fulfillment of Mechanical Engineering 490)

by

David Krause

Approved by

F.G. Hammitt

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4.0 OVERVIEW OF STEAM TUNNEL SYSTEM (continued)

The high velocity steam is condensed in a once-through mixing condenser and pumped into the storm drain. The basic components of the steam tunnel facility are displayed in Fig. 1 below.

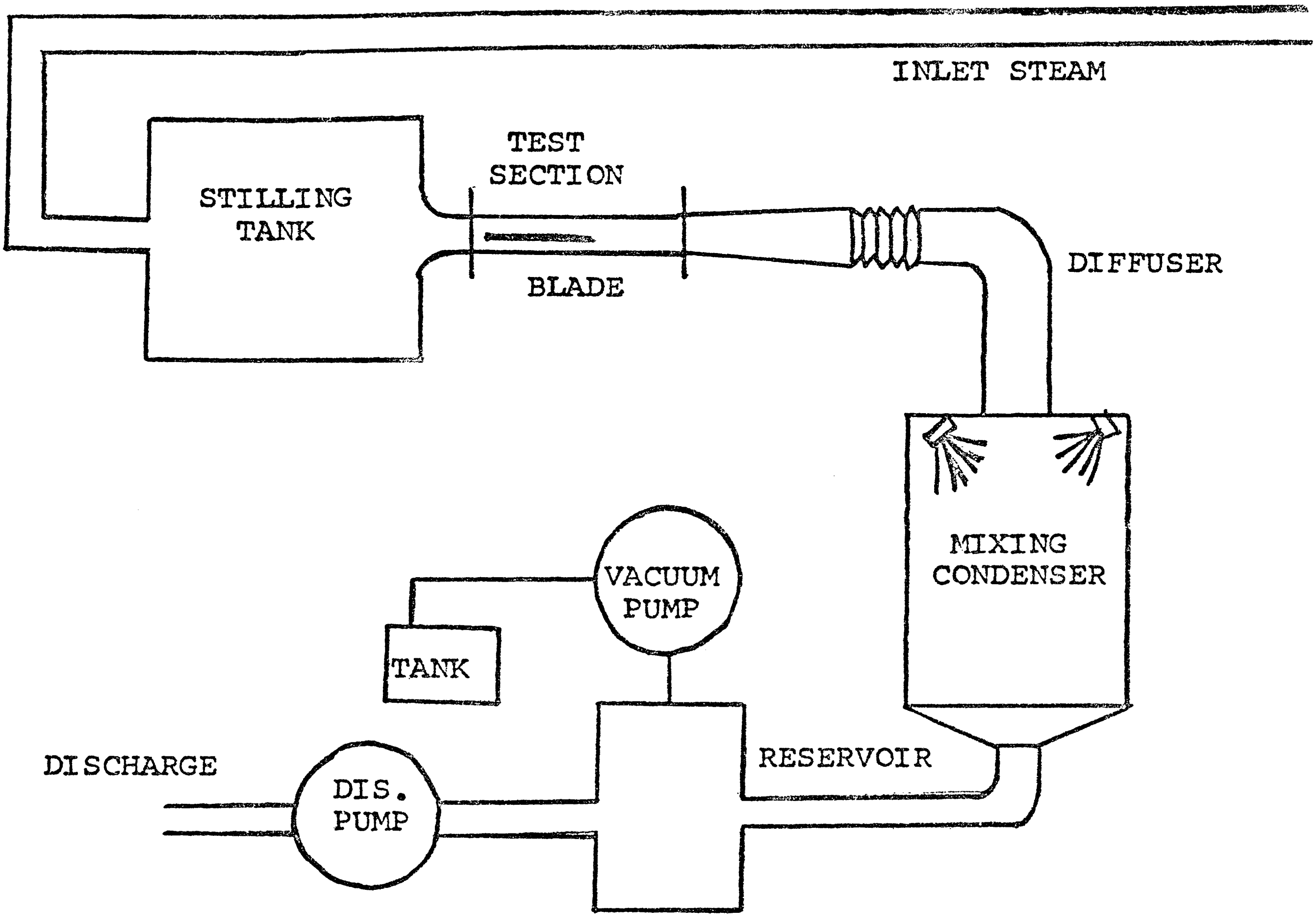

Fig. 1 STEAM TUNNEL SCHEMATIC

From Fig. 1 above the major components of the system can be easily identified. However, it should be noted that this schematic differs from previous ones since it has an additional vacuum pump and holding tank installed in the reservoir of the discharge pump. Thus, it is possible to remove excess air and water vapor that collect in the reservoir and effect the stability of the system. In the next section I will identify this problem further and attempt to examine the probable causes.

5.0 EVIDENCE OF EXCESS AIR ACCUMULATION

My study indicates that the accumulation of water vapor and air in the discharge pump reservoir led to the instability of the steam tunnel system. The pump is unable to handle a flow consisting of both liquid and vapor. Therefore, this flow pattern led to a significant and sudden decrease in the efficiency and head output of the machine. This conclusion is supported by experimental evidence of system cavitation, irregular flow formations, improper system priming, and system leakage.

5.1 SYSTEM CAVITATION

A practical problem that often arises when pumps are used with liquids is the occurrence of system cavitation in the low pressure regions of the flow. This phenomenon may be described as local boiling resulting in the formation of bubbles and regions of vapor within the liquid as a result of the lowering of the local pressure to the vapor pressure of the liquid. Therefore, a significant portion of the low pressure zone may become filled with vapor. The low pressure region experiences a loss in total pressure due to vigorous mixing of the main stream and as a result decreases the efficiency. The velocity in the remainder of the passage is thereby increased and the static pressure of the flow is even further decreased. Eventually, the distortion of the flow pattern and energy loss caused by system cavitation leads to an abrupt decay of effeciency as well as head output of the pump.

5.1.2

In the existing steam tunnel system, it was noted that a large pressure drop occurs in the flow as it passes from the condenser to the pump reservoir. This pressure drop was due to pipe friction and the number of ninety degree bends in the flow circuit. When the local pressure was reduced to the vapor pressure, the flow would contain pockets of vapor. These vapor pockets eventually collected in the pump reservoir and caused the sudden drop in pump output.

5.1.3

To maintain constant pump output and thereby achieve system stability, it was necessary to remove the vapor that had collected in the reservoir of the discharge pump. This was done by addition of the vacuum pump and collection tank directly to the reservoir. The vacuum pump continually removed the pockets of trapped vapor and insured steady state operating conditions.

5.2 IRREGULAR FLOW FORMATIONS are distortions of the regular flow patterns which cause a drop of the local pressure in the flow. As a result, the low pressure zone may fill with vapor. Vortex flow was observed at the condenser drain of the steam tunnel system. This particular formation may also have been induced by the tall cylindrical design of the condenser and the fact that the condenser was the direct contact mixing type. Removal of this irregular flow was achieved by securing screens inside the condenser that served to retard the vortex formation. Any vapor formation that resulted due to this minimal flow impairment could also be removed in the discharge pump reservoir.

5.3 SYSTEM PRIMING is of major importance if the system is to be started up from complete shutdown. If the discharge pump reservoir is filled with water and maintained void of any pockets of water vapor by the vacuum pump; maximum pump output could be achieved and steady state steam tunnel operating conditions could be realized sooner. Limitations on the pump speed are avoided when vaporization of the fluid is kept to a minimum. Therefore, the discharge pump may be run at a lower speed with higher head output if care is taken to properly prime it and keep the reservoir free of all air and water vapor.

5.4 SYSTEM LEAKAGES were responsible for introducing air into the system. Although this cause was of minor importance when compared to the others, it was nonetheless a contributing factor. However, system leakages could be repaired only by direct observation of the system under operating conditions. With this disadvantage only the most obvious leaks could be repaired.

6.0 OTHER PLAUSIBLE ALTERNATIVES REJECTED

On the basis of my review, the evidence seems to support my previous conclusion that the accumulation of water vapor and air in the reservoir of the discharge pump led directly to the instability of the steam tunnel system. However, I believe this study would not be totally conclusive without having examined all the possibilities. For that reason I investigated alternatives that suggested that system blockage and pump damage were the major problems.

6.1 SYSTEM BLOCKAGE at first seemed to be a very attractive solution because system debris could easily lodge itself in the discharge pipe and cause a sudden head loss. Also, the fact that a large number of ping-pong balls were placed in the condenser to aid condensation seemed to enhance the possibility that they somehow blocked pipes or the pump inlet. However, examination of pipes and the pump inlet failed to disclose sufficient evidence that debris had plugged any key passages and was responsible for the head loss.

6.2 PUMP DAMAGE was a logical solution to the problem because it was the most direct. The steam tunnel had been run previously with some success, but only recently had the sudden inability of the pump to handle the condensate flow become so crucial. Also, if the pump was cavitating the pump impeller would have been damaged by the pressure waves originating from the collapsing bubbles. However, examination of the pump impeller revealed no damage due to cavitation and that the pump was mechanically sound.

6.3 On the basis of my review of pump damage or of system blockage as possible causes of system instability, I conclude that they should not be considered as plausible causes. However, my investigations of them led me to the actual causes and will answer any questions as to whether or not they were contributing factors.

7.0 RESULTS AND CONCLUSIONS

My objective in this study was to find the cause of the instability in the steam tunnel system and thereby enable research to continue.

I believe that the problem involved the accumulation of air and water vapor in the reservoir of the discharge pump. Since the pump was not able to handle this two phase flow efficiently, the system experienced a sudden decline in output. The air and water vapor were introduced into the system by means of: system cavitation, irregular flow formations, improper system priming, and system leakages.

Other alternatives such as pump damage and system blockage were not found to be contributing factors. However, even though the system is able to function at steady state conditions with the additional vacuum pump and holding tank at the discharge pump reservoir, further observation of system operation is warranted.