COBEM 87 — IX Congresso Brasileiro de Engenharia Mecânica, Florianópolis, SC (Dezembro, 1987)
9th Brazilian Congress of Mechanical Engineering

Experimental Investigation of Radial Vane Steam Separators in a Air-Water Loop

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ABSTRACT

An experimental investigation was carried out on centrifugal steam separators. The principal aim was to study and to understand the performance of these separators. Three kinds of radial separators were studied on an experimental rig which operated with two fluids (air-water) to simulate two-phase flow (vapor-water). Pressure drop and carry-over were measured over a wide range of operational conditions.

INTRODUCTION

Steam separators are used inside steam generators to produce moisture-free steam. Carryover of water with the generated steam is detrimental to turbine performance since one percent of moisture presente in the high pressure turbine stages may bring about seven percent loss in turbine efficiency |1|. Separation is typically accomplished in two stages. Mechanical separation, usually with centrifugal separators, is followed by a stage of drying (using chevron driers , for example). Design of a centrifugal separator involves a compromise among compactness, carryunder of steam, carryover of liquid and pressure drop |2|. The last three quantities must be kept low for a wide range of operational conditions. Low carryovers can be attained by impinging higher centrifugal forces to the two-phase mixture inside the separator, however at an expense of higher pressure drops. For a recirculating steam generator, higher pressure drops at the end of the boiling path means lower buoyancy-driven flow and, possibly, hidrodynamic instability. Related design problems are also of concern in the areas of drainage and venting which should be such that interference between stages is minimized |3|. The separator behavior directly affects the performance of the steam generator and consequently the economics and safety of the plant. The purpose of this study is to obtain meaningful data on local and integral separator parameters in order to better understand the mechanisms associated with the separation process and to help the validation and improvement of existing mathematical models used in analysis and design.

EXPERIMENTAL APPARATUS

Data were obtained on an air-water experimental rig (fig. 1) which operates at atmospheric pressure. Tests were conducted on three radial steam separators. The range of operational and geometric parameters is showed in Table 1.

The homogenization of the two phases (air and water) is accomplished in the mixer where the air flows through a porous element. After leaving the mixer the two-phase mixture is driven to the test section tank where mechanical separation takes place in the separator under test. The remaining liquid still carried by the air is totally separated in the drier and sent to the carryover measuring tank.

Figure 2 show an schematic view of the test separator. Flanges installed in the test separator also permit changes in the riser length.

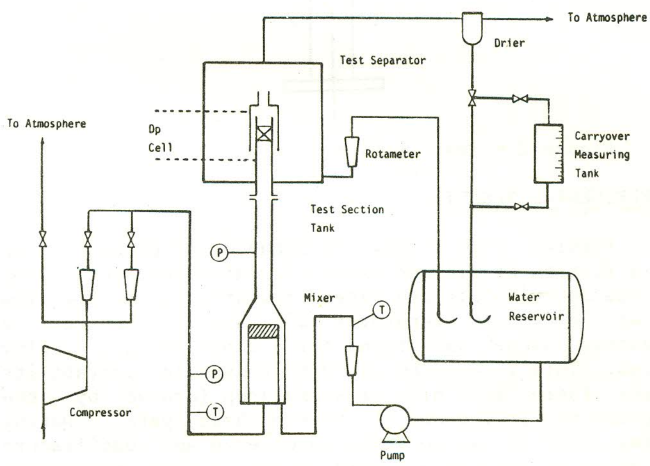

Figure 1 - The two-phase test rig.

Tabela 1. Range of parameters

SEPARATOR	LENGTH AFTER THE BLADES	LENGTH BEFORE THE BLADES
S222	222	0
S165	165	57
S114	114	108
FLOW	AIR (Kg/s) 0 TO 0.25	WATER (Kg/s) 0 TO 6.1
LEVEL IN TANK	210 - 344 - 419 (mm)	

Pressure drops were measured by capacitive-type pressure transducers and registered on paper while carryovers were obtained by measuring the time needed for the liquid to fill a known volume in the carryover measuring tank.

All experimental data were reduced by means of a computer programa in which fluid properties and rotameter calibration curves were programmed in the form of polynomial curve fits.

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In a static separator the phenomen of phase separation is governed by gravitational, centrifugal and interphase drag forces. Scaling requires that the proportionality of these forces be kept constant between the model and the prototype. Analysis reveal that this is accomplished if density ratio, geometry and flow pattern are maintained. Obviously, an air water mixture cannot simulated the density ratio of a steam-water mixture at high temperature. Therefore, only geometric and flow pattern were conserved in this study. Flow pattern is essentially dictated by the values of phasic superficial velocities which were chosen to cover the range found in a typical steam separator.

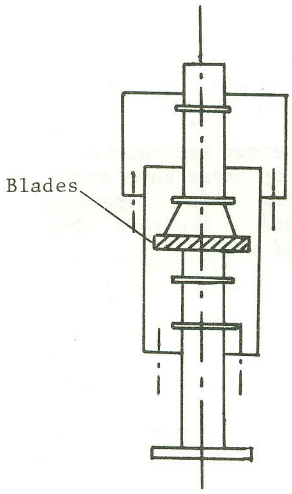

Figure 2 - Test section

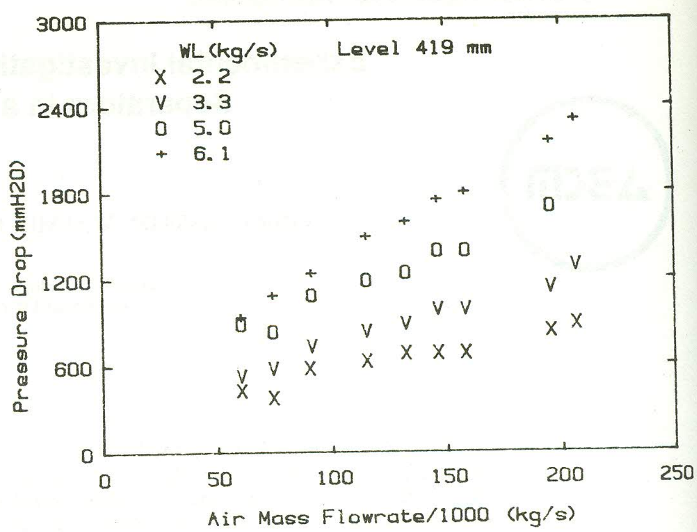

Figure 4 - Pressure drop vs flowrate for separator 114.

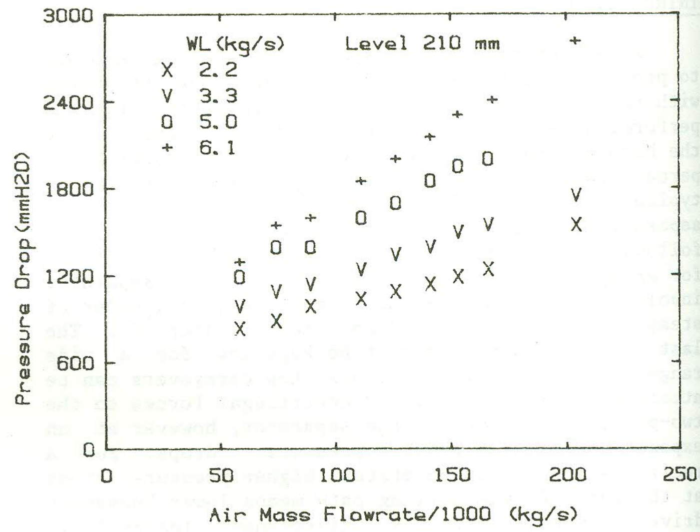

Figure 5 - Pressure drop vs flowrate for separator 165.

EXPERIMENTAL RESULTS

Figures 3 to 8 show the behavior of pressure drop as a fuction of air and water flowrates. Pressure drop increases with air and water flowrates except for low water levels in separator 222 (Fig. 8) where a negative slope was found for a range of air flow rates. This is attributed to hydrodynamic instability since there is a high pressure drop (caused by the separator) at the end of the two-phase path. During these runs it was possible to observe an oscillatory behavior of two-phase flowing mixture. This phenomenon is not solely caused by the separator itself. The eventual analysis must take the whole circuit path into account.

Water levels also plays a significant role on the pressure drop when no oscillations are present. Figures 3 to 6 show that higher levels tend to decrease the pressure drop.

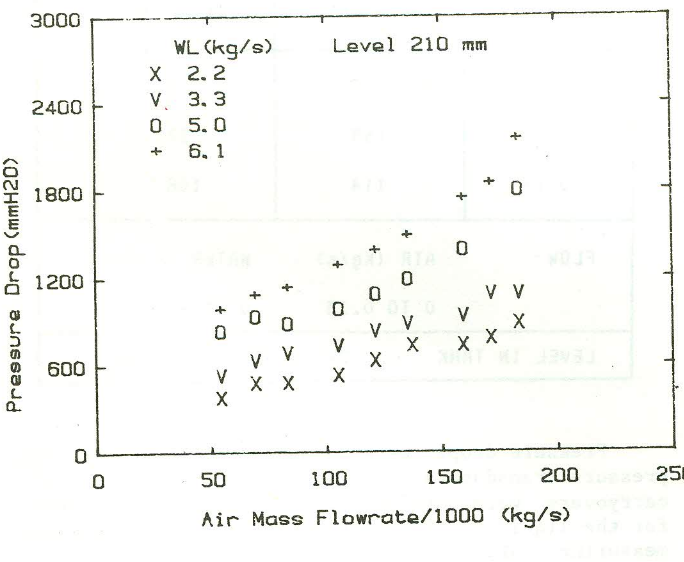

Figure 3 - Pressure drop vs flowrate for separator 114.

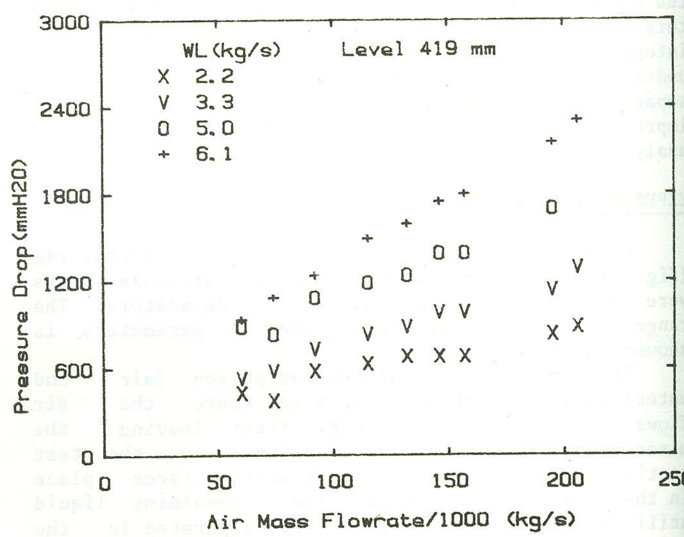

Figure 6 - Pressure drop vs flowrate for separator 165.

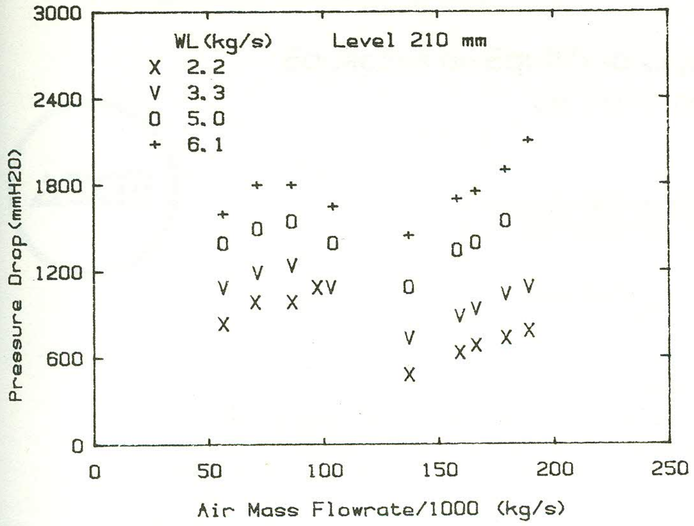

Figure 7 - Pressure drop vs flowrate for separator 222.

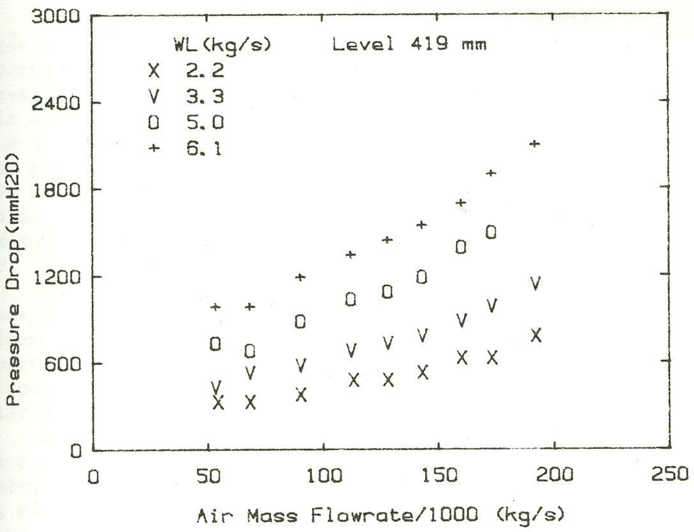

Figure 8 - Pressure drop vs flowrate for separator 222.

CONCLUSIONS

A large number of experimental data was obtained on the pressure drop and carryover characteristcs of radial vane steam separators. Both water level and riser length have a strong influence on pressure drop and carryover. Experimental results have also shown a fact observed in other two-phase flow applications, that is, the concentration of a high pressure drop at the end of flowing path can induce flow instability.

REFERENCES

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