CHAPTER 10

CONCLUSIONS

Dimple plate heat exchangers provide a highly efficient type of heat exchanger that has numerous possibilities for application in industry in general and specifically in the petrochemical, chemical and refining industries. At the writing of this study flow-induced vibration was a problem that was solved in a hit and miss fashion.

From the literature the three most destructive mechanisms for flow-induced vibration are fluid-elastic instability, vortex shedding of the plates and vortex ejection from the dimples. The designers of the dimple plate heat exchangers take steps to eliminate fluid-elastic instability. However, the other two types of vibration remain possible causes of excessive vibration and damage when the induced vibrations are close to the natural frequencies of the structure.

During qualitative experiments, using dimpled panels mounted in a blower tunnel, two distinct flow-induced vibration frequencies were observed. These two vibrations were assumed to be attributable to vortex shedding and vortex ejection.

By replacing the current very stiff (almost rigid) steel connection between the heat exchanger and the structure with a soft rubber (mounts) connection, additional degrees of freedom could be created that altered the vibrational response and the natural frequencies of the system. This solution could, therefore, reduce the response due to a forcing frequency close to its original natural frequency by altering the location of that natural frequency.

The problem, however, could arise that an additional forcing frequency close to the new natural frequency could become the new cause of failures. Special precautions should be taken during the design of the mounting system to ensure that the highest natural frequency of the mounted system is far enough above the fluid induced frequency.

The system was modelled in the direction of the lowest natural frequency of the dimple plate heat exchangers, which was also the most likely direction that the fluid-induced vibrations would excite. The model was simplified further to the two degrees of freedom system by only simulating the movements of the plate pack and the top structure of the heat exchanger.

The mathematical models indicated that the dynamic forces in the elements of the heat exchanger could be reduced considerably by changing the current mounting system from very stiff steel-mounted to a soft rubber-mounted system. With the correct choice of stiffness for the soft rubber mounting system, the forces in the elements (especially the plate pack) could be reduced significantly without changing the structure or working of the heat exchanger.

The reduction in the dynamic forces in the elements would lead to a reduction in cyclic stresses, which would, therefore, prevent premature failures of the components. The reduction, therefore, would increase the life of the components and the heat exchanger as a whole and would improve the availability of any system into which the heat exchanger is installed.

The effect of the design change and the accuracy of the two degrees of freedom theoretical models were verified experimentally by constructing a model of a Sasol column-top condenser. Vibration measurements were taken for two forcing frequencies when the model was mounted with stiff steel bolts to the support frame and the same frequencies when the model was mounted with soft rubber mounts to the frame.

The experiment close to the natural frequency of the stiff steel-mounted system proved that a reduction of up to 97.8% could be achieved for forces in the plates themselves, together with significant reductions in all the other elements.

Neither of the two degrees of freedom models predicted the effect of the isolation accurately, with both the models significantly over- and under-predicting the values in the different elements. The two DOF model that incorporated damping was found not to improve the accuracy of the predictions over a model that does not take damping into account.

The possible cause of the inaccuracy is the assumption that the model's supporting frame is rigid. It is not practically possible to build a truly rigid frame. Due to budget and transportation constraints, the frame could not be further stiffened. The laboratory is further situated on the first floor of a reinforced concrete building, which is not ideal due to the floor's inherent flexibility.

The inaccuracy caused by this assumption can clearly be seen in high-force values calculated from the experimentally measured values.

It is possible to eliminate the effect of this problem by measuring the vibration on the frame itself and subtracting it from the measured amplitudes at the current locations (top and bottom frame of the model).

A further source of inaccuracy could be attributed to the characterisation of the different rubber components, due to the fact that vibration characteristics of the rubber are load-, frequency- and amplitude-dependent.