8. CONCLUSIONS

- A generalised mathematical model that describes the dynamic behaviour of pure single refrigerant multi-stage refrigeration systems has been presented, and applied to a an industrial-base case study of a two-stage system with propylene working fluid. For this case, a non-linear simulation model has been implemented using ACSL, and a linearised model has been derived and validated.

- The two-stage refrigeration system investigated in detail has been shown to exhibit true interactions, especially involving evaporator liquid levels. This may make the system of interest to other researchers as a case study of use in developing techniques for interaction and control system analysis in multivariable systems.

- In the two-stage refrigeration system, the best performance is achieved through direct control of the process stream outlet temperature TP1o. This is best implemented by a cascade control system with the LP evaporator pressure as the slave loop and the process stream outlet temperature as the master loop.

- Using level or pressure control cascaded on to a slave flow control loop does not result in any significant performance improvement based on the ISE of TP1o.

- Reducing the number of control loops to three by eliminating the IP or HP loop results in slight deterioration in the process performance based on ISE in TP1o. However, the performance of the level loops improves.

- Two level control loops must be used to guarantee the system's stability against disturbances. While the inclusion of liquid level in the HP receiver as a controlled variable (instead of any evaporator liquid level) improves the performance of the control system, it cannot guarantee effective heat transfer in the evaporators (where heat transfer surface could become exposed).

- Published methods that investigate the favourable selection of measured / manipulated variable sets for control purposes (e.g. controllability, resiliency, Input and Output Effectiveness), that give guidance on pairing measurements and manipulated variables (e.g. Relative Gain Array and Relative Interaction Array) and that give measures of interaction in fixed measured / manipulated pairings (e.g. Jacobi Eigenvalue Criterion, Dynamic Interaction Measure, Performance Interaction Measure, μ Interaction Measure) were all applied to develop a control system for the two-stage refrigeration process. The results obtained were conflicting and sometimes misleading when looked at on the basis of performance of the control systems developed through heuristics and simulation. This is because these published methods do not properly account for the relative importance or relative precision of individual variables in meeting the control objectives.

- Specific examples where some of the published methods fail have also been identified for the RGA, the Niederlinski Index and the Dynamic Interaction Measure. These examples could form a basis for further refinement of these techniques in future work.

- A new general steady state method for giving guidance on pairing measurements and manipulated variables in a set of SISO loops, denoted as the Input / Output Interaction Array (IOIA), has been proposed. The IOIA has been tested on three different cases: a low order interactive system (2 loops), the two-stage refrigeration system (5 loops) and a coal gasifier system (4 loops). In each case, the prediction for the IOIA about variable pairings agrees with the performance of the systems observed through simulation.

- The IOIA is based on a full state space model rather than the system transfer function matrix and can thus reveal the extent of underlying interactions within the system structure. In comparison with a related approach made by Johnston (1990), it can provide an assessment for systems of any order whereas the method proposed by Johnston is only practical to low order cases.