some questions to the authors, because we think that some points are not sufficiently clear in the paper.

Our first question is related to the way that component maps have to be modified in order to match overall engine performance. Since the authors state that their model is useful for inexperienced operators, we wonder how such operators will be able to produce the required changes on map parameters, without risking being involved in a lengthy trial and error procedure. The authors do not seem to be aware of the existence of methods of automatically adapting the component maps to engine performances (Stamatis et al., 1990a).

A second question is related to the calculation method itself. It is not clear to us how the iterations are done. Since constants *A*, *B*, *C*, *D* contain the compressor efficiencies, their estimation will have to be effected at each iteration. It seems, therefore, that at each step it will be necessary to "go back to the beginning of the calculation," contrary to what the authors state. With respect to the comments of the authors about other iteration procedures, we would like to know what the authors mean by "difficult numerically." Do they imply long computer time, or problems of nonconvergence and instability? Although the authors discard solution procedures involving matrix methods, they do not state how their iteration procedure is effected, implying that it is a direct substitution one. For such a method, however, it is known that convergence problems may exist. In this respect we would like to mention the work of Wang Yonghong (1991), which has actually introduced the same idea as the one the authors employ in engine modeling, while it discusses comprehensively the numerical aspects of the problem.

We would also like to have information about the reduction in computer memory and running time achieved by the proposed method. Could the authors provide figures about memory requirements and speed of their model, as well as of models over which they claim improvement? Here we would like to comment that in our opinion the necessary speed of calculations is being provided by present-day computer capabilities. In this respect we think that sacrificing model accuracy by simplifying assumptions (as for example by assuming a single turbine characteristic at low pressure ratios or not correcting for compressor efficiency variation) should be avoided. Our experience is that very low running times (fractions of a minute) can be achieved when using full models in today's standard portable PCs.

A final point we would like to have the authors' comments on, is the usefulness of fault matrices. Although they were of great value when first introduced, in the early 1970's, we think their current usefulness is being overemphasized in the present paper. Such matrices give only qualitative information about faults and anyway cannot at all resolve situations with simultaneous presence of different component faults. On the other hand, quantitative methods capable of directly identifying component problems as to their kind and location have been introduced (Stamatis et al., 1990b). In any case the present-day needs (as identified, for example, by Doel, 1990) require information interpretable by expert systems, rather than relying on observations by the engine operator. The method of the present paper does not seem to reply to such needs.

References

Doel D., 1990, "The Role of Expert Systems in Commercial Gas Turbine Engine Monitoring," ASME Paper No. 90-GT-374.

Stamatis, A., Mathioudakis, K., and Papailiou, K. D., 1990, "Adaptive Simulation of Gas Turbine Performance," ASME Journal of Engineering for Gas Turbines and Power, Vol. 112, No. 2, pp. 168–175.

Stamatis, A., Mathioudakis, K., Smith, M., and Papailiou, K. D., 1990, "Gas Turbine Component Fault Identification by Means of Adaptive Performance Modeling," ASME Paper No. 90-GT-376.

Wang Yonghong, 1991, "A New Method of Predicting the Performance of Gas Turbine Engines," ASME Journal of Engineering for Gas Turbines and Power, Vol. 113, pp. 106–111.

Authors' Closure

The authors are grateful for the interest in their paper.

It was made clear in the paper that there was absolutely no information available to the authors on either compressor or turbine characteristics. The objective of the work was to produce a full-range thermodynamic model of the engine, which had recently entered service. Compressor characteristics were generated from generalized maps previously published, while single line characteristics based on nozzle data were used for turbines; there would certainly not have been any point in using variable speed turbine characteristics. It should also be noted that the gas generator turbines operate over restricted running ranges, and only the power turbine is subjected to operation over a wide range of speed and pressure ratio. When field test data became available the authors made adjustments to the characteristics to achieve good agreement; it was never intended that field operators would be involved in this process.

The Hot End Method introduced in the paper (HEM) permits all turbine working points to be established initially, and by using pressure equilibrium the work compatibilities can be reduced to a second-order equation with only one unknown. As this equation is solved, the compressor working points can be fixed on the maps; any errors in compressor efficiency can be corrected through iteration and update of the constants *A*, *B*, *C*, and *D*. This is a half-loop iteration and it is not necessary to go back to the beginning of the calculation. The computer program was computed in the winter of 1989 and the work of Wang Yonghong did not become known to the authors until after the publication of this paper. Both Wang's method and the HEM start from the turbine matching process, fixing the turbine operating points. Wang makes use of this to avoid the numerical instability of the full matrix and then solves a reduced matrix for work compatibility and the cold end; HEM solves the second-order equation directly and finds the rest of the unknowns from flow compatibilities of the cold end. HEM uses a simple one-dimensional search method based on the basic thermodynamic cycle. The authors feel that the simple mathematical model using basic concepts is preferable to a more complex numerical model.

The authors agree that the power of modern PCs makes computing speed a secondary issue; this particular model required about 1.5–2 min running time. They do not agree that using multiline turbine characteristics would improve accuracy, especially where no data are available.

There is no doubt that in the future expert systems will play a role. The key point, however, is where can the data be found to produce the required rules? It will certainly not be easy to generate these from actual field data; failures may arise where no previous information was available, so no rules would exist. Different engine types will exhibit different deterioration modes, but a large amount of operational data will eventually determine the more common causes of failure. The fault matrix is still valuable as a means of systematically predicting the effect of various faults that can be introduced; what is needed, however, is experimental work to define better the magnitudes of efficiency/flow deterioration in components and studies of this type are being initiated at Carleton University by Sjolander. Another potential source of information is test bed evaluation of engines returned for overhaul in "as-received" condition. A great deal of work still must be done to develop soundly based rules for use in expert systems.