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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Extension of a fundamental approach to combustion modelling was continued with development and testing of a flow algorithm suitable for highly swirling flows. The approach was shown to be much superior to current models as indicated by calculated and measured flow fields in a cyclone. Additional turbulence assessments were made by the computation of the performance of a cyclone separator which is a highly swirled device. Good agreement was found between calculated and observed grade efficiency curves. Residence time distribution measurements in a gas turbine using a non-intrusive pulsed mercury tracer

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were concluded by comparison of measured and calculated functions using the flow trajectory algorithm. Overall these comparisons were found to be good with some discrepancies near the highly swirled region which may be related to the earlier turbulence model which these flow fields used.

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~~Annual~~ Report 1981-1982

USAF/EOAR Report of Research Activities 1981/82

Title Fundamental Study of Three-Dimensional Two Phase Flow in Combustion Systems.

Principal Investigator Professor J. Swithenbank

Current Research Objectives

The wider objective of this program has been to develop a comprehensive design procedure for combustors of interest to USAF, and in recent periods this has resulted in combustion models which simultaneously incorporated droplet trajectory, evaporation and kinetics in a gas turbine can. Certain limitations to the current state of the art in flow modelling have highlighted certain additional areas in need of study, and these have related to the shortcomings of present turbulence models in cases of high swirl.

A more fundamental model developed at Sheffield has been designed to overcome these problems and the present period has been concerned with its further development and experimental verification. Specifically the following areas have formed the research objectives:

1) Experimental verification of turbulence model in cases of high swirl
2) Measurement of residence time distribution functions in a gas turbine combustor
3) Exploratory studies of the influence of turbulence on droplet trajectories

Progress During the Past 12 Months

The importance of swirling flows in combustors and the need to have an adequate turbulence model to describe the mixing process has focused attention on the development of an algebraic stress turbulence model at Sheffield to surmount some of the shortcomings of the existing $k - \varepsilon$ turbulence model in combustion and fluid flow calculations when large swirl is involved.

For this reason, measurements and calculations have been carried out on a device best suited to such a study, namely a single exit cyclone chamber. Using the backscatter laser Doppler anemometry system at Buxton, tangential and axial velocity profiles were made at a number of axial stations within the cyclone. These results also provide turbulence levels and have been compared with values calculated using the k - ε model and Sheffield model. These are shown in Figure 1. The important observations from from these results are that the reverse axial flow on axis and the steep tangential profile at the axis are both reproduced by the Sheffield model but not by the k - ε model. These results clearly demonstrate the need to incorporate such a model into the overall flow and combustion algorithm.

Two further experimental approaches have been used to investigate the models The first of these involves the measurement of the residence time function in a gas turbine can using narrow pulses of mercury vapour which are detected optically at the exit. These are generated using a 4mm diameter twin bore spark electrode. the tip of which may be located at various positions inside the chamber. These residence time functions may also be calculated from the computed flow field for the cold combustor using the particle trajectory algorithm and incorporating the random effects of turbulence, and provide a valuable insight into the reliability of the computed time history. Examples of these results are shown in Figure 2 for different tracer input positions. Of the five cases, the three input positions at and downstream of the primary port provide remarkably good agreement when consideration is paid to similar theoretical studies in simpler systems. Upstream of the primary port however, significant discrepancies exist implying that a larger plug flow region exists in this part than is found by experiment. Since the flow field and turbulence and turbulence level is based on the k - ε model, this may well be a comment on the effective mixing predicted by the model in this swirling region and deserves further investigation.

The second experimental approach involves the application of particle trajectory calculations in an alternative area of cyclone practice as a means of validating the Sheffield turbulence model. This involves cyclone separators, the calculated efficiencies of which depend very much on the turbulence levels used since these serve to throw particles into escape regions which they would not otherwise reach in a laminar flow. An appropriate measure of the flow field and trajectory algorithm is the grade efficiency curve which gives the fraction of particles of a particular size which are trapped in the cyclone Figure 3 is such an example and the good agreement between calculated and observed efficiencies, particularly on the rising part of the curve, indicates that the algorithm is providing an accurate flow field.

Technological Significance

Previous research programs in this area have helped to develop the combustioj algorithm to a level suitable for real applications and the present work has served to point the way for its further advancement into the regime of strongly swirling flows, which continue to be of major interest to USAF. The results underline the shortcomings of recent turbulence models and emphasise the suitability of the algebraic stress model developed at Sheffield.

Work is currently continuing in the assessment of the model in all the relevant regimes and it isclear that an important phase of work must be its incorporation into the overall combustion model.

Report Bibliography

Publications:

1) 'The Measurement and Prediction of Residence Time Functions in a Gas Turbine Combustor', B.C.R.Ewan, F.Boysan, W.H.Ayers, J.Swithenbank, to be published
2) 'Calculation and measurement of a Cyclone Flow Field', F.Boysan, J.Swithenbank, B.C.R.Ewan, to be published
3) 'Three Dimensional Model of Spray Combustion in Gas Turbine Combustors', F.Boysan, W.H.Ayers, J.Swithenbank, Z.Pan, to be published in Journal of Energy E785, Sept-Oct 1982
4) 'Afundamental Mathematical Modelling Approach to Cyclone Design', F.Boysan, W.H.Ayers, J.Swithenbank, Trans. I.Chem E. Vol. 60, 1982
5) 'Fundamental Study of Two Phase Turbulent Flows in Cyclone Separators', W.H.Ayers, F.Boysan, J.Swithenbank, I.Chem.E. Jubilee Symposium, April 1982
6) 'Fundamentals of Reactant Mixing in Reactor Systems', Invited paper for Interflow 81. I.Chem.E./I.Plant E. J.Swithenbank, F.Boysan, W.H.Ayers

Names of Contributors

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At present the AFOSR principal investigator is not participating in any other U.S Government Grant or Contract projects.

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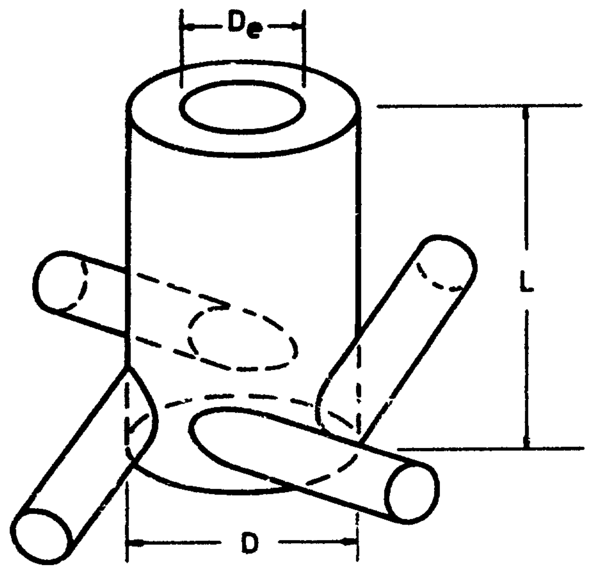
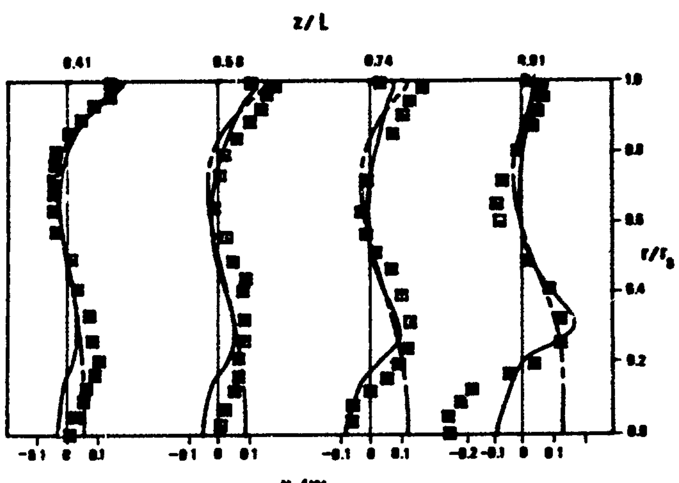
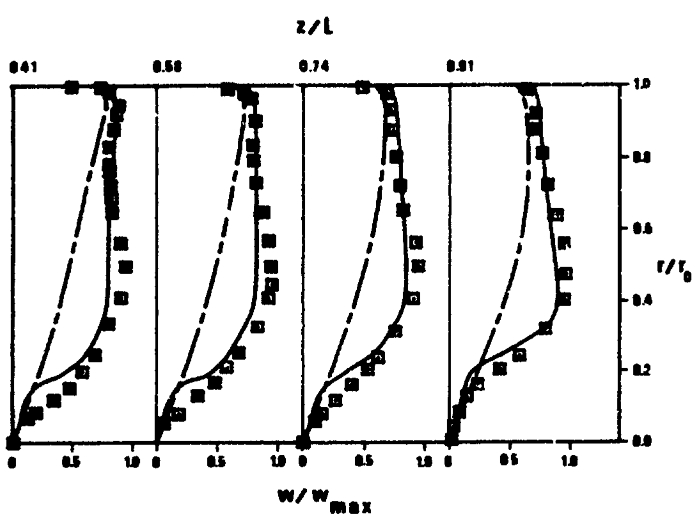
SRC Post Doctoral Research Fellow	-	Dr. F.Boysan
Univ. Senior Experimental Officer	-	Dr. D.S.Taylor
SRC Programmer	-	W.H.Ayers
Technician Grade VI	-	A.Jackson



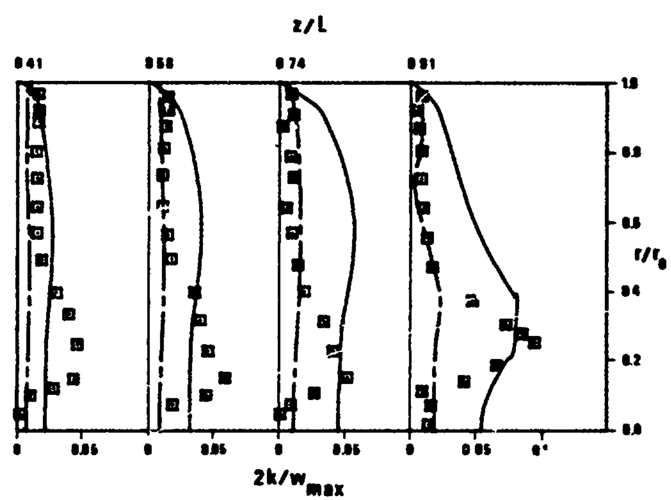
Multiple Entry Cyclone Chamber



Comparison of predicted and measured axial velocity profiles at four axial stations. ☐ experiments, —— algebraic stress model, —·— k-ε model.

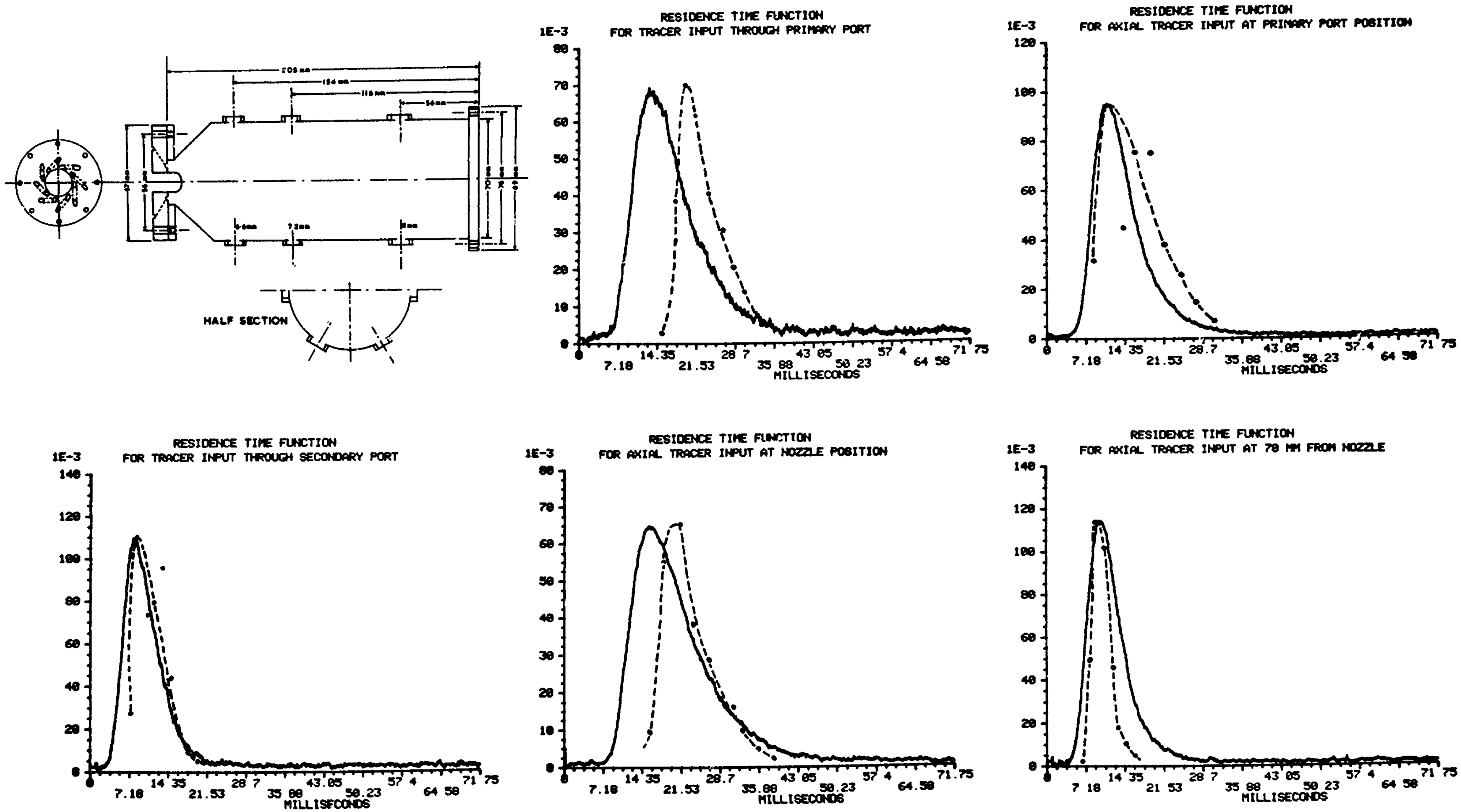


Comparison of predicted and measured tangential velocity profiles.



Comparison of predicted and measured tubulence kinetic energy profiles.

FIGURE 1 COMPARISON OF CYCLONE FLOW FIELD USING SHEFFIELD AND $k - \varepsilon$ MODELS.



<u>FIGURE 2</u> COMPARISON OF MEASURED AND CALCULATED RESIDENCE TIME FUNCTIONS AT VARIOUS TRACER INPUT POSITIONS FOR THE GAS TURBINE CAN SHOWN.

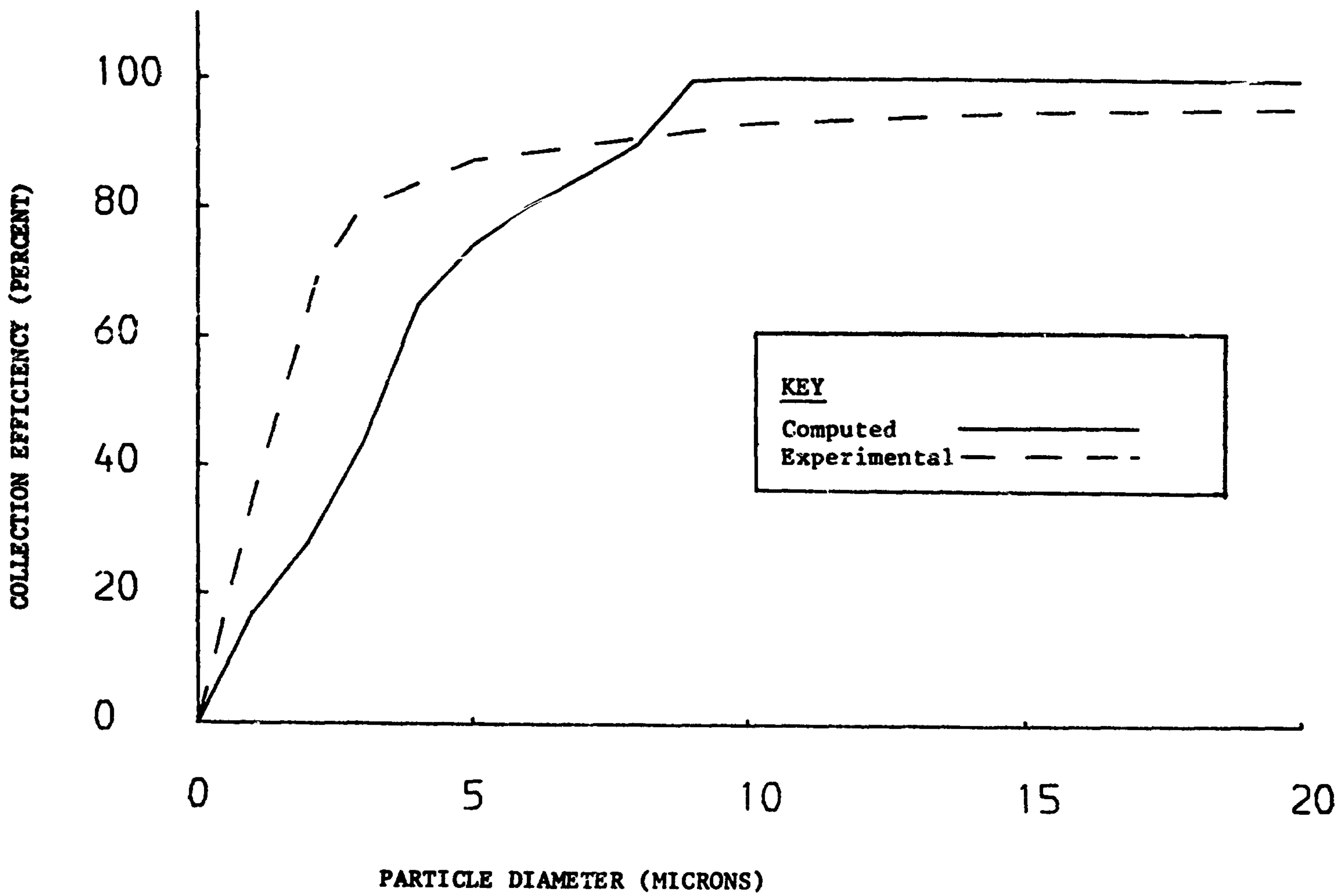


FIGURE 3 COMPARISON OF MEASURED AND CALCULATED GRADE EFFICIENCY CURVES FOR STAIRMAND CYCLONE - USED AS A MEANS OF VALIDATING SHEFFIELD TURBULENCE MODEL.