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OPTIMISATION OF KENICS STATIC MIXERS FOR TEXTILE FIBRE MELT PROCESSING

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The mixing and flow characteristics of the Kenics Static Mixer have been assessed by both laboratory experimentation and, more recently by the use of Computational Fluid Dynamics (CFD) modelling. Accurate visualisation of the mixing process, prediction of mixture quality, pressure loss and heat transfer coefficients now enable the designs to be optimised in processes involving the mixing, thermal homogenisation, heating or cooling of textile fibre melts.

1. Introduction

The Kenics Static Mixer (fig 1) is a motionless pipeline mixing device which has been widely used throughout the textile industries since its original development in the 1960's. Typical applications are blending of different polymer melts, thermal homogenisation of melts within distribution manifolds, combined mixing, heating or cooling of melts to achieve optimum spinning temperatures and the continuous mixing of colours or additives into melts.

Early research (ref 1) into the flow characteristics of the Kenics Mixer used two coloured resins to visualise the mixing of species as they progress through the mixer (fig 2).

Subsequent laboratory testing evaluated the relationship between Reynolds number and pressure drop through the device (fig 3) as well as its effectiveness at increasing internal heat transfer coefficients compared to an empty pipe (fig 4).

More recently our research efforts have been aimed at the use of CFD to predict mixing rates and pressure drop, to generate visualisations of mixing occurring within the device, and to assist in the design of Static Mixer heat exchangers for high viscosity melts. Our objectives at Chemineer have been to validate our CFD procedures against previous laboratory work in order that they can then be used to optimise equipment design and performance more rapidly than was ever previously possible.

2. Modelling of the mixing process in Kenics Mixers

CFD software supplied by Fluent (version 4.10) was used to establish a model using six Kenics Static Mixer elements 0.02m diameter and 0.24 metres long, at a Reynolds number of 10. The details of the procedure used can be found in ref. 2. After a number of trials and several weeks of processing time a converged solution was found which correctly represented the laboratory experiments. The results of this simulation are shown in the lower part of figure 5. The correlation between the CFD model and the laboratory test is excellent.

3. Modelling of pressure drop in Kenics mixers

The ratio of pressure drop in a Kenics Mixer divided by the pressure drop in the same length of empty pipe at the same operating conditions is called the "K factor". At a Reynolds number of 10, a typical value of K for a production mixer is 5.7. The CFD procedure (ref. 2) modelled pressure drop and found a figure only 8% away at 5.3. This is regarded as on excellent validation of the procedure and confirmation that our CFD can be confidently used to model the pressure drop across different mixer designs or under differing flow conditions.

4. Heat exchanger modelling

Examples of single and multitubular static mixer heat exchangers can be seen in figs 6a and b. The ability of Kenics Mixers to improve internal film heat transfer coefficients compared to empty tubes has been studied (ref. 1, 3) under laboratory conditions (fig. 4). The CFD procedures described above will shortly be adapted to enable us to model the thermal performance of different element designs.

Of even more importance is the need, in the case of multitubular exchangers (fig. 6b) to design inlet/outlet heads such that equal flow is provided to every tube, in order that mal-distribution and the resulting unpredictability of performance is avoided. CFD techniques have been successfully applied to this field (ref. 4). A number of different head shapes have been modelled as well as the effect on flow patterns of non-Newtonian fluids. Figure 7. shows the result of one such analysis demonstrating the velocity vectors of flow through the heads and tubes of a Kenics Mixer heat exchanger handling a high viscosity, non-Newtonian Polymer. Although the velocity profile in the inlet tube is parabolic, the effect of the head design, combined with the flow resistance in each Static Mixer tube equalises the fluid velocity in each.

The technique can now be used to model different head shapes and fluids with different physical properties.

5. Conclusions

CFD techniques have been successfully applied by Chemineer to optimise the design of mixers, heaters and coolers for high viscosity textile fibre melts. Simulations can be performed more rapidly than with laboratory experimentation once the procedures have been validated, allowing the rapid development of specific designs of equipment taylored to individual client needs.

References

1. "KTEK" Booklet, Chemineer Inc., 1988.

2. "Laminar mixing with Kenics in-line mixers", A. Bakker and E. M. Marshall, Fluent Users meeting, October 1992.

3. "Tech News" leaflet, Chemineer Ltd, 1988.

4. "Flow conditions in the low volume head of a Kenics Heat Exchanger", A. Bakker and J. Fasano, Chemineer Inc, 1992.

Nomenclature used in Figures 1-7

ID or D = Diameter of mixer

K = Ratio of pressure drop in mixer divided by pressure drop in empty pipe of same L and D.

L = Length of mixer.

Nu = Nusselt Number.

Pr = Prandtl Number.

Re = Reynolds Number.

List of Figures

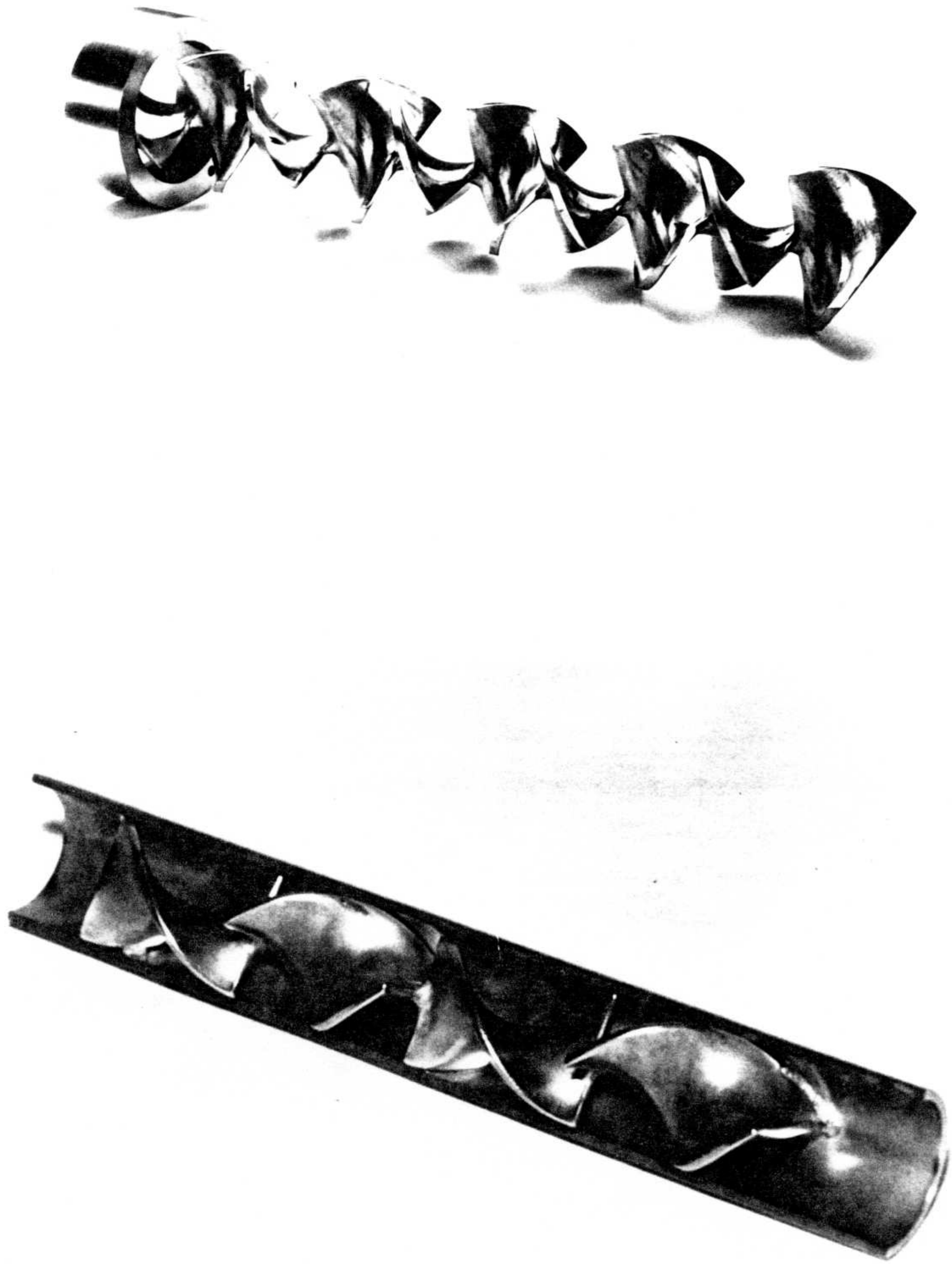
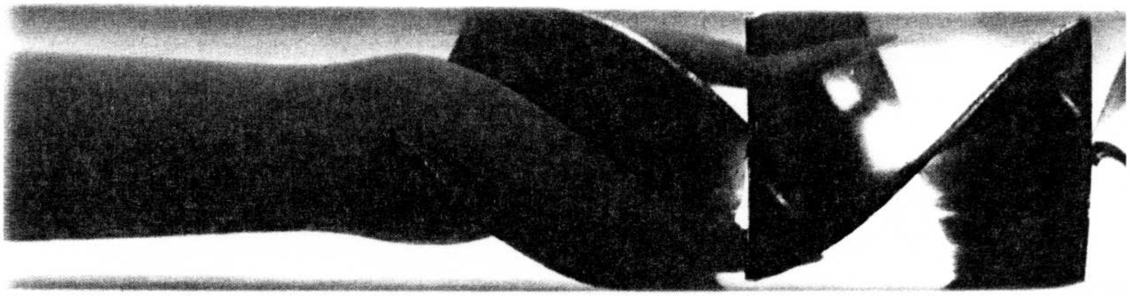


Figure 1 – Different types of Kenics Static Mixer internals.



LAMINAR FLOW - VISCOUS SUGAR SOLUTION

KENICS STATIC MIXER

LAMINAR FLOW - SECTIONS THROUGH MIXER SHOWING PROGRESSIVE MIXING OF RED AND WHITE RESIN

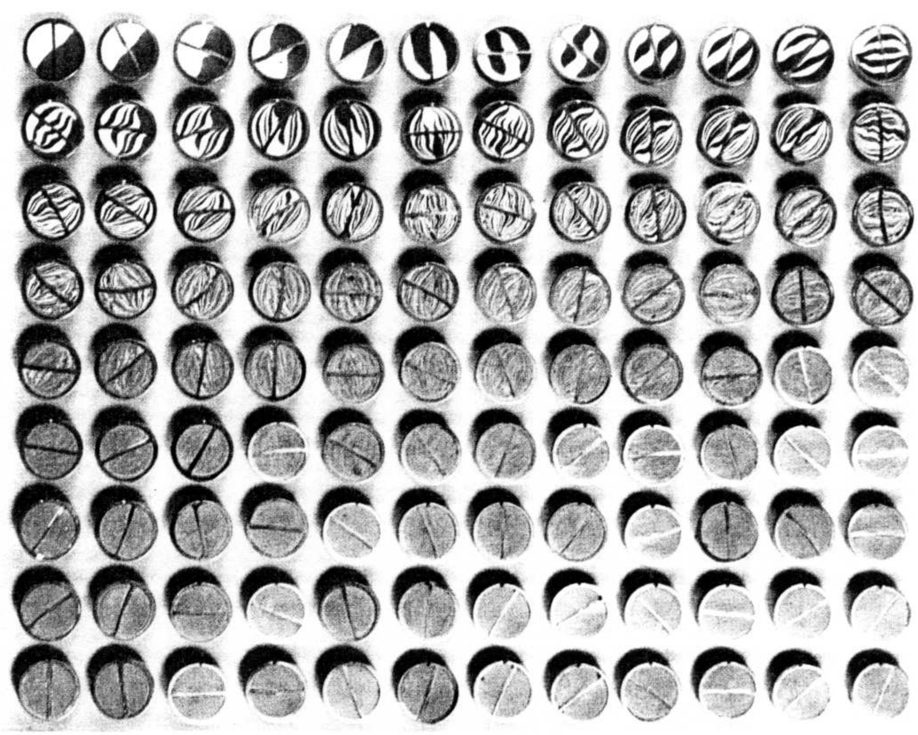


Figure 2 – Laboratory generated visualisations of laminar flow mixing of two differing colour fluids.

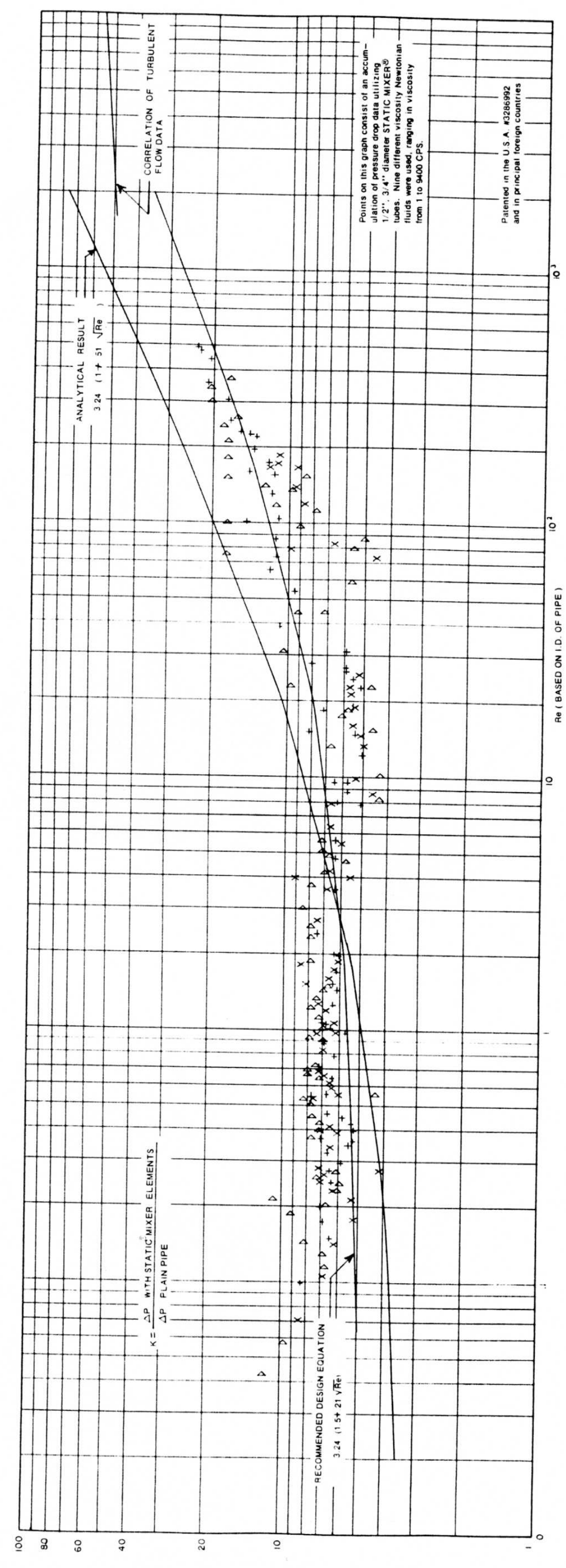


Figure 3 – Typical laboratory generated pressure drop data for Kenics Static Mixers.

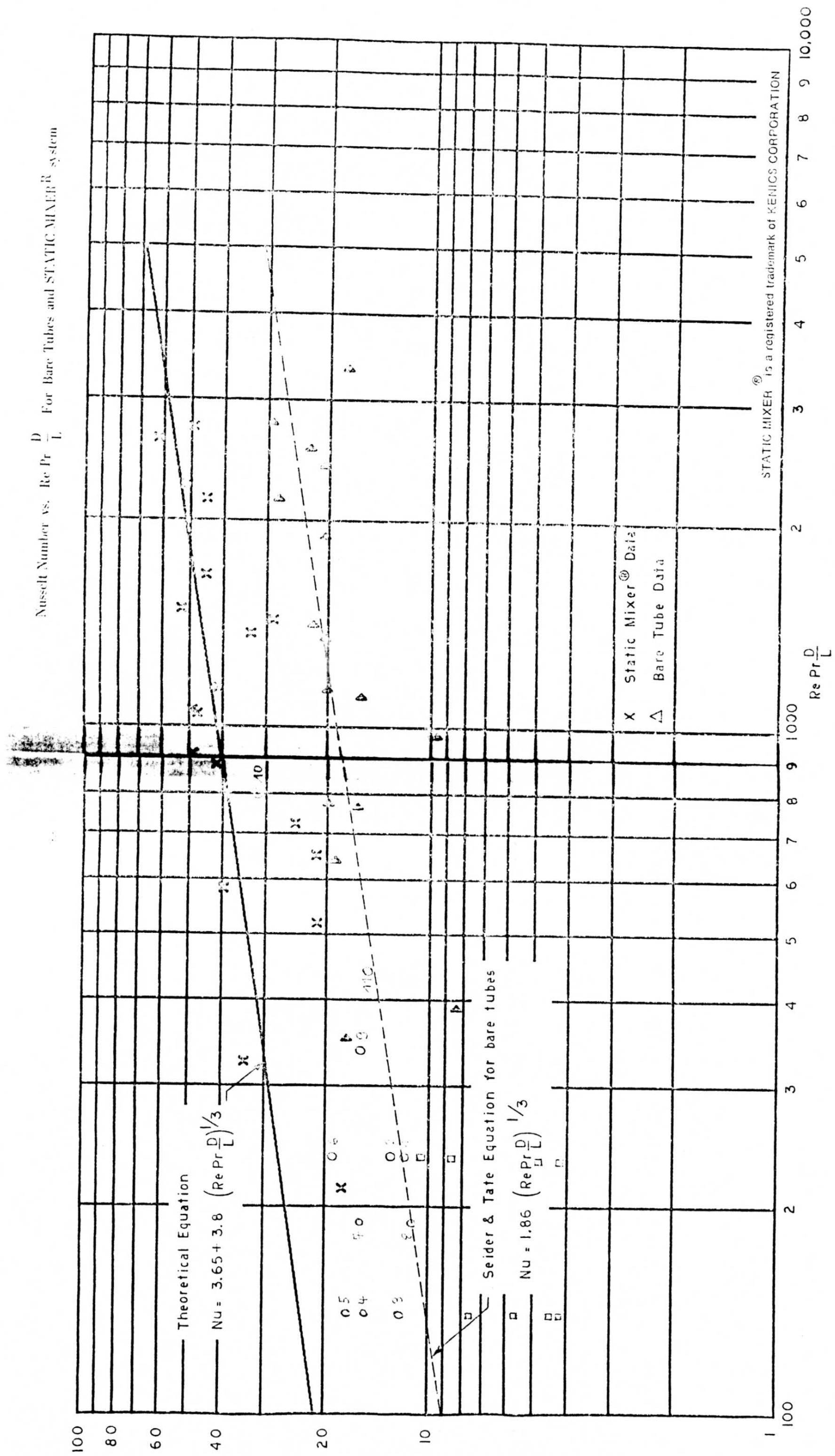
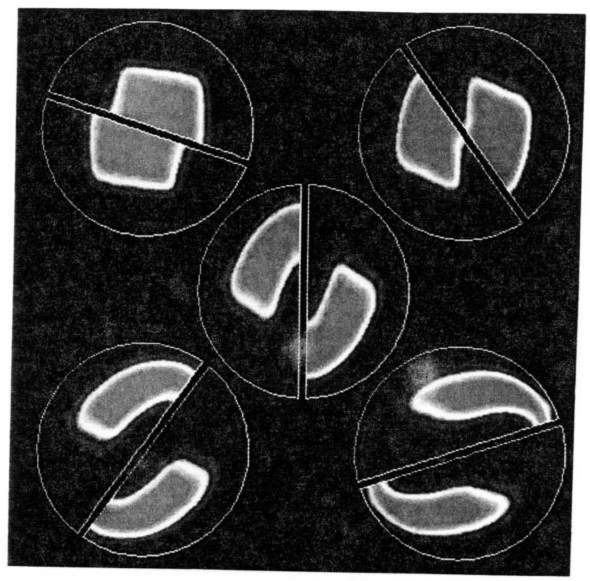
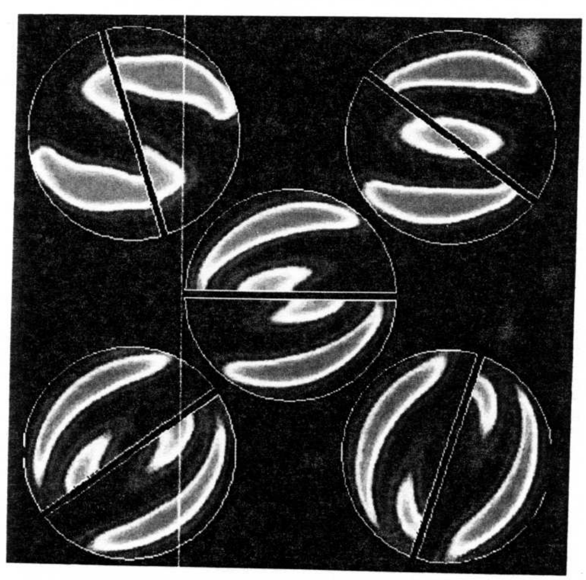


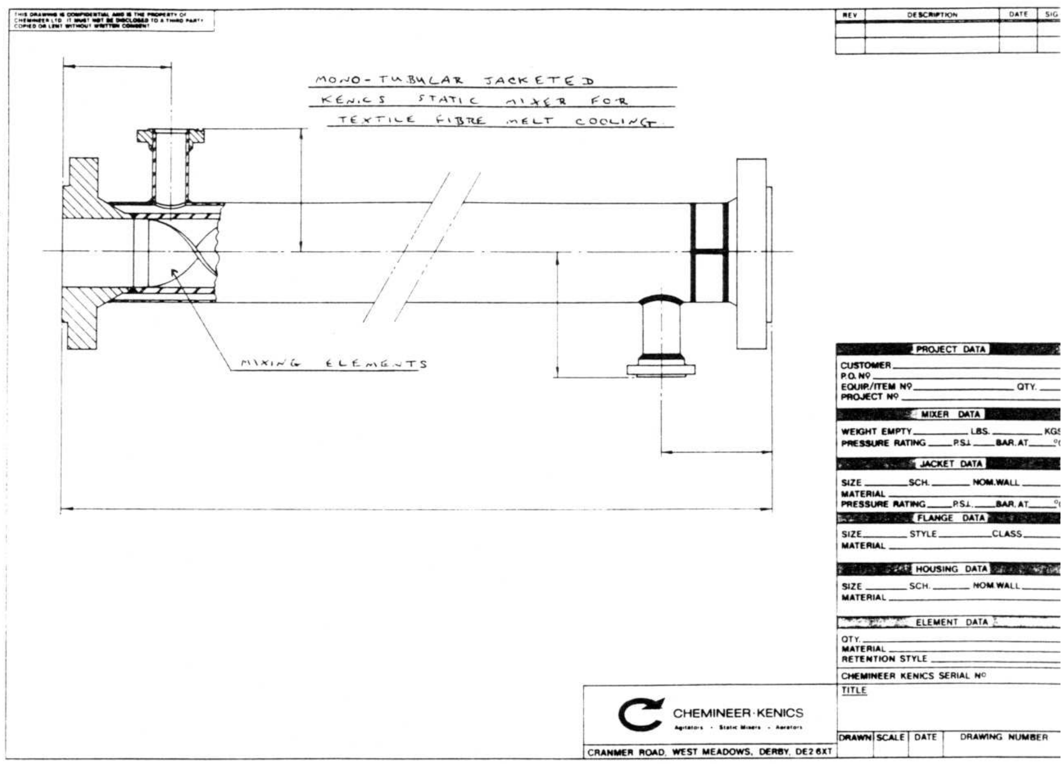
Figure 4 – Typical laboratory generated heat transfer data for Kenics Static Mixer.

Figure 5 – Upper photo – Laboratory generated laminar mixing example over a six element mixer in laminar flow.

Lower photos – CFD predictions of mixing.
(Middle photo – over first mixer element, lower photo – over second mixer element.)







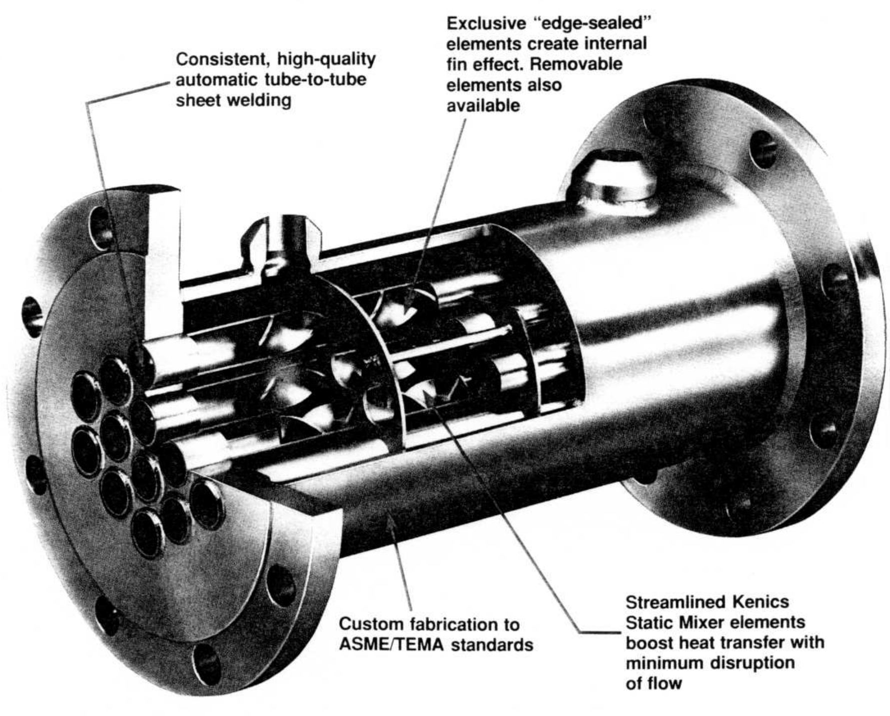


Figure 6 – fig. 6a – Single tube Kenics Static Mixer heat exchanger.

fig. 6b – Multitubular Kenics Static Mixer heat exchanger.

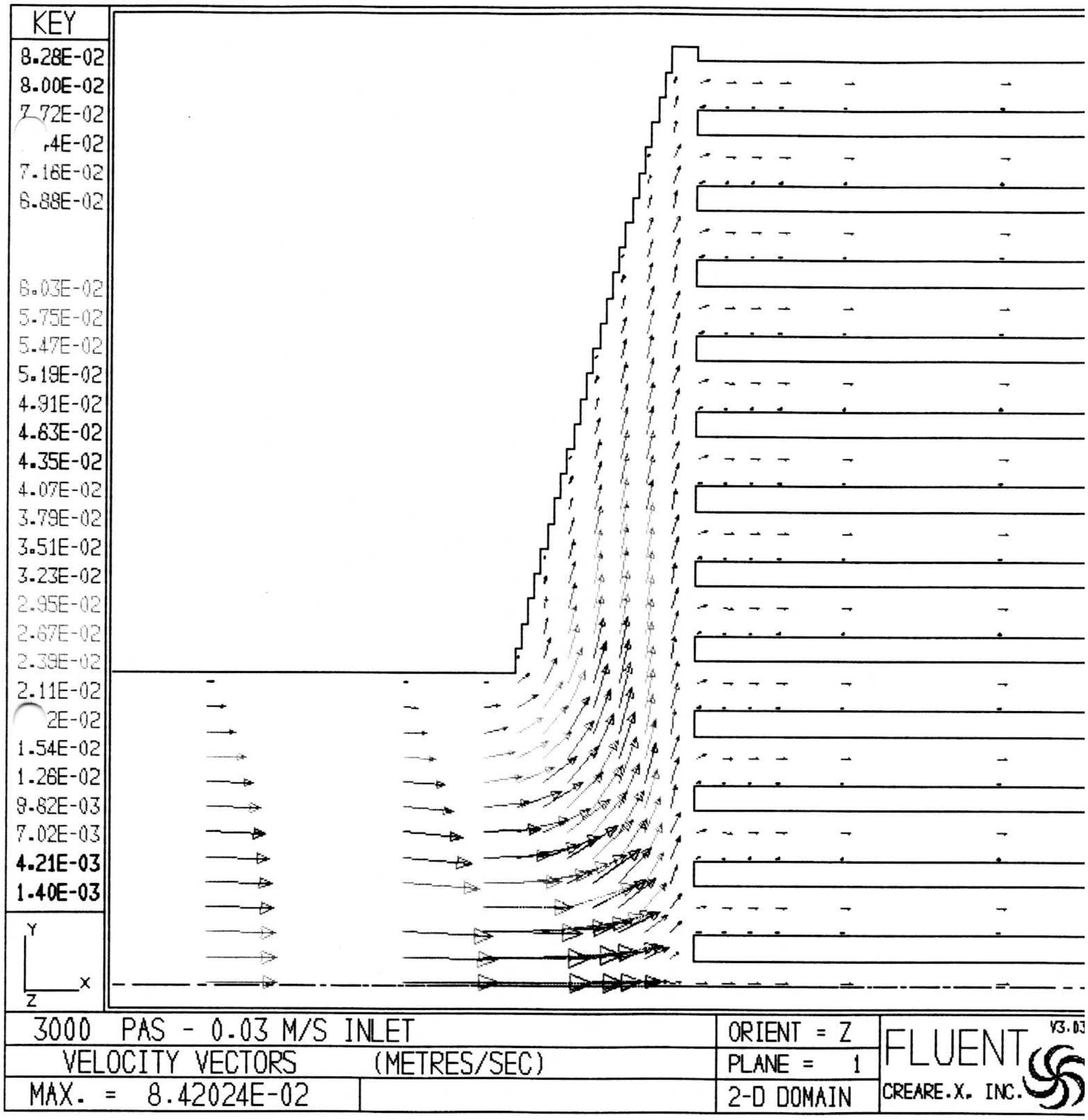


Figure 7 – CFD prediction of Velocity vectors for non-Newtonian polymer flowing through the head of a multitubular Kenics heat exchanger.