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An evaluation of some static mixers in multiphase flow.

Tested using on-line evaluation equipment

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ABSTRACT: In multiphase flow measurement there may be a need to homogenise the mixture of the three phases upstream of the measurement point. This is attempted in many applications by installing a static mixer upstream of the measuring instrument. Most of the commercially available static mixers are designed for liquid-liquid mixing, and their performance in multiphase flow is not well documented. On this background Statoil, Agip and Elf initiated a research project at CMR to evaluate the performance of a range of available mixers. The mixing efficiency of the different mixers with respect to pressure drop, homogeneity, interphasial slip etc. is tested over a wide range of flowrates and compositions. Reference instrumentation includes high speed video, isokinetic sampling, gamma density measurement and capacitance cross-correlation velocity measurements. In addition, chemometric analysis has been implemented for on-line determination of how the quality of the flow develops downstream of the mixer. The mixing capability of both a V-cone meter and a classical venturi were evaluated. The presentation will give the background and criteria for the work. The reference measurement system and the test facility will be described. The development of the evaluation method and the evaluation test will be described. High speed video of multiphase flow in the test section will be presented.

1. Evaluation of static mixers for preconditioning of multiphase flow

This paper is a result of a research project completed at Christian Michelsen Research on the behalf of our clients Statoil, Elf Aquitane, and AGIP. The background for the project is the need for development and qualification of new technology for multiphase transport of oil, water and gas in connection with the potential use of new development concepts for marginal oil and gas reservoirs in the North Sea. One such new technology is the measurement of multiphase volume flow. Several multiphase meters currently under development will require an upstream mixer, or at least give improved performance when installed downstream of a mixer. It is however not evident that commercially available mixers are suitable for this application.

Our clients engaged CMR to evaluate the performance of available multiphase mixers through an extensive test program, and found the multiphase flow facility at Christian Michelsen Research suitable for the objective of uch a test programme. The project was completed in winter 1994.

There are several classes of commercially available mixers. A very rough grouping is to classify them as either

- static mixers, which requires no energy input, and with no moving parts, or
- dynamic mixers, which require energy input, and which generally have moving parts.

A further grouping is as mixers with

- radial mixing effect, that is that they create a homogeneous phase and velocity distributions over the pipe cross-section downstream of the mixer, or
- with axial mixing effect, that is that they act as a "filter" for phase distributions along the pipe, thereby smoothening e. g. slug flow.

The performance of a particular mixer can be dependent on both the installation and the application. Typically, the performance of a mixer can be dependent on if the application

- is in vertical upwards flow
- is in vertical downwards flow
- is in horizontal flow
- has fully developed flow at mixer inlet

and on the pipe configuration upstream of the mixer inlet. In addition, the performance of a mixer can be dependent on the application flowrates and phase composition.

To evaluate all types of mixers for a large number of applications would be a very challenging task, as well as quite time consuming and costly. In the evaluation project described in this paper, the objective therefore was to concentrate the effort to a limited number of mixing devices for the specific application of installation in vertical upwards flow.

The objective of the project was

> *to test and evaluate static mixers for installation in vertical upwards multiphase flow over a wide range of flowrates and compositions, and for varying inlet flow conditions.*

For this purpose there were identified and developed a set of measurement methods suitable for characterisation of important characteristics of a multiphase flow, for example

- bubble size distribution
- velocity profile
- interphasial slip
- axial and radial phase distribution

These different flow characteristics were integrated into a reference measurement test section for characterisation of the multiphase flow immediately upstream and downstream of the mixer. Considering these measurements, the aim was to evaluate the different mixers in terms of homogeneity downstream of mixer, and overall mixer efficiency. These objective measurement methods were also supported by subjective "measurements" by installing perspex sections and using high speed video techniques.

In addition to the actual testing of the different static mixers under various conditions as described above, we also aimed to give a technical description of each mixer and its operating principle. In the final evaluation, also operating parameters like pressure drop and operational limits for flowrates and/or compositions were evaluated.

2. Test set-up

A customised test section was developed and a data acquisition system was developed on an IBM PC compatible computer. The test section was integrated in the existing multiphase flow rig at Christian Michelsen Research. To implement the on-line evaluation tool, a setup for measuring different calibration quantities off-line has been developed.

This chapter contains a brief description of the tested mixers and a description of the technical implementation of the different data acquisition systems and how they work together.

2.1. Reference system and model calibration

The on-line evaluation tool was established by relating off-line reference measurements and evaluation methods to the on-line signals from the capacitance detector pairs. The test section developed for this purpose is shown in Figure 2.1.

This test section is placed directly at the outlet of the mixer and the capacitance detector pair arrangement is aimed at observing how the flow develops in vertical upwards flow at the outlet of the mixer. For reference, another capacitance detector pair is placed at the inlet of the mixer.

To relate the on-line capacitance detector pair signals to how well the flow is mixed, several parameters are used. From the on-line capacitance detector pair signals, two very important parameters can be extracted directly. These are

- Cross-correlation velocity, V_x
- Local gas fraction, α

These two parameters are directly linked to the behaviour of the flow. Several other parameters can also be extracted from the capacitance detector pair signals, like

- Permittivity average value, emean
- Permittivity standard deviation, estd
- Permittivity maximum, emax
- Permittivity minimum, emin
- Permittivity span, emax - emin
- Permittivity signal center frequency, f_c
- Permittivity signal whiteness, f_w (f_{max} - f_{min})
- Power spectrum symmetry, f_{w-s} ((f_{max} - f_c) / (f_{max} - f_{min}))

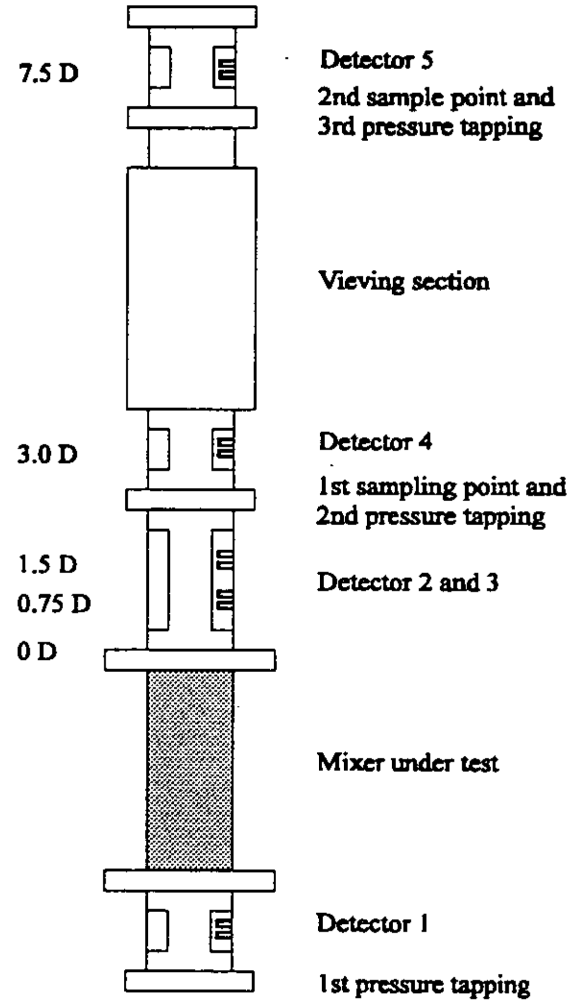

Figure 2.1 The mixer test section.

The definitions of the variables extracted from the time domain are given in Figure 2.2.

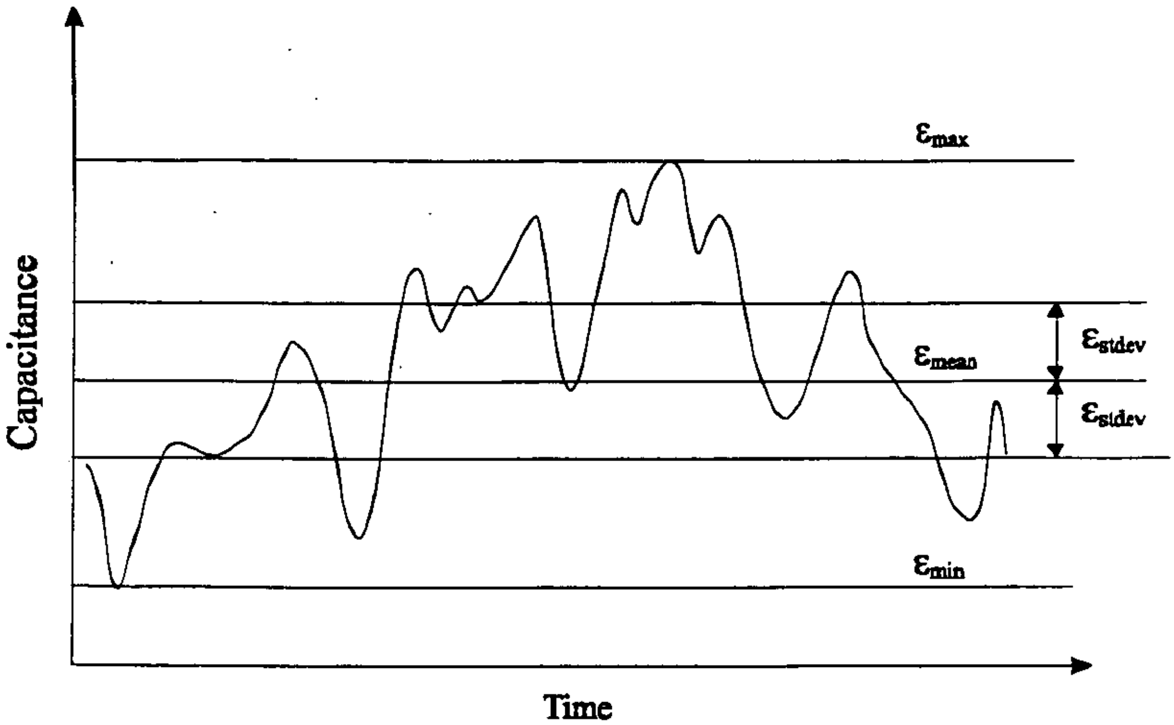

Figure 2.2 A capacitance time domain signal and the variables extracted from this signal.

The definitions of the variables extracted from the frequency domain are given in Figure 2.3.

These signals are indirectly linked to the phenomena that is studied in this project. The average value, standard deviation, maximum, and minimum of the permittivity are derived from the permittivity time domain signal. The center frequency, bandwidth, and cut off frequency is derived from the power spectrum of the permittivity time domain signal.

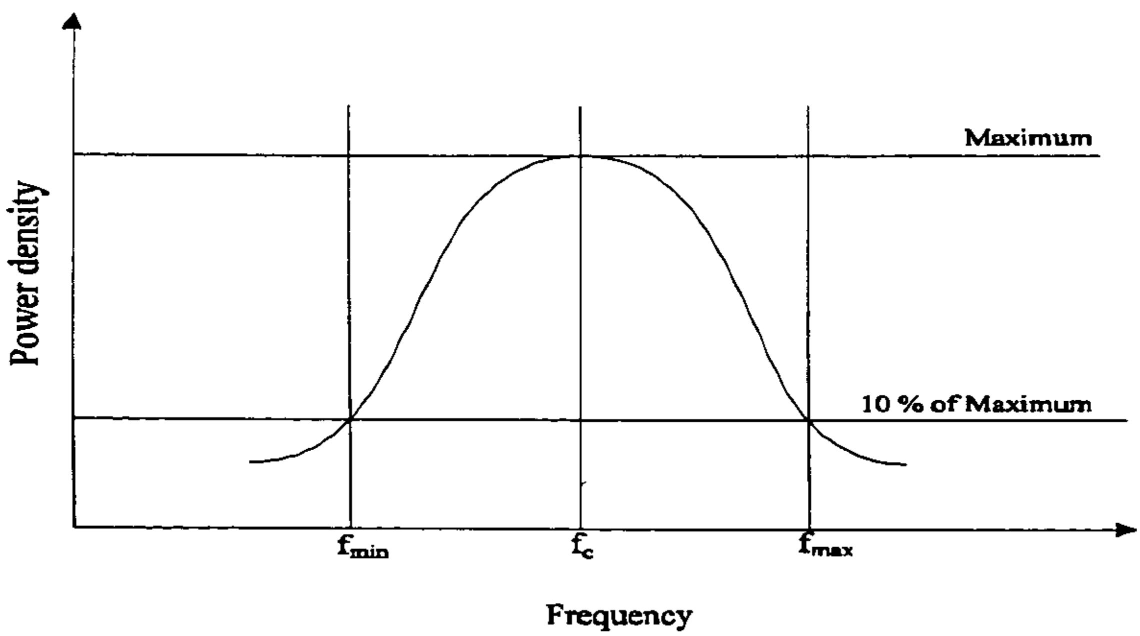

Figure 2.3: A capacitance signal power spectrum and the variables extracted from this signal.

If a mixer creates a well-mixed flow at the mixer outlet, the flow will start to develop towards a bubbly or churny flow shortly after the mixer outlet in a vertical upwards flow. One of the important differences to look for from mixer to mixer is the time (or distance) it takes before this development becomes significant. The mixer evaluation test section is designed to monitor these local variations.

The task of linking variations in all the seven indirect variables to the flow conditions at all test points in the mixer test section and for all flow rates and flow conditions is time consuming and requires a complex set of laboratory routines. In addition, the evaluation will be subjective and can thereby be influenced by the operator.

To avoid this, a statistical model relating these indirect variables and a term called radial gas distribution (RGD) was developed. When developing this model, all the information available from the reference system was used to relate the on-line signals from the capacitance detector pairs to the RGD. The actual model was established by the UNSCRAMBLER statistical modelling software package from CAMO of Trondheim in Norway.

In this way, the evaluation of the indirect variables is performed by a computer, and the possible subjectivity included in the statistical model will be imposed equally on all the mixers.

When using this statistical model, the RGD can be divided in five main categories. These categories are defined in Table 2.1.

To make this software generate the statistical model, a set of input signals (derived from the permittivity signal) and the output signal (RGD) must be available. The input signals can be recorded in the laboratory. The RGD is not a physical variable and can not be measured directly, hence it must be generated through the modelling process.

Table 2.1: RGD categories.

No mix	0 - 20
Bad mix	21 - 40
Fair mix	41 - 60
Good mix	61 - 80
Excellent mix	81 - 100

To be able to quantify the RGD, the on-line input signals are logged for a wide range of flow rates and conditions that cover the conditions that are to be applied in the mixer test. At every single point, a set of off-line reference data is recorded. All this information is then presented to a panel of experienced scientists, and this panel determines the RGD for each test point, see also section 2.3 below. This process is repeated in two different and independent panels and the results are combined. This set of RGD values is then used in the statistical modelling to generate the model coefficients.

2.2. Evaluation parameters

Each capacitance detector contains a pair of detectors, and the signals from both detectors in these pairs are cross correlated. The velocity read from this cross-correlation is an indication of the velocity of the large bubbles in the flow. In a well-mixed flow, the bubble size should not vary significantly and there should be a neglectable slip between these bubbles and the liquid. Hence, the velocity detected from cross-correlation will be close to the reference multiphase flow velocity. In a badly mixed flow, the bubble size varies a lot, and there will be a slip in order of magnitude meters pr. second between the large bubbles and the liquid. Then the cross-correlation velocity will be larger than the reference multiphase flow velocity.

The two capacitance detectors in a detector pair are combined to generate a better sensitivity in the detector when the permittivity is measured. The permittivity measurement is used to measure the local gas fraction. In a well-mixed flow the local gas fraction will be the same as the gas fraction calculated from the single phase reference meters. If there is a slip, a part of the gas will travel at a higher velocity, hence it will stay a shorter time in the capacitive detector and the local gas fraction will decrease. From this difference in gas fraction the slip can be calculated.

For the same nominal gas fraction, the measured average permittivity will vary due to the homogeneity of the flow. If a small change in the permittivity is due to a change in the nominal gas fraction, this may incorrectly be interpreted as a change in homogeneity.

To avoid this effect, all permittivity variables were normalised versus the permittivity average prior to predicting the homogeneity using the statistical model. The variables extracted from the permittivity time domain signal to be used as inputs to the statistical model are then:

- $\varepsilon'_{std} = \varepsilon_{std} / \varepsilon_{mean}$
- $\varepsilon'_{max} = \varepsilon_{max} / \varepsilon_{mean}$

- $\varepsilon'_{min} = \varepsilon_{min} / \varepsilon_{mean}$
- $\varepsilon'_{span} = (\varepsilon_{max} - \varepsilon_{min}) / \varepsilon_{mean}$

The average value of the permittivity is directly linked to the gas fraction, hence it can be analysed by itself. These normalised values are then relative to the actual gas fraction.

For the variables extracted from the power spectrum, the same rationale is valid concerning the conflict between the local variations and the nominal set-point for the gas fraction. In this case, the variables are normalised versus the center frequency. The variables extracted from the power spectrum and used as input to the statistical model are then:

- Permittivity signal whiteness, f_w $((f_{max} - f_{min}) / fc)$
- Power spectrum symmetry, $f_{w\text{-}s}$ $((f_{max} - f_c) / (f_{max} - f_{min}))$

2.3. Test set-up and equipment

The test rig used is shown in Figure 2.4. The path through pump 2 and the mixer test section is used in this project. The tests were performed in oil continuo's diesel oil. The valves at the water and oil outlet were continuously controlled to provide a constant water cut of 5% in the diesel oil measured by the WIOM (Fluenta Water In Oil Monitor). The 5% water cut was added to enhance the resolution in the capacitance measurements by increasing the difference in permittivity from the liquid phase to the gas phase. The distribution of the water in the liquid phase is *not* an issue in this study. The gas used was air from the on site compressor.

To generate two different inlet conditions, two gas injection points have been established. Gas injection point no. 1 is used to generate slug flow at the mixer inlet when the flow is *not* diverted through the vertical loop. Gas injection point no. 2 is *not* used in this project. Gas injection point no. 3 is used to generate flow without slugs at the mixer inlet when the flow is diverted through the vertical loop. When gas injection point 3 is used, the flow into the mixer has a uniform axial gas distribution, and when gas injection point 1 is used, the flow into the mixer has a *non*uniform axial gas distribution.

All the tests were performed at atmospheric pressure and room temperature.

The instrumentation on the rig is used as reference measurements in this project. The instruments used are:

- The Fluenta WIOM (*W*ater *In* *O*il *M*onitor) is used as a reference measurement for the water cut (water fraction in liquid phase).
- The liquid turbine meter gives the liquid flow rate in m^3/h.
- The gas turbine meter gives the gas flow rate in m^3/h.

The mixer test section is shown in Figure 2.1. The electrodes in the five pairs of capacitance detectors have an internal distance between 32 and 34 millimetres. The sampling probe and the high speed video were used when gathering information for use when calibrating the statistical model.

A fifth pair of capacitance detector electrodes was placed directly upstream of the mixer. The purpose of this detector pair is to provide a 'reference measurement' for the flow condition at the inlet of the mixer. By comparing the signals from the four detector pairs downstream of the mixer with the signals from the detector pair upstream of the mixer, the development of the flow parameters when the flow passes through the mixer under test can be investigated.

All test points in the calibration test matrix were recorded by high speed video. This camera records 200 frames pr. second, eight times as many as conventional video. By replaying these recordings at regular speed, the panel of scientists could view the details of flow and observe the degree of homogeneity in the flow.

The isokinetic sampling probe was used to extract samples of the flow at two radial points and at two axial positions in the mixer test section during the calibration test. Four samples were taken from the flow at each flow condition during the calibration test. These samples were extracted

- 1 cm from the wall at 1st sampling point
- In the tube center at 1st sampling point
- 1 cm from the wall at 2nd sampling point
- In the tube center at 2nd sampling point

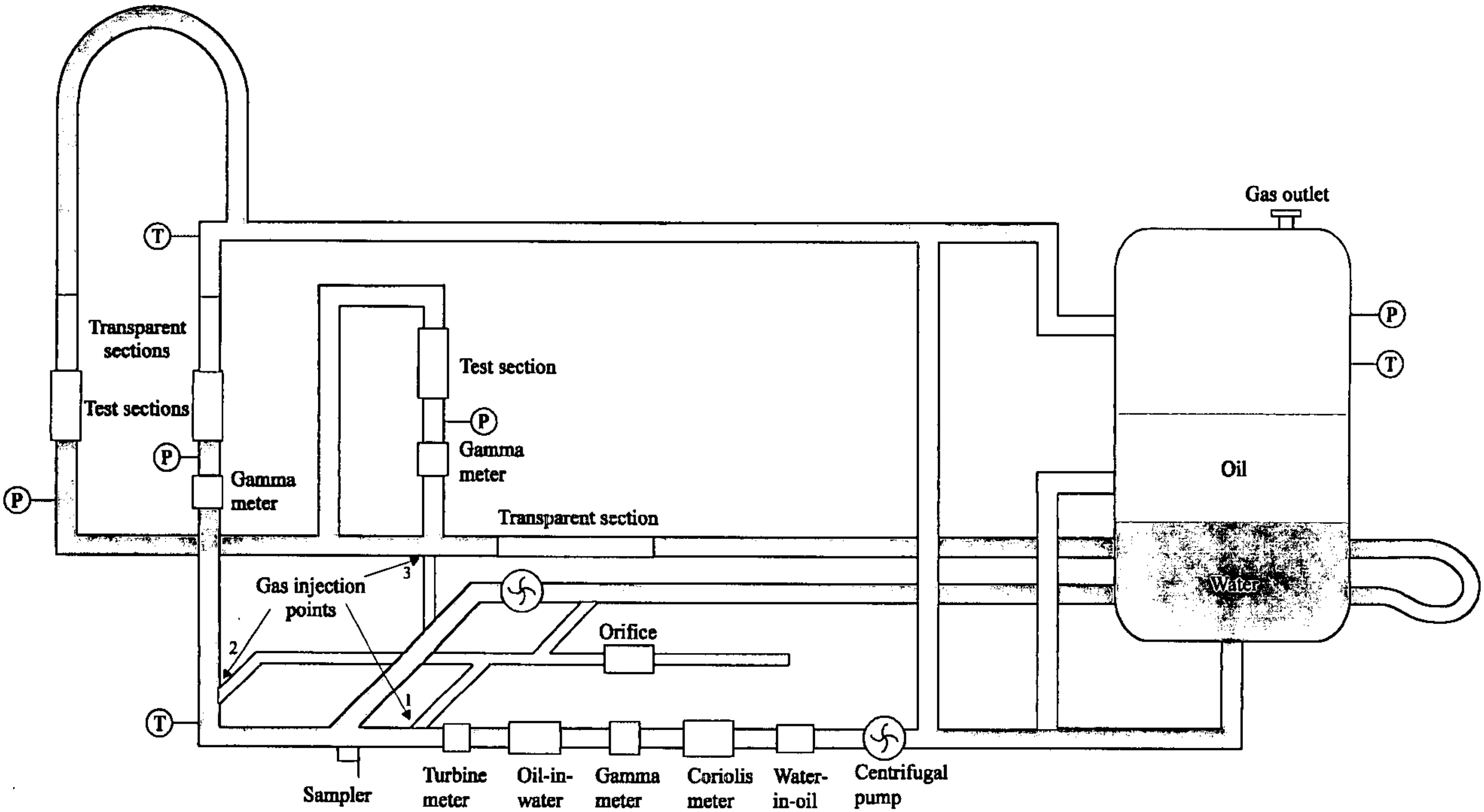

Figure 2.4: The multiphase test-rig used.

To achieve isokinetic conditions at the probe point, a suction pump was used to 'pull' the sample from the flow. Obvious outliers collected using this method were discarded.

The details from the video, the sampling results, and all the recorded values from the capacitance detectors were used as the information basis for determining the RGD during the calibration test.

3. Model verification

To be practically applicable the generated model needs to be properly validated. The validation gives a measure of how good the model is, and how accurate predictions can be made from the model. To verify that the model was properly calibrated, a verification test was performed.

Verification of the statistical model was done by running 12 tests covering the valid model range. Since a reference for the RGD needs to be known, the predicted objects were selected as repeated test points from the calibration tests. The results are shown in Figure 3.1.

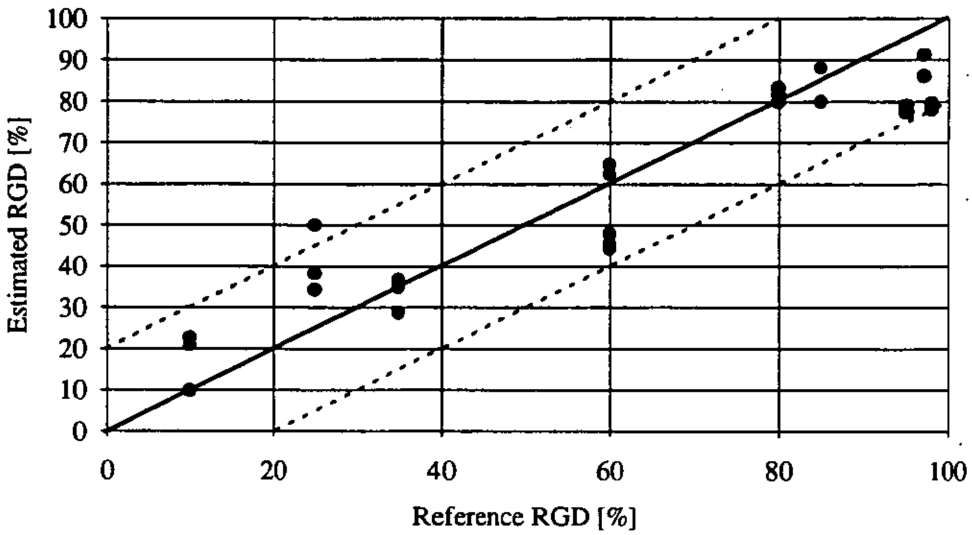

Figure 3.1: Validation test at the multiphase loop of the multivariate model. Test results of estimated radial gas distribution (RGD) compared to off-line determined references are shown.

It is observed that the uncertainty of the model is ±20% in absolute percentage terms. The radial gas distribution is a fuzzy quantity whose exact value is very difficult to determine. Therefore, the relatively large uncertainty of the estimation most likely comes from the off-line subjective evaluations of the radial gas distribution during the calibration test. However, the repeatability of the estimations has been found to be good.

4. Static mixer tests

The evaluation of the test results is based on the

- Gas fraction considerations
- Slip considerations (related to cross-correlation velocity)
- Differential pressure
- Radial gas distribution based on the statistical model.

Table 4.1 Mixer test matrix.

Liquid flow	Gas flow	Nominal gas fraction
10	1.1	10
10	3.3	25
10	10	50
10	30	75
10	90	90
25	2.8	10
25	8.3	25
25	25	50
25	100	80
50	5.6	10
50	17	25
50	50	50
50	93	65
75	8.3	10
75	25	25
75	75	50

For each test point, the software wrote five measurements to file at a 30 seconds' interval. All measurements written to file are an average over these 30 seconds. If all these five measurements are approximately the same, the conditions are said to be stable. If they have unrealistic values, or are clearly unstable, all five measurements are discarded.

The test matrix used is shown in Table 4.1.

4.1. Interpreting the data plots

The amount of data to be analysed in this analysis is extensive. The data have been compressed into a set of three-dimensional plots. The cross-correlation velocity, the gas fraction and the RGD have been plotted for each of the five capacitance detectors.

Two kinds of plots are used to describe the mixers:

- Surface plot. One plot for each capacitance detector pair, with an X-Y plane covering the tested range of flow rates and compositions. Examples of these plots are found section 4.3.
- Mean and standard deviation. A plot showing the development in the different analysis parameters relative to the input condition along the pipe downstream of the mixer. An example of these plots section 4.3.

4.1.1. Interpreting surface plots

If absolute values are used in this kind of surface plot, the plot does not give a good indication of how the different parameters develop downstream of the mixer. To improve this, only the plot of the parameter at the mixer inlet contains absolute values. The rest of the plots are made relative to this value at the input of the mixer.

For the ideal mixer, the development should be:

- An increase in gas fraction
- A decrease in cross-correlation velocity
- An increase in RGD

In addition to this, the information about the pressure loss is plotted in a separate plot. All these plots are generated for both well mixed and slugging flow at the mixer inlet.

The plots are placed in a vertical series on the page to illustrate the vertical upwards flow. The relative plots of gas fraction for the detectors downstream of the mixer have been compensated for the pressure loss across the mixer. By doing so, a gas fraction increase due to this pressure loss does not favour the mixers with a high pressure loss.

4.1.2. Interpreting the mean and standard deviation plots

This two dimensional plot shows the development of the parameter relative to the inlet condition along the pipe downstream of the mixer. The values plotted are the average values, and the error bars are the standard deviation.

This plot then contains the information about the mixer at all flow rates and compositions. If a mixer influences a parameter differently from flow condition to flow condition, the standard deviation will increase.

4.2. Test data pressure compensations

All the tested mixers generate pressure drop, although this varies a lot from mixer to mixer. This pressure drop also causes the gas to expand, and this expansion turns out to generate some effects that have to be eliminated.

If the slip is reduced by a mixer, the gas fraction will increase and the cross-correlation velocity will decrease, and vice versa. The pressure drop over the mixer will also cause the gas volume to increase, and this increase is ideally proportional to the pressure drop, if the liquid phase is not saturated with gas. Hence, a mixer that generates large pressure drop may appear to reduce the slip, and may get a better evaluation than it deserves. This effect was removed by transforming the gas fraction measured at detector 2 in Figure 2.1 with respect to pressure to the condition at detector 1, and then make the measured gas fraction relative to the gas fraction measured at detector 1.

The influence on the cross-correlation velocity due to the pressure loss is more complex. As the gas fraction increased due to the pressure drop, the total multiphase volume flow rate increased. In this study, the changes in the flow characteristics were studied, and a change in flow velocity is interpreted as a change in flow characteristics. Hence, the change in flow velocity due to gas expansion had to be eliminated from the velocity measurements to avoid misinterpretation of the gas expansion effect. By transforming the flow condition at the output of the mixer to the flow conditions at the input of the mixer, and then performing the comparison of the flow characteristics at that flow condition, this was achieved. It was shown that the change in velocity due to gas expansion can be eliminated by the equation 4.1.

$$\upsilon_1^{*} = \upsilon_1 \bullet \frac{(1-\alpha_1)}{1-\left(\alpha_1 \bullet {P_1}/{P_2}\right)} \qquad (4.1)$$

where
υ_1^{*} = velocity transformed from mixer outlet to mixer inlet
υ_1 = velocity at mixer inlet
α_1 = gas fraction measured at the mixer inlet
P_1 = pressure at the mixer inlet
P_2 = pressure at the mixer outlet

In the plots described in section 4.1.1 and 4.1.2, these transformed values of gas fraction and cross-correlation velocity were used.

4.3. Test data example

Figure 4.1 shows an example of the data overview plots from an example mixer. As described in section 4.1, the plotted data in the four top rows are columnwise relative to the absolute data shown in the bottom row. Hence, in any column, the brown, green, yellow, and blue plot are all relative to the red plot. The gas fraction and cross-correlation velocity data are compensated both for the static head and for gas expansion effects as described in section 4.2.

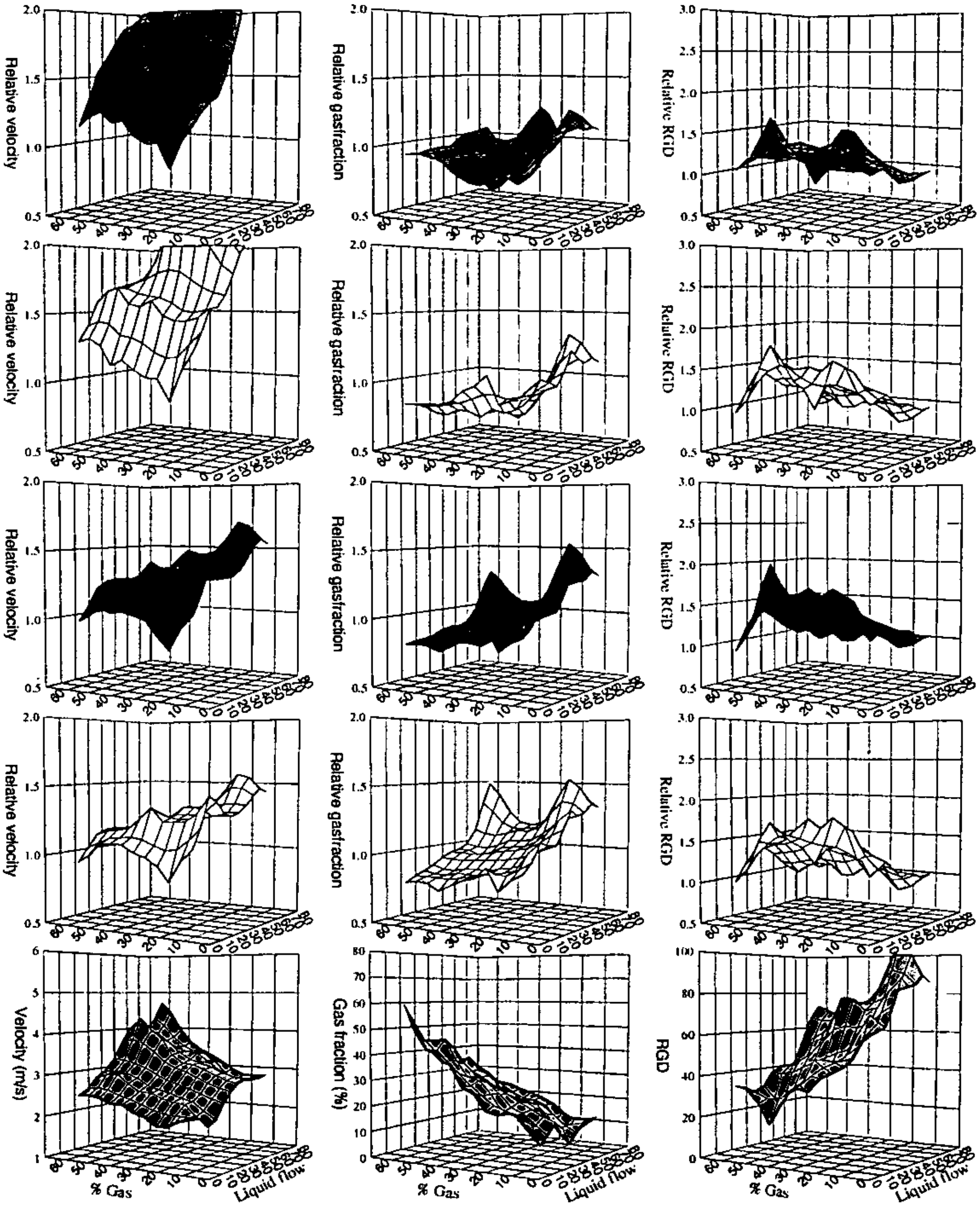

Figure 4.1: The example mixer performance, with gas injection point 3.

4.3.1. Relative gas fraction, velocity, and RGD development

In Figure 4.2 shows the mean and standard deviation of the relative gas fraction development across the example mixer. The standard deviation shown is a measure for the influence this mixer has on the gas fraction over the different flow conditions tested. If the standard deviation is large, the mixer creates a change in gas fraction that is dependent on the flow rate and composition, hence the gas fraction measured is dependent on the mixer itself. This effect is denoted as uniform or non-uniform mixer performance over the tested flow range.

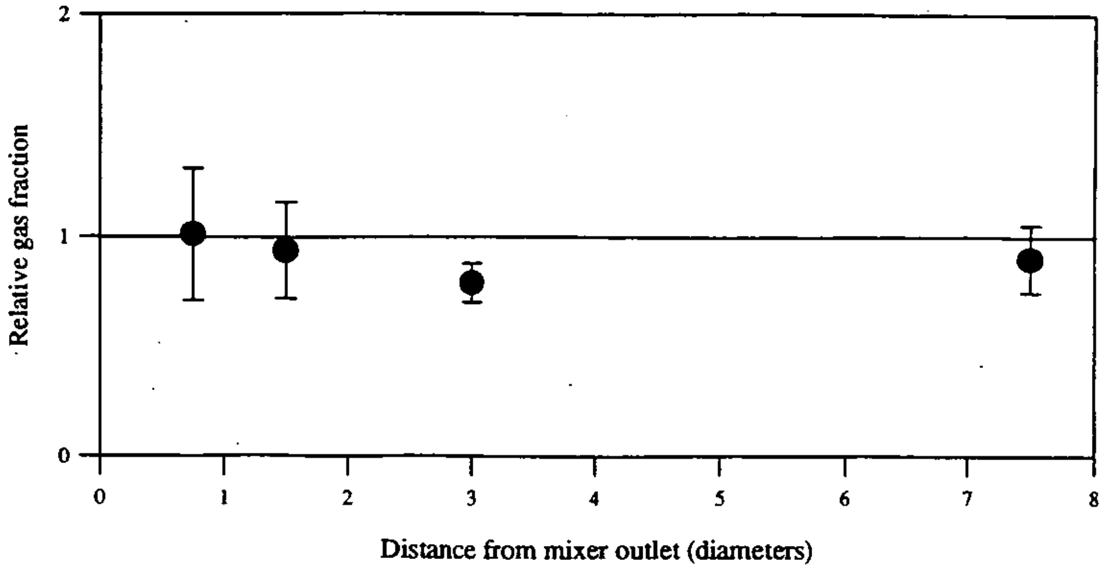

Figure 4.2: Relative gas fraction development downstream of the example mixer with gas injection at point 3.

Figure 4.2 shows a decrease in gas fraction as the distance from the mixer outlet increases, which indicates slip. Also, the standard deviation is higher close to the mixer, which indicates non uniform performance at this position over the flow range tested.

In Figure 4.3 the mean and standard deviation of the relative cross-correlation velocity development across the example mixer are shown. If the standard deviation is large, the mixer creates a change in cross-correlation velocity that is dependent on the flow rate and composition, hence the velocity at the measuring point is dependent on the mixer itself.

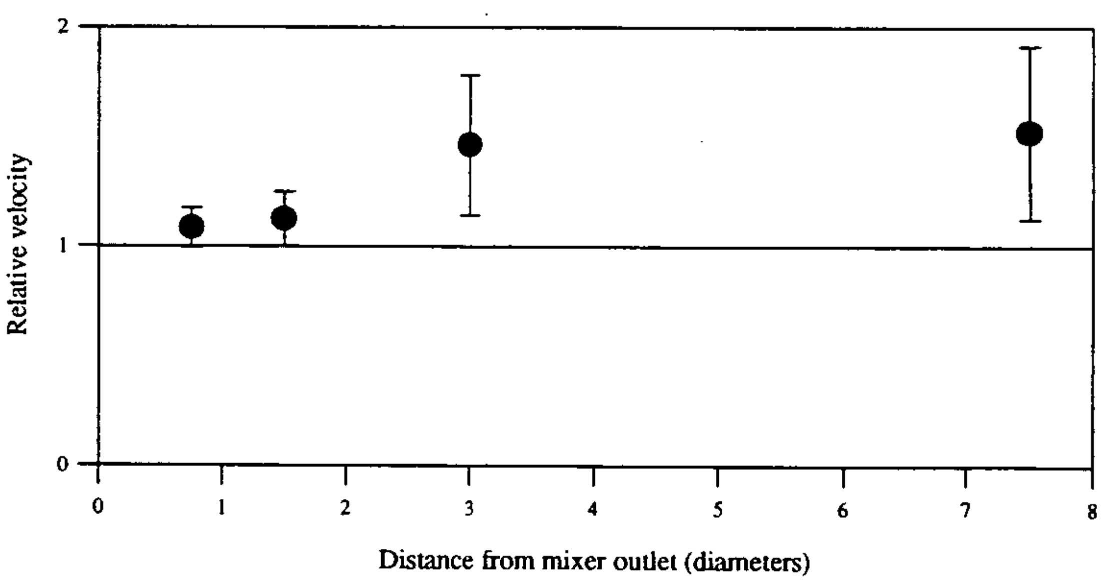

Figure 4.3: Relative velocity development downstream of the example mixer with gas injection at point 3.

Figure 4.3 show an increase in cross-correlation velocity as the distance from the mixer outlet increases, which indicates slip. Also, the standard deviation is higher far from the mixer, which indicates non uniform performance at this position over the flow range tested.

In Figure 4.4 the mean and standard deviation of the RGD across the example mixer is shown. If the standard deviation is large, the mixer creates a change in RGD that is dependent on the flow rate and composition, hence the RGD at the measuring point is dependent on the mixer itself.

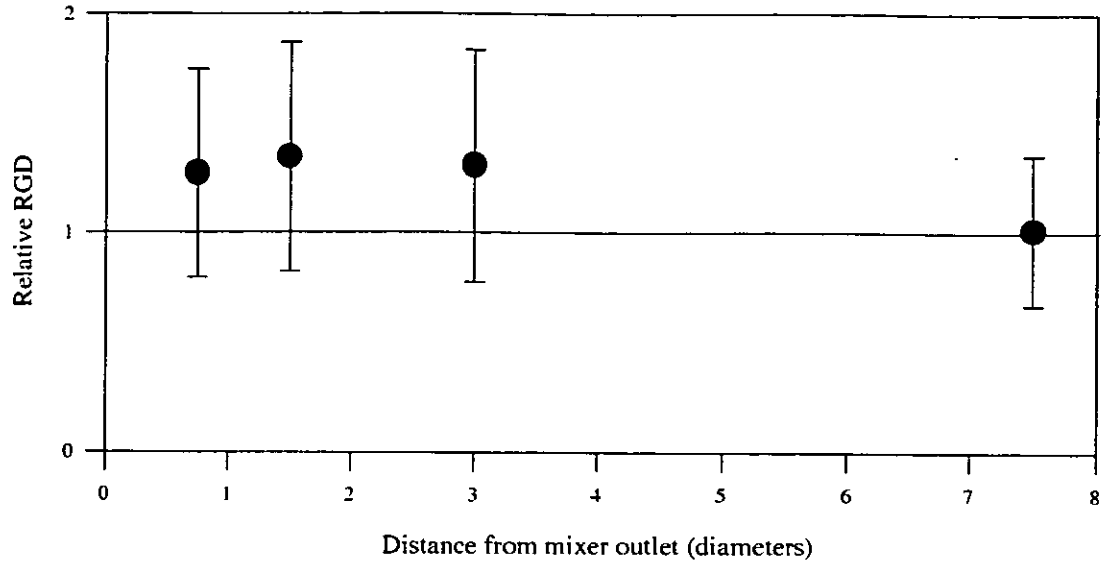

Figure 4.4: Relative RGD development downstream of the example mixer with gas injection at point 3.

Figure 4.4 shows a decrease in RGD as the distance from the mixer outlet increases. The statistical model is not calibrated to interpret swirl, so the results from the model may be misleading.

4.3.2. Pressure drop across mixer.

The development of the pressure drop with the example mixer over flow range tested is shown in Figure 4.5. This figure shows a remarkably low pressure drop over the mixer, although this mixer is one of the devices with the largest pressure drop among the tested mixers.

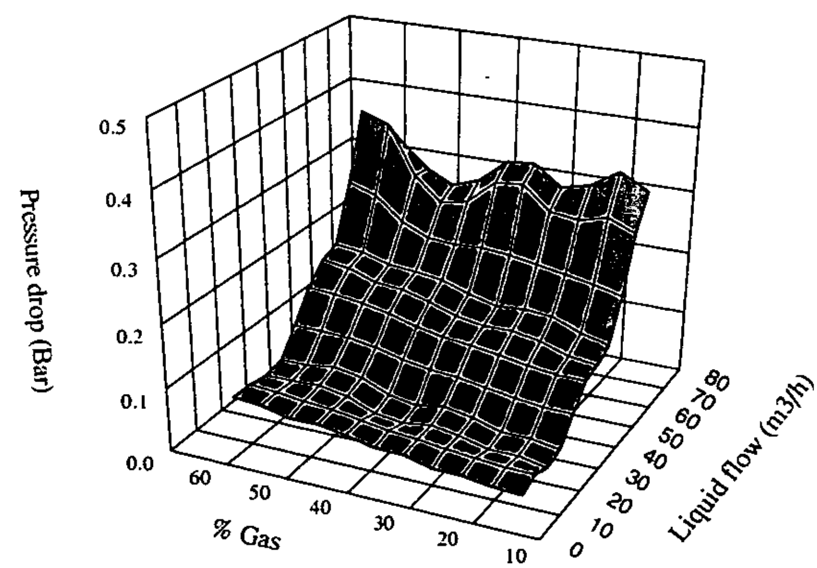

Figure 4.5: Pressure drop across example mixer.

4.3.3. Example mixer conclusions

Highlights:

- Velocity increase along pipe downstream of mixer
- Gas fraction reduction along pipe downstream of mixer
- RGD best close to mixer outlet
- Heavy swirl at mixer output excludes the mixer from multiphase applications

From the high speed video it can be seen that the example mixer generates heavy swirl. This together with that the gas fraction decreases and the cross-correlation velocity increases as the downstream distance to the mixer outlet increases, leads to the conclusion that the example mixer concentrates the gas in the pipe center.

This is the same effect as is utilised for separation in a hydrocyclone. The centrifugal force throws the liquid towards the pipe wall, and the gas is concentrated in the pipe center. As the gas is concentrated in the center of the pipe, the buoyancy effect becomes more dominant, which generates an increase in cross-correlation velocity and a decrease in gas fraction.

The example mixer has the best performance at high gas fractions within 2 diameters downstream of the mixer outlet. The pressure drop is relatively high with an average of more than 120 millibar and a maximum of 450 millibar.

5. General conclusions

The mixers included in this evaluation have been developed for different applications. The efficiency of static mixers as a preconditioner in multiphase flow is heavily influenced by the design criteria given in the intended application. This work does not contain any conclusions regarding the efficiency of the static mixers when used in the application they are specifically designed for.

In the following, our general experiences with the static mixers we tested are discussed.

5.1. Radial mixing

Using a single static mixer, reasonably good radial gas distribution can be achieved over a limited flow composition range. Our experience is that the influence of most mixers on the slip and the local gas fraction will change if the flow rate and composition are altered. Hence, if a mixer is used as a preconditioner for a multiphase flow meter, it may be necessary to calibrate the flow meter for the varying performance of the mixer.

5.2. Axial phase distribution

The static mixers have marginal effect on the axial distribution of the phases. A large body of gas or liquid, 10D or more with only one phase occupying almost the entire cross section, will pass through such a mixer with the internal mix in the body being modified, but without any interchange of mass with the preceding or succeeding bodies of flow.

A liquid and/or gas hold-up volume must be introduced in the flow line to improve the axial gas distribution. This can be done by using a device as developed by FRAMO Engineering or by careful design of the upstream piping.

5.3. Pressure drop

The tested devices generated less pressure drop than expected. The pressure drop tapping downstream of the mixer was placed at a distance 2.5D from the mixer outlet, at which pressure recovery should be completed. In crude oil environments, the instant pressure drop at the outlet of the mixer could cause boiling, but that effect has not been studied in this project.

The highest pressure drop recorded during these tests was 496 millibar. The mixer with the lowest pressure drop had a maximal pressure drop of 44 millibar. We found no correlation between the pressure loss and the efficiency of the mixer.

5.4. Secondary flow effects

Static mixers generating heavy swirl is practically useless in vertical upwards multiphase flow, due to the fact that heavy swirl in effect is a hydrocyclone separator. The liquid will be thrown towards the pipe wall and, due to the large difference in density, the gas will be forced towards the center of the pipe. This gas will then coalesce and form larger bubbles, which will accelerate relative to the liquid and create a large interphasial slip.

Static mixers generating turbulence appears to have a positive effect on the conditions for measuring multiphase flow. The plausible cause of this is that turbulence will both split larger bubbles in the flow and reduce small bubble coalescence, hence preventing large interphasial slip.

We have not studied the performance of these devices in any other configuration than vertical upwards multiphase flow, hence our experiences may not be relevant in other flow configurations.

6. Acknowledgements

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Agostino Mazzoni	AGIP, Italy
Bernhard LeMoullec	Elf Aquitane, Norway
Philipe Jouve	Elf Aquitane, France

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