

Method used at Munters Euroform for Droplet Measurement

Preface

With this paper we try to give some information to everybody who is interested in droplet measurement.

Basic information is given therein by explaining the necessity of measuring droplets with respect to our products and by presenting basic measuring methods. References are given to make detailed information more comprehensible and to give hints for other contact persons.

A concern of our company is to present the measuring methods used at Munters Euroform to anyone interested and to explain why precisely these measuring methods were chosen and used by preference.

Larger way has been given to the presentation of the impactor probe. This was necessary because considerable improvements were made in recent years at the impactor probe, whereby a wider range for application and better accuracy of the measurements were achieved.

Table of Contents

	Page
1. Necessity of Droplet Measurement	1
2. Description of Basic Measuring Methods	2
3. Specific Demands on a Measuring Method	3
4. Impactor Probe	4
4.1 General Remarks	4
4.2 Arrangement of the Impactor Probe	5
4.3 Determination of the Measured Values with the Impactor Probe	6
4.4 Evaluation of the Measured Values	7
4.5 Importance and Influence of the Inertia Parameter	11
5. References	13

1. Necessity of Droplet Measurement

It is of basic importance to know the nature and quantity of liquid load of a gas both for the optimum selection and dimensioning of a mist eliminator. Furthermore, the liquid load of the gas behind the mist eliminator can also be of interest for various reasons. From this results the need of droplet measurement.

Droplet measurement means gathering of information as to measuring technique on the drop size distribution and/or on droplet mass flow respectively the liquid load of the gas corresponding directly to this.

It differs from case to case whether the liquid load of the gas or the drop size distribution is more important. In most cases it depends upon the nature of the required information for which droplet measurement is indispensable. In most cases both the liquid load of the gas and the drop size distribution are of great importance.

When talking about the separation and measurement of liquid particles, different terms are used: Drops, droplets, aerosols and mist. In the following all liquid particles, irrespective of their size, will be called "droplets".

2. Description of Basic Measuring Methods

As already mentioned in section 1, distinction must be made between the measurement of liquid load of the gas without considering the drop size distribution and the measurement of liquid load of the gas, considering the drop size distribution at the same time.

For the measurement of the liquid load of the gas without considering the drop size distribution among others the following measuring devices are available:

- a) Throttling calorimeter
- b) Heated probe
- c) Double calorimeter
- d) Condensation method
- e) Cyclone separator

For the measurement of the liquid load of the gas and the drop size distribution the following measuring devices are available:

- a) Impactor method
- b) Light scattering probes
- c) Laser probes

Further details on the above mentioned measuring devices, especially on their functioning and application, are given in Reference [1].

Which measuring method is suitable must be studied on the basis of the edge conditions under which the method should be used and what information this method should provide.

3. Demands on a Measuring Method

The following demands are made on and must be met by a method for the measuring of droplets behind mist eliminators:

- a) The measuring method provides some information on the drop size distribution. The drop size distribution which can normally be influenced by a vane type mist eliminator is in the range from 15 μm to approx. 2000 μm ;
- b) The measuring method provides some information on the droplet concentration;
- c) It must be possible to use the method both in saturated and unsaturated gas streams;
- d) With the method it must be possible to determine liquid loads of the gas which may range from a few up to several thousands mg/m^3 ;
- e) The measuring device must be easily portable at industrial measurements;
- f) It must be easy to insert and to position the device in a gas stream
- g) The impactor method meets these demands in an optimal manner. It will be described in the following.

4. Impactor Probe

4.1 General Remarks

Collection of droplets for evaluation purposes by means of an impactor is a very old method which was already described by May [2] in 1950. Munters Euroform has developed an impactor probe on the basis of the principle described by May and has improved this in course of the years.

When selecting an adequate impactor, droplet sizes from approx. 15 μm up to approx. 2000 μm can be measured with the described impactor probe.

The impactor probe consists in the most simple case of a support on which the impactor is clamped. As impactors glass carriers are used, which are coated e. g. with magnesium oxide for measuring small droplets (15 - 200 μm). The impactor is maintained in the gas stream with the coated side against the flow direction whereby droplets are collected on the impactor leaving craters on the plate. Droplet sizes can be attributed to these craters by a calibration curve.

For bigger droplets (200 - 2000 μm) the impactor can also consist of a „Sensitive Paper“ which becomes discoloured on the impact spots. Droplet sizes can also be attributed to the discoloured area by a calibration curve.



Fig. 1: Basic Arrangement of the Impactor Probe during measuring

4.2 Arrangement of the Impactor Probe

The impactor probe consists of the support on which the impactor is clamped. The support is placed in a shield tube to make possible the introduction of the impactor into the gas stream loaded with droplets.

The probe is also provided with a mechanism to open the impactor for a definite time.

The time during which the impactor is exposed to the gas stream is determined by means of an electronic time recorder.

The basic arrangement of the impactor probe is shown in Fig. 2.



Fig. 2: Impactor Probe with time recorder (impactor with Shield Tube opened)

4.3 Determination of the Measured Values with the Impactor Probe

1. The support is provided with the impactor and fitted into the shield tube and warmed up to the gas temperature.
2. The impactor probe is introduced into the gas stream and fixed to a definite measuring point.
3. With a special mechanism a portion of the shield tube is opened in the impactor area thus exposing the impactor to the gas stream loaded with droplets. The duration of the exposing time will be between 0.5 sec. up to some minutes based on the liquid content.
4. The shutter is closed, so that the impactor is no longer exposed to the gas stream. The effective time of exposure is measured with the time recorder and filed.
5. The support with the impactor is taken out of the shield tube.
6. The impactor is carefully kept for evaluation later on.
7. The relevant flow velocity must also be determined exactly at the place of exposure and will be measured with the Pitot tube or a Vortex-Probe.

And so, the proper determination of measured values of measuring point is terminated.

4.4 Evaluation of Measured Values

The evaluation comprises the following steps:

1. The number and diameter of the craters on an impactor are determined by a microscope or video analysis system.
2. Droplet sizes are attributed to the respective crater diameters by calibration curve.
3. Depending upon the prevailing inertia parameter, adjustment is made considering the efficiency of the impactor probe (detailed explanation is given in section 4.5).

Based on the before mentioned steps 1 to 3 some statement for evaluation can already be made on the drop size distribution.

Usually either the effective droplet amount or the portion of droplets is plotted as a function of the droplet size, as shown in Fig. 3 (Frequency distribution).

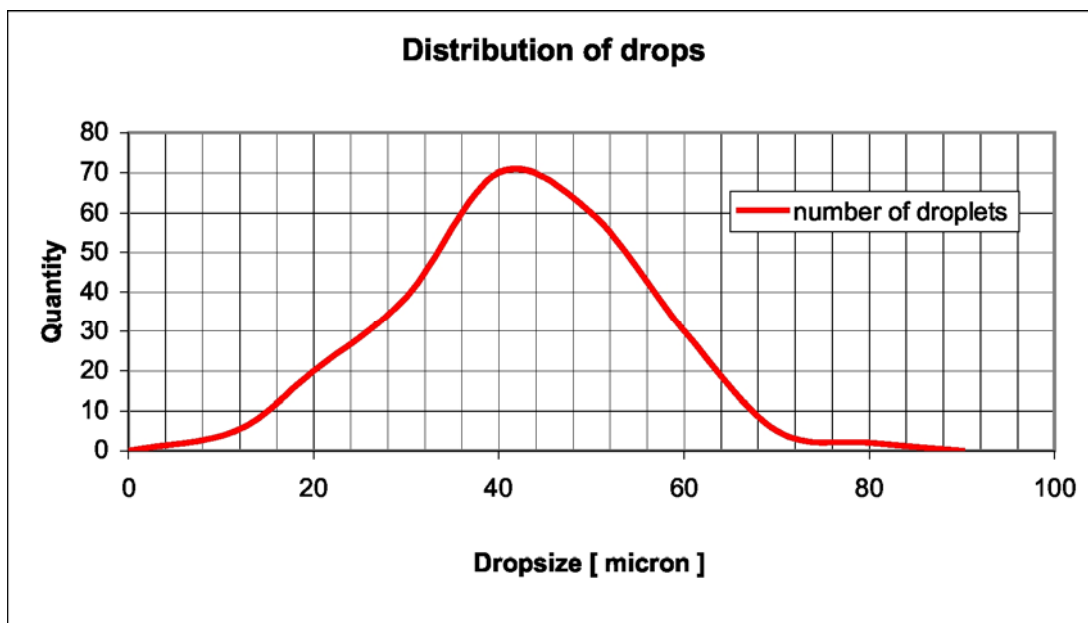


Fig. 3: Frequency Distribution (Basic Presentation)

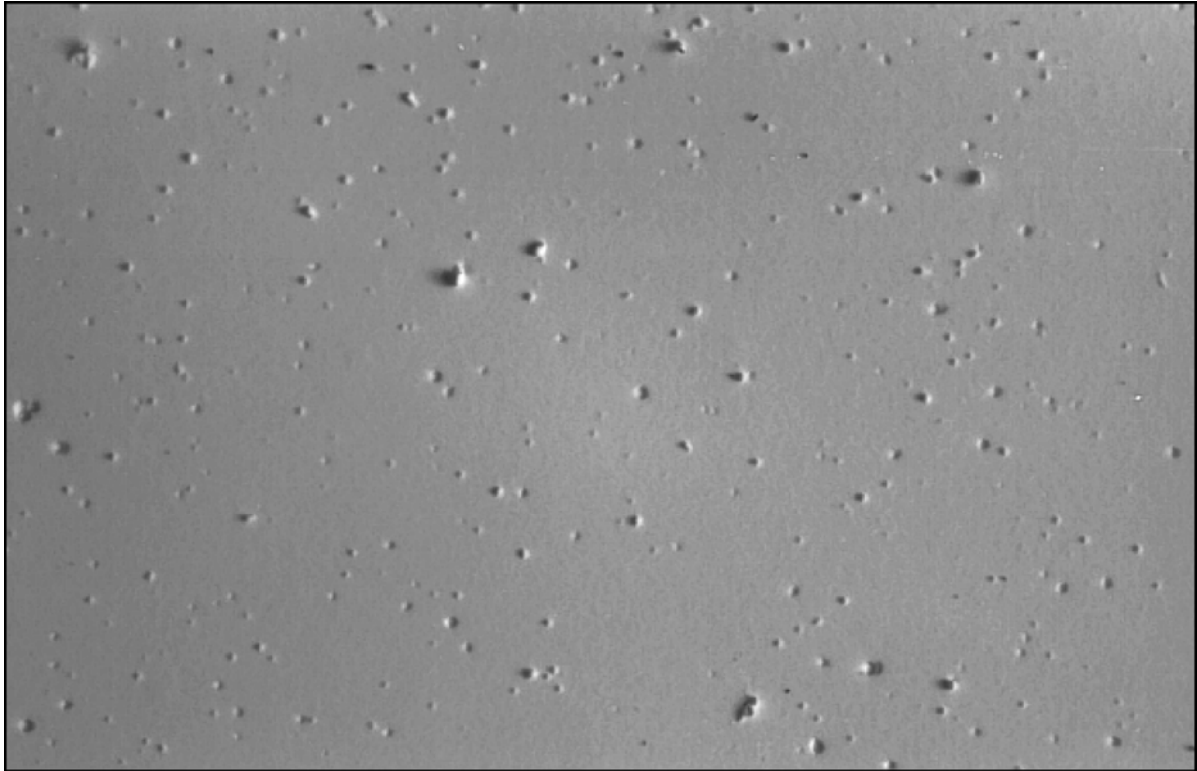


Fig. 4: Magnesium Oxide Impactor with Craters (Extract, enlarged approx. 60 times)

To determine the mass flow of the droplets or the liquid load of the gas stream, further steps are necessary at the evaluation.

4. Utilizing the information on the time of exposure of the impactor and the face velocity of the impactor, the liquid load B of the gas stream can be calculated according to the following equation:

$$B = \frac{V_L \cdot \rho_L}{A_I \cdot C_A \cdot T_E}$$

B	(kg/m ³):	Liquid load of the gas
V _L	(m ³):	Droplet volume attributed to the impactor area Density of droplets
ρ _L	(kg/m ³):	Density of droplets
A _I	(m ²):	Impactor area
C _A	(m/s):	Face velocity in front of the impactor
T _E	(s) :	Time of exposure of the impactor

The following relationship exists between the droplet volume that can be attributed to the impactor area and the diameter of craters available on the impactor.

$$V_L = \sum_{D_{K \min}}^{D_{K \max}} \left\{ \frac{1}{\eta(\psi)} \sum_{i=1}^n \left[(D_K \cdot Y_K)^3 \cdot \frac{\pi}{6} \right]_i \right\}$$

D_K	(m):	Crater diameter on the impactor
Y_K	(-):	Factor respectively spot diameter establishing the relationship between the crater diameter D_K and producing droplet size, D_{TR} (further details in Reference [2])
n	(-):	Number of craters with diameter D_K
ψ	(-):	Inertia parameter (see Section 4.5)
η	(-):	Efficiency of the impactor (considers the difference between the droplets collected by the impactor and those reaching the impactor area) $\eta = \eta(\psi)$
$D_{K \min}$	(m):	Smallest crater diameter available on the impactor
$D_{K \max}$	(m):	Largest crater diameter available on the impactor

The equations presented for the evaluation of the impactors reveal that the evaluation of this measuring method which is very simple in its principle is not trivial at all and requires a lot of care and systematics. The results are shown in the form of diagrams which demonstrate the cumulated load as a function of the droplet size distribution. From this diagram all essential results of a droplet measurement can be seen at a glance.

- Total load
- Load in a certain droplet interval
- Droplet size distribution

In Fig. 5, the result of a droplet measurement is given as an example in the described manner.

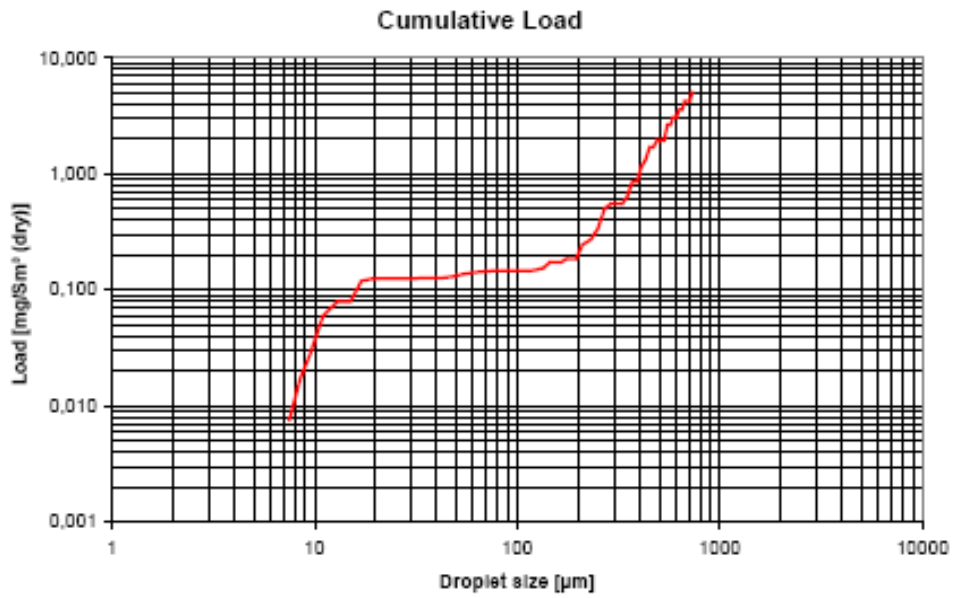


Fig. 5: Cumulative Liquid Load of the Gas depend on the Droplet Size

4.5 Importance and Influence of the Inertia Parameter

The droplets approaching the impactor with the velocity C_A are captured by the impactor only to a certain extent and thus documented. A percentage of droplets follows the streamlines. Therefore, the basic question is to determine how many droplets have effectively been collected by the impactor. The efficiency of the impactor is considering this.

The efficiency of the impactor depends upon a large number of influencing factors enumerated in the following:

- Droplet size
- Droplet density
- Face velocity of the droplet onto the impactor
- Dynamic viscosity
- Geometry of the measuring probe

By means of the dimension analysis this multitude of influencing factors can be combined to non-dimensional factors. The most important of these factors to be considered is the so-called inertia parameter (Stokes parameter) defined as follows:

$$\psi \equiv \frac{\rho_L \cdot C_A \cdot D_{TR}^2}{18 \cdot \eta_G \cdot D_S}$$

ψ	(-)	Inertia parameter
ρ_L	(kg/m ³)	Density of droplets
C_A	(m/s)	Face velocity
D_{TR}	(m)	Droplet diameter
η_G	(kg/ms):	Dynamic viscosity of the gas
D_S	(m)	Characteristic diameter of the probe

The functional relationship between the separation efficiency and the inertia parameter can be calculated. F. Löffler and W. Muhr [3] have presented the necessary basics and critical reflections thereon. Other interesting details on this topic are given in Reference [4] to [8].

On the basis of the mentioned authorities Munters Euroform has elaborated a computation program [9] by means of which the separation efficiency of the probe was calculated as function of the inertia parameter. Hereby the special geometry (circular cylindrical shield tube and plane impactor plate) has been taken into account.

Fig. 6 shows the result of our computation and presents - for rough comparison purposes - the results of a computation by Langmuir and Blodgett as well as the measuring results by May and Clifford (Reference [3], page 512, Fig. 4)

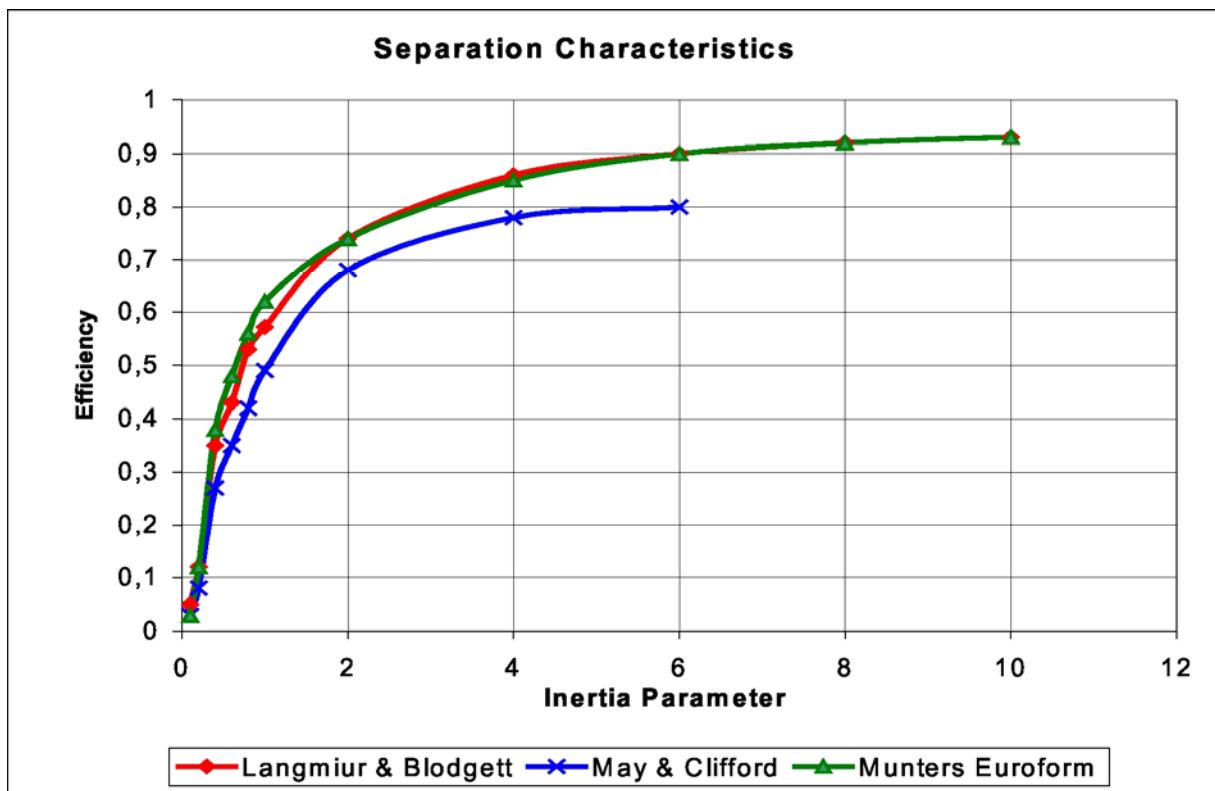


Fig. 6: Separation Characteristic of the Impactor Probe

5. References

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