Application Note:

Inertial Pre-Separation Efficiency for Water and Oil Aerosols
MMF-80 MaestroGuard® Filter – Low-Flow Bypass Operation





1. Purpose of the Inertial Pre-Separator

The MMF-80 MaestroGuard™ filter incorporates an **integrated inertial pre-separation stage** upstream of the dual MaestroGuard™ membrane system.
The purpose of this inertial pre-separation stage is to:

- Remove **free liquids and coarse aerosols** (water and oil) from the gas stream
- Reduce liquid load on the membranes
- Prevent membrane wetting and mechanical stress
- Increase service life and measurement reliability of downstream analyzers

This passive separation stage operates without moving parts and is effective even at **very low sample flow rates**.

2. Operating Conditions and Geometry

The following analysis applies to the MMF-80 operated under typical sample conditioning conditions:

Parameter	Value
Gas	Air (representative for natural gas and inert gases)
Bypass flow	Max 5 L/min
Operating pressure	Up to 160 bar
Temperature	Ambient
Internal inertial chamber radius	18 mm
Separation principle	Inertial pre-separation

Inlet and Outlet Geometry

- **Gas inlet:**
  Radial, tangential inlet located at approximately the **8-o'clock position**, oriented tangentially to the circular path of the Inertial Chamber.
- **Bypass outlet:**
  Radial, tangential outlet located at approximately the **6–7-o'clock position**, following the outer inertial flow path.

Both inlet and outlet are tangential to the inertial chamber circumference, promoting **rapid inertial formation**, **high flow stability**, and **minimal droplet re-entrainment**.

Concave Chamber Geometry

The inertial pre-separation chamber incorporates a **concave wall geometry** that supports stable rotational flow, particularly at very low bypass flow rates.

The concave surface guides the swirling gas stream, reduces premature swirl decay, and promotes droplet migration toward the wall. Liquid droplets are encouraged to coalesce at the wall surface and are reliably directed toward the tangential bypass outlet, reducing re-entrainment into the gas core.

Liquid droplets and heavy aerosols experience inertial forces and migrate toward the outer wall, where they coalesce and are discharged through the tangential bypass outlet.

3. Separation Mechanism

The inertial separation performance is governed by the balance between:

- Inertial forces acting on droplets
- Drag forces imposed by the gas
- Droplet diameter and density

Larger and denser droplets exhibit higher inertia and are preferentially separated from the gas stream.

Unlike a classical cyclone separator, the inertial pre-separator does **not function as a particle classifier** and does **not provide a sharply defined cut diameter (d_{50})**.
Instead, it provides **inertial pre-separation**, primarily targeting **free liquids and coarse droplets**.

For the MMF-80 inertial geometry and a bypass flow of 5 L/min:

- Free liquid and coarse droplets (> ~5 µm) are efficiently removed
- Fine aerosols remain entrained in the gas and are intentionally passed to the membrane stage

This behavior is **intentional and optimized** for low-flow sample conditioning.

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4. Effective Inertial Removal Performance of the Inertial Pre-Separation Stage

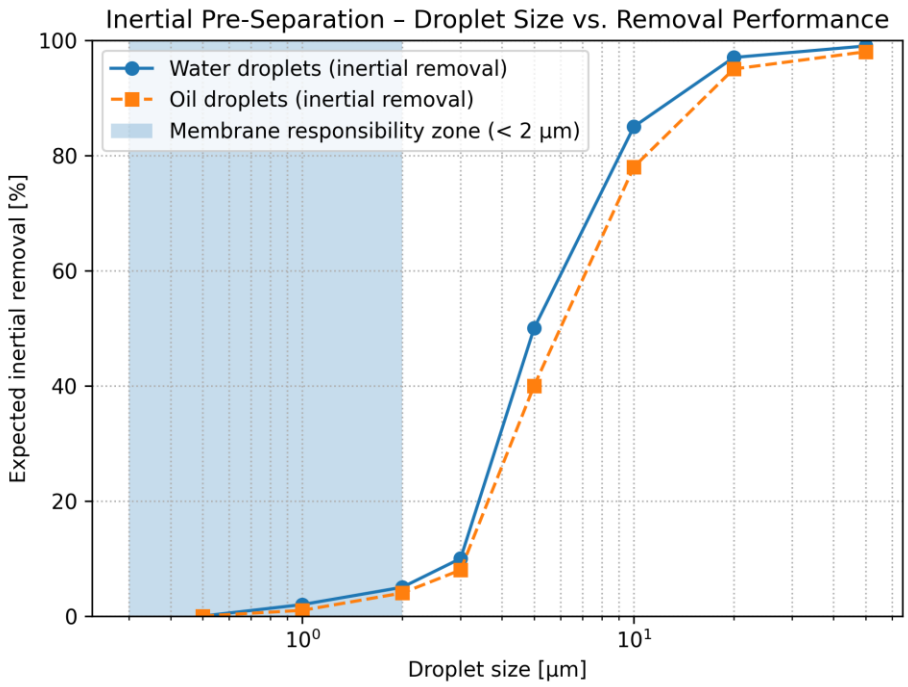
Inertial pre-separation mechanically removes free liquids and coarse droplets using their inertial, protecting the fine filtration stage that follows.

The **inertia liquid pre-conditioning stage of the MMF-80** provides effective inertial removal of free water and oil droplets prior to membrane filtration.

Its function is optimized for **free liquids and coarse droplets**, not for fine aerosol classification.

At a typical bypass flow of **5 L/min** and operating pressures between 3 and 160 bar, the expected inertial removal performance is as follows:

Droplet size	Expected inertial removal	Remarks
< 1 µm	~0 %	Follows gas stream
1–3 µm	< 10 %	Not targeted mechanically
~5 µm	**30–60 %**	Onset of effective inertial separation
≥10 µm	**70–90 %**	Highly effective removal
≥20 µm	**>95 %**	Near-complete removal
Free liquid slugs / films	**≈100 %**	Reliably discharged



These values represent realistic **inertial pre-separation performance** for a compact tangential stage operating at very low flow rates.

Fine aerosols are intentionally not forced into mechanical separation but are handled by the downstream membrane stage.

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5. Staged Separation Concept: Inertial Pre-Seperation + MaestroGuard® Membranes

Fine aerosols below approximately **2 µm** are intentionally passed to the **MaestroGuard® membrane stage.**
At these particle sizes, inertial separation becomes physically inefficient, as droplet inertia is insufficient to overcome gas drag. Forcing mechanical separation of fine aerosols would require excessive turbulence and pressure drop, increasing the risk of droplet fragmentation and re-entrainment.

Instead, the MMF-80 follows a **deliberate staged separation concept**:

- The **inertial pre-separator stage**
  - removes **free liquids and coarse droplets**,
  - reducing mechanical stress and liquid impact on the membrane.
- The **MaestroGuard® membrane**, (**pore size of 0.1 µm)**
  - Absolute liquid barrier
  - Hydrophobic and oleophobic
  - No membrane wetting
  - No fiber shedding
  - No liquid breakthrough
  - No absorption or diffusion effects
  - Stable performance independent of pressure and flow fluctuations

The MaestroGuard® membrane is manufactured from **100 % PTFE.** Fine water and oil aerosols cannot penetrate or wet the membrane surface. Instead, they coalesce at the membrane interface and are actively repelled, ensuring stable operation independent of pressure and flow fluctuations**.**

The inertial removes what should be removed mechanically.
The membrane blocks what must never pass.

6. Influence of Operating Pressure

The inertial pre-separator remains effective across a wide pressure range.

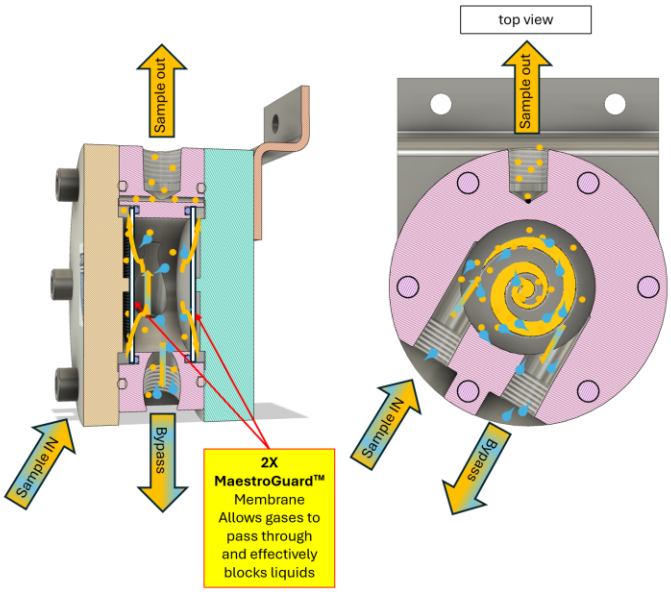
Key effects of increasing pressure:

- Gas density increases → inertial forces increase
- Gas viscosity increases slightly → minor reduction in fine droplet separation
- Liquid surface tension may decrease → finer droplet formation possible

Net result:

- Removal of free liquids and coarse droplets remains stable
- Fine aerosols are consistently handled by the membrane stage
- Overall system performance remains robust and predictable

Functional diagram illustrating the MF-series of MaestroGuard™ filter



In real systems, any minor pressure-related effects are fully compensated by the **dual MaestroGuard® membrane stage**, which provides absolute liquid blocking.

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7. Role Within the MMF-80 Dual-Barrier Concept

The inertial pre-separator functions as a **first passive safety barrier** and is not intended to replace fine filtration..

System architecture:

1. **Inertial pre-separator**
    - Removes free liquids and coarse droplets
    - Protects membranes from liquid impact
2. **Dual MaestroGuard® membranes (0.1 µm nominal)**
    - Absolute gas/liquid barrier
    - Hydrophobic and oleophobic

- No absorption, no fiber shedding

This combination represents a **best-in-class protection concept** for sensitive analyzers (GC, BTU, moisture, sulfur, oxygen, hydrogen purity).

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8. Key Benefits for Analyzer Protection

- Reliable operation even with **unexpected liquid carryover**
- Stable performance at **very low sample flow rates**
- Reduced maintenance intervals
- Extended membrane lifetime
- Highest analytical accuracy

Even at low bypass flows, the inertial stage provides a meaningful reduction of liquid load before the membrane, making the MMF-80 particularly suitable for **trace analysis and high-value analyzers**.

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9. Summary

The integrated Inertial liquid pre-conditioning stage provides effective inertial removal of free water and oil droplets, achieving **70–90 % removal for droplets ≥10 µm** and **>95 % removal for droplets ≥20 µm**, while free liquids are reliably discharged.

Combined with the **0,1µm dual MaestroGuard® membrane system**, the MMF-80 offers absolute **liquid stop** - the **most advanced, robust and reliable sample conditioning concepts** available for gas analysis applications.

About Analytical Filters Engineering

Analytical Filters Engineering Kft develops and manufactures high-performance filters and sample-conditioning components for gas and liquid analysis. All MaestroGuard® products are designed and assembled in the EU, combining robust construction with the highest analytical precision.

Contact us today for application-specific guidance or a sample demonstration.

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