

Why “in-line”?

Viscosity is a rheological property . . . meaning a property involved with the deformation of flow. The key word is flow. The best location to measure and control a property of the flow is within the flow itself . . . not along side the flow (a sidestream) and not in a laboratory. The measurement and control of viscosity (and temperature) directly in the flow provides real time rheological data . . . no lag time and no process delays. In the end, plants will achieve the highest process efficiency while improving product quality.

The TOV Viscometer System . . . what is it?

The Mansco Products TOV Viscometer System is a process viscometer designed and built for in-line use. It is the most sensitive, stand-alone control device for measuring viscosity and temperature in an in-line environment. It is unlike capillaries or laboratory viscometers in that the TOV is installed directly into the main process pipeline . . . no sidestream is needed. It is unlike any other viscometer because of its sensitivity, repeatability, robustness, and low maintenance requirements. And, Mansco Products provides installation, training, and comprehensive support services. In other words, the TOV System is the most effective process viscometer available and the TOV System has no peer.



Why the TOV? . . . why is the TOV Viscometer System so much better?



What's Inside:

What is viscosity & why is it important?	2
More about shear rate . . .	2
TOV Applications	2
The TOV Probe	3
The TOV Transducer	3
The TOV Adaptor	3
Most Common TOV Installation	4
What we need to know about your process	4
Contact information for Mansco Products & Lawson-Hemphill	4

Quite simply, the engineering and “know-how” incorporated into each TOV System is what makes the TOV better. For example, the TOV operates at a low shear rate. By definition, viscosity is the ratio of shear stress to shear rate. In turn, the TOV measures shear stress of the process fluid to determine the process viscosity. Sounds easy, right? . . . Well, it's not that simple. The instrument must be engineered and designed to withstand the harsh operating environments of process lines while providing high sensitivity and repeatability levels for very reliable process control . . . all while eliminating the effects of the plant environment. The TOV does just that.

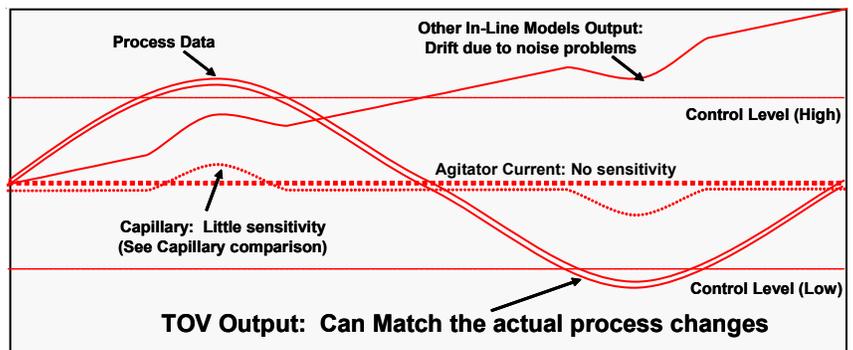
- Reliability & Repeatability:

With a repeatability factor of over 99.5%, the TOV produces the same results over and over again, day after day, week after week, year after year.

- Very User-Friendly: After initial set up, the TOV requires little or no maintenance . . . including calibration.

- Durability: The TOV System is very durable. Many TOV's have been installed in pipelines for a decade or more without interruption.

- Lab-Like Results in Real-Time: The TOV is designed so the customer can measure viscosity and temperature within range and within the target viscosity level.



Graphical Representation for Illustrative Purposes Only

What is viscosity and why is it so important?

“All fluids possess a definite resistance to change of form and many solids show a gradual yielding to forces tending to change their form. This property, a sort of internal friction, is called viscosity; it is expressed in dyne-seconds per cm² or poises.”* In terms of physics, viscosity is the ratio of shear stress to the shear rate. The viscosity of a polymer decreases as shear rate increases. This property is referred to as pseudoplastic behavior or shear thinning.

Viscosity is a rheologic property. Rheology is the science of deformation and flow of materials. Viscosity is just one of the many important rheological properties. Because of this inter-relation, viscosity can be used as an indirect measurement of properties such as crystal concentration, and other important properties. In other words, with the accurate measurement of viscosity, plants can tightly control their entire process flow.



$$\text{Shear Stress} = \frac{F}{A}$$

$$\text{Shear Rate} = \frac{\Delta v}{\Delta x}$$

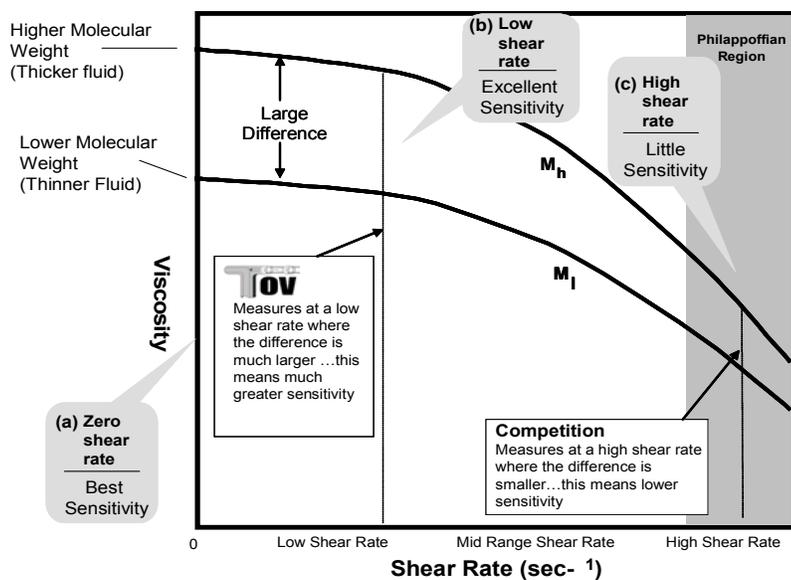
$$\text{Viscosity} = \eta = \frac{\text{Shear Stress}}{\text{Shear Rate}} = \frac{F/A}{\Delta v / \Delta x}$$

*CRC Handbook of Chemistry and Physics, 62nd Edition, Copyright 1981-82, pg. F-40, CRC Press.

More About Shear Rate:

Intrinsic Viscosity, Shear Rate, & the TOV Viscometer System

Melt Viscosity vs. Shear Rate



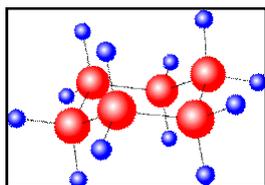
In a condensation polymerization process the material exits the “finisher” and moves slowly toward spinning with a shear rate of less than 10 sec⁻¹. To obtain the most reliable viscosity measurement apparent viscosity at different shear rates should be analyzed. At low shear rates the viscosity remains near η_0 , sometimes referred to as the intrinsic viscosity. But as the shear rate of measurement increases, the apparent viscosity drops until reaching another asymptotic plateau, called the Philappoffian region. The reason for the decrease of apparent viscosity with increased shear rate is not all segments of a

molecule can respond to the more and more rapid motion of the measuring device. This is demonstrated in the accompanying curve “Viscosity vs. Shear Rate.”

The TOV Viscometer System (TOV) measures viscosity well before the Philappoffian region, at much lower shear rates where the measurement of viscosity is much more significant. With its unsurpassed sensitivity at its operating shear rate, the TOV provides much more effective results on a more repeatable basis.

TOV Applications

The general rule is that: “If the fluid can be pumped, then it can be measured using the TOV System. Applications include, but are not limited to:



Polyester
Nylon
Acrylic
Polyethylene
Polyurethane
Polypropylene

Polycarbonate
Polysulfone
Spandex
Glass Fiber
High Viscosity
Special Polymers

Please note: Each TOV System is custom designed to meet each applications needs and specifications. The TOV sensor is selected and designed for optimal viscosity measurement while the Transducer is calibrated for optimal narrow ranges within the product specifications.

The Key Components of the TOV Viscometer System

The TOV Probe

The superior design of the TOV Probe provides the most sensitive, accurate, and reliable viscosity measurement in the world.

The Probe's Sensor

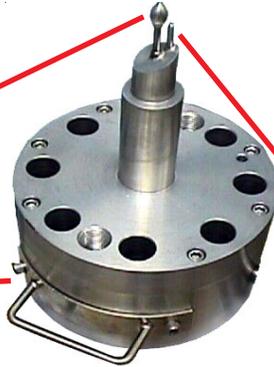
The TOV Probe's sensor incorporates over 40 years of experience and know-how. The sensor is designed for minimal flow disruption while providing the most sensitive and reliable viscosity results.

Mass Flange

The Probe's massive flange provides a reference so that plant influences are eliminated.

Safety

TOV Probes models are approved for Class 1, Division II, Group A,B,C,D service by Entela and UL.



TOV Probe's Construction

The superior engineering and design incorporates decades of field and engineering experience leading to today's unmatched know-how. Each TOV Probe is custom designed to provide the most effective and reliable results on a repeatable basis.

Platinum RTD Element

The built-in Platinum RTD provide a very accurate temperature reading at the point where temperature is most significant . . . where the viscosity is measured.

Probe's Interior and Torsional System

The TOV Viscometer System operates utilizing the torsional principal. Each TOV Probe incorporates the most advanced engineering . . . from the torsional elements to the pickup to the electromagnets.

The TOV Transducer

The TOV Transducer makes up the electronic component of the TOV System. It supplies power to the probe, receives probe signals, and conditions these signals before outputting as 4-20mA signals..

Conditioned Signal

To reduce noise influences from the pipeline operation, the signal from the Probe is conditioned in the Transducer to provide a steady, distortion free signal.

Four Isolated Signals

- Compensated Viscosity
- Uncompensated Viscosity
- Broad Range Temperature
- Compensating Temperature

Front Panel Access

All Transducer settings are made via the front door panel access.

On-line Probe Checks

Operational Probe Checks are included that allow for the testing of the Probe and Transducer functions without removal in the field making process troubleshooting simpler.



Power Checks

Model SC-03 Slide Chassis provides automatic and manual checking of all power supplies during TOV System operation. Also included is a true differential meter for making voltage measurements.

The TOV Adaptor

The TOV Adaptor, designed specifically for the Probe, is machined for a smooth interior transition between the Probe and Adaptor, minimizing build-up and disturbances.

Experienced Design

The Adaptor is designed based on customer and process specifications using the years of experience of Mansco engineers. Even if Adaptor drawings for customer manufacture are purchased in

place of a Mansco built Adaptor, the same detail and experience are used to ensure the high quality of the TOV System.

Minimal Flow Disruption

The Adaptor's specially machined internal contour allow

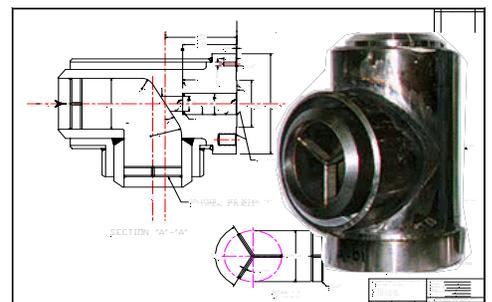
smooth flow characteristics and minimized pressure drops.

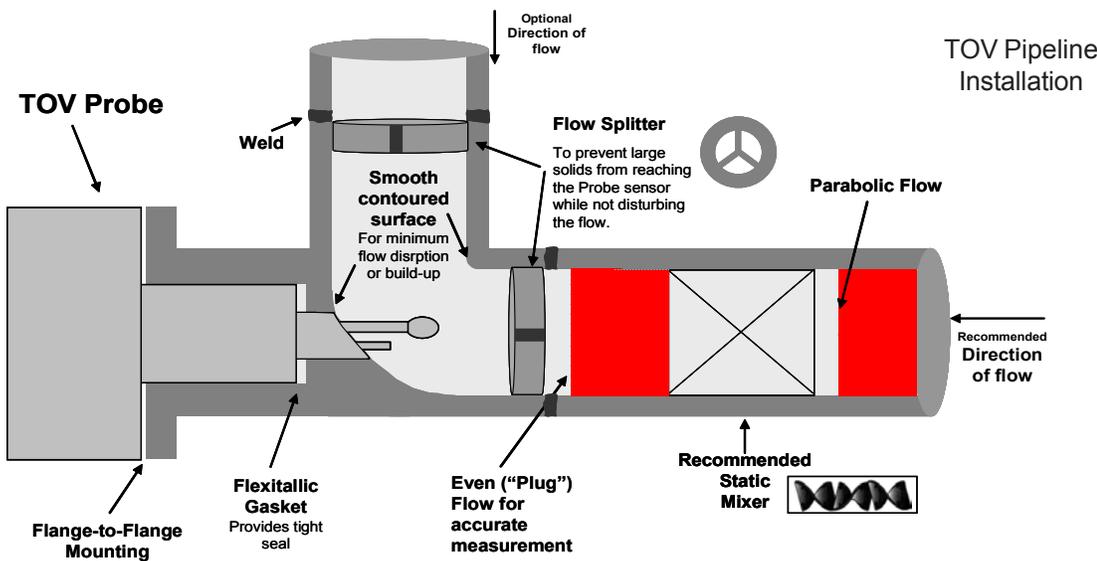
Any Core Pipe Size or Schedule

From the 1" unjacketed pipelines used in research and extrusion to the 8" jacketed pipeline adaptor (shown at left) used in CP's, the Adaptor can be designed for any core pipe size.

Flow Splitter

Special flow splitters are used for protection of the Probe.





What we need to know about your product and process

Because each TOV System is customized for each process and installation, we need to understand your product(s) and process.

For product information, product family (polyester, nylon, etc.) and target viscosity & temperature range are important considerations when designing and manufacturing a customized TOV .

For process information, data for the polymerization process method (CP, autoclave, etc.) and operating pressure range are important TOV considerations.

For TOV Adaptor design, whether we make the Adaptor or the customer manufactures locally, the pipeline specifications are needed. The core pipe size, schedule and materials of construction are important considerations. And, if the jacket is present, the jacket specifications are needed.

Finally, to ensure proper location of the TOV Probe installation, we need your help by providing a sketch or even pictures of the process with available locations for Probe installation. This is even more important in vessels where agitators are present. With your help, we can work together to select a location where the Probe can be successfully installed to produce the results you expect.

TOV Installation:

Where Should the "TOV" Be Installed?

TOV Systems are custom designed. Characteristics of the process fluid, the Probe's installation location, and other specifics are important considerations:

Probe Location:

The most common pipeline installation of a TOV Probe is in a pipe elbow. Straightline locations are also acceptable. In either, the Probe is installed into the main process pipeline and in a location where viscosity control can take place as possible.

In vessel installations, the Probe is often located in a recycle line (pipeline installation) or into the vessel itself near the exit.

Features of note:

Adaptors are designed for minimal disruption to the process flow. The contours of the Adaptor are engineered and machined to match the pipeline. The Adaptor incorporates safety features such as the Flow Splitters to protect the TOV Probe.

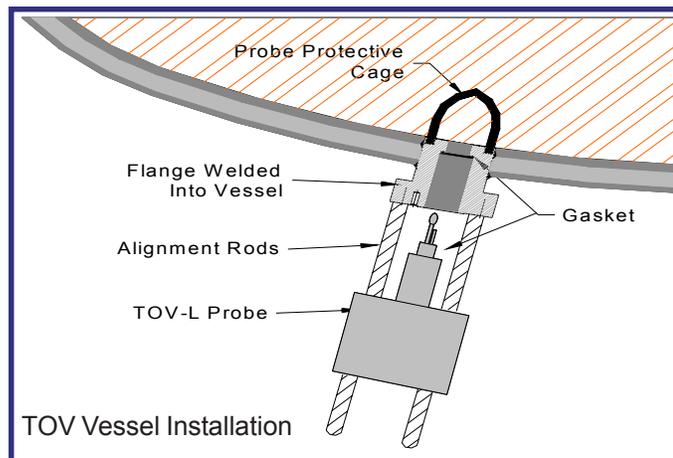
Homogenous Flow:

Fully developed, well mixed flow is an important consideration for any in-line measurement such as viscosity, temperature or pressure. In installations where the Probe will be considerably away from a mixing action (pump, static mixer, etc..), a new location or the addition of a mixer should be considered.

Integral Part of the Pipeline:

Once the Probe is installed, it becomes a part of the pipeline or vessel. It should be heated the same as the process with no outside cooling.

Adaptors are designed for all sizes, from small pilot lines to large vessels. Mansco's years of experience and know how provide the best design and ultimate success of the TOV System.



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the TOV viscometer Probe

The Probe is the mechanical portion of the TOV System that installs directly into the process environment.

The Probe's Sensor

Viscosity sensor is sized and shaped according to the process specifications for greater sensitivity.

Mass Flange

Mass flange provides reference to reduce/eliminate extraneous plant noise influences.

Safety

TOV Probe models are approved for Class 1, Division II, Groups A,B,C,D by Entela and UL

Probe Interior Torsional System

Operates utilizing the torsional principal...no motors or gears, less moving parts, and no maintenance

TOV Probe's Construction

All weld construction allows Probe designs for high pressures (over 10,000 PSI or 700 Kg/cm²) and high temperatures (up to 350°C)

RTD Element

Built-in Platinum RTD provides accurate temperature reading (.1%)

Approx. 9.625 Inch (244.5 MM) Dia.
Approx. 85 lbs (38.5 Kg)

Model TOVS Probe shown as example.
Specifications above are for Model TOVS Probes.
Operating temperatures vary by model.



Model TOVS

For Pipeline, Vessel, and Extruder Installations

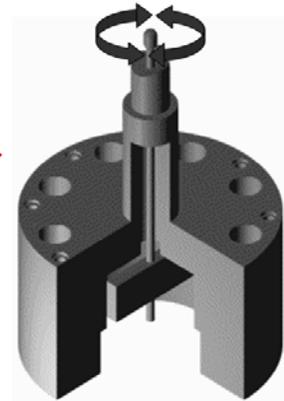
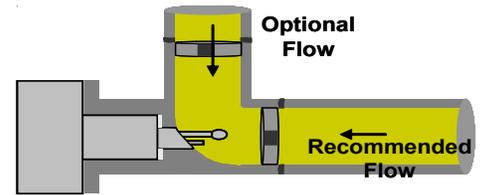


Model TOVL

For Vessel and Extruder Installations

How it works ...

- The TOV Probe's sensing device is immersed in process fluid.
- The TOV Probe is allowed to oscillate at its own resonance frequency...no motors or gears.
- Power to start and maintain the TOV Probe's oscillation is supplied by the TOV Transducer.
- As the viscosity increases, more power is needed to maintain the oscillation. For a lower viscosity, less power is needed.
- The Transducer continually monitors how much power is needed meaning the viscosity is also constantly monitored. No sampling time....only REAL TIME measurement.



specifications

TOV Probe Model TOVS-HT,MT, or LT

Viscosity Range:	0.01 to 100,000 poise (.001 to 10,000 Pa.s)
<u>Working Temp. Range</u>	
Model TOVS-HT:	0°C to 350°C (32 to 662°F)
Model TOVS-MT:	0°C to 230°C (32 to 446°F)
Model TOVS-LT:	0°C to 120°C (32 to 248°F)
Temperature Accuracy:	±0.1°C of the balance point
Design Pressure Range:	0.01 to 10,000 PSIG (700kg/cm ²)
Installation and Mounting:	Flange mounted with pipeline, vessel, or extruder adaptor/flange
Mass Diameter:	9.625 in (244.5 MM)
Lid:	Standard thin Rupture Disk available Special Thick Lid design
RTD:	Dual Element, 100 ohm Icepoint
Size: Sensor Length	3 inches (76.2 MM)
Overall Length	14 inches (355.6 MM)
Weight:	Approx. 85 lbs. (38.5 Kg)
Materials:	Generally 316 S.S., others available
Safety Certification:	US Entela Certified for UL1604 Class 1, Division II, Groups A,B,C,D Certification 8769
Viscosity Repeatability:	±0.2% of reading
Viscosity Accuracy:	±1% of range in use

Other TOVS models are available.

TOV Probe Model TOVL-HT, MT, or LT

Viscosity Range:	0.01 to 100,000 poise (.001 to 10,000 Pa.s)
<u>Working Temp. Range</u>	
Model TOVL-HT:	0°C to 350°C (32 to 662°F)
Model TOVL-MT:	0°C to 230°C (32 to 446°F)
Model TOVL-LT:	0°C to 120°C (32 to 248°F)
Temperature Accuracy:	±0.1°C of the balance point
Design Pressure Range:	0.01 to 10,000 PSIG (700kg/cm ²)
Installation and Mounting:	Flange mounted with vessel or extruder adaptor/flange
Mass Diameter:	6.500 in (165.1 MM)
Lid:	Standard Thick Lid design
RTD:	Dual Element, 100 ohm Icepoint
Size: Sensor Length	3 inches (76.2 MM)
Overall Length	14 inches (355.6 MM)
Weight:	Approx. 40 lbs. (18.1 Kg)
Materials:	Generally 316 S.S., others available
Safety Certification:	US Entela Certified for UL1604 Class 1, Division II, Groups A,B,C,D Certification 8769
Viscosity Repeatability:	±0.2% of reading
Viscosity Accuracy:	±1% of range in use

Other TOVL Model Probes are available.

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the TOV viscometer

Transducer

The TOV Transducer is the electronic component of the TOV System.

- Constant feedback with TOV Probe to provide real-time viscosity measurement.
- Monitors changes in power needed by the Probe and converts these into changes in the viscosity.
- Conditions Probe signal to output “real” viscosity changes.
- Located in or near the control room (control room environment)



Model TOVM 1.4

- Most complete Transducer available
- Includes 4 outputs (See specifications)
- Includes Multi-feature option
- Standard Pressure Compensation
from customer provided pressure signal (4-20 mA)



Model TOVL 1.1

- Standard for one product use
- Includes 2 outputs (See specifications)
- Optional Pressure Compensation
from customer provided pressure signal (4-20 mA)

New Model SC-03 Slide Chassis

- New features
- Standard for Model TOVM 1.4 and TOVL 1.1 Transducers
- Available as upgrade for earlier models

Built-in TOV System checks

- Probe Function Checks
- Probe Simulator



Up to 4 Outputs available

- 4-20 mA outputs
- Isolated signals

Front Access adjustments and Connections



Model SC-03 Slide Chassis

New Features

- Built-in Differential Meter
- Automatic Start-up Power Supply Checks
- Manual Power Supply Checks
- New LCD Display

Feature/Specification	Transducer Model		
	TOVM 1.4	TOVM 1.3	TOVL 1.1
Processor Model	TOVM 1.4	TOVM 1.3	TOVL 1.1
Power Input from Field: 110VAC 50/60Hz Service	√	√	√
Maximum Power Output: 0.5 Amps from P.S.	√	√	√
<u>Analog Output Signals (4-20 mA)</u>	<u>4</u>	<u>4</u>	<u>2</u>
Compensated Viscosity	√	√	√
Uncompensated Viscosity	√	√	
Broad Temperature Output Ranges Available:			
• 0 to 100°C (32 to 212°F)			
• 100 to 200°C (212 to 392°F)			
• 200 to 300°C (392 to 572°F)	√	√	
• 250 to 350°C (482 to 662°F)			
• 0 to 350°C (32 to 662°F)			
Compensating Temperature: +/-5°C (9°F) from Temperature Compensation setpoint	√	√	√
Pressure Compensation (Press input 4-20MA by customer): Max Press Comp: Span of Incoming Pressure Transmitter	Standard	Standard	Optional
Linear Temperature Compensation from Probe RTD signal within +/- 14°C (57.2°F) from setpoint	Standard	Standard	Standard
Transducer Accuracy: ±0.1% of reading	√	√	√
Transducer Precision: ±0.1% of reading	√	√	√
Multi-Features	Standard	Standard	Not Available
In-line Probe Performance Tests for testing Probe operating parameters:	Standard	Standard	Standard
Built-in Simulator feature	Standard	Standard	Standard
Built-in Calibration features	Standard	Standard	Standard
Push Button Compensating Temperature Balance	Standard	Standard	Standard
LED Readout of Direct Process Temperature	Standard	Standard	Standard
New Slide Chassis Model SC-03	Standard	Not Available	Standard
Differential Voltage Meter	√	Not Available	√
Start-up Power Checks	√	Not Available	√
On-line Power Supply Checks	ALL	Limited	ALL
LCD Meter Display	√	Not Available	√
Front panel access to Transducer settings	√	√	√
Microprocessor features	√	√ Limited	√
Noise reduction conditioning	√	√	√
CE Compliant Availability	Not Available	√	Not Available

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the TOV viscometer Adaptor

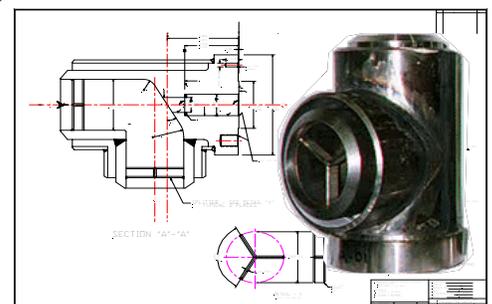
The TOV Adaptor (or Flange) is an integral part of the TOV System.

The Adaptor is designed specifically for the TOV Probe and is machined for a smooth interior transition between the Probe and the interior of the pipeline or vessel, minimizing any flow disturbances and process build-up.

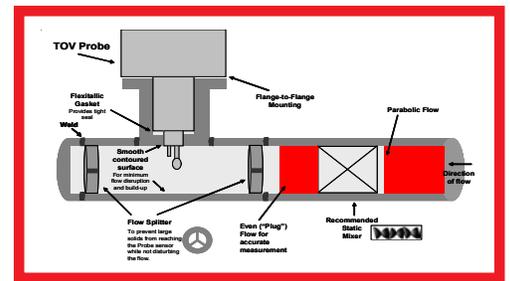
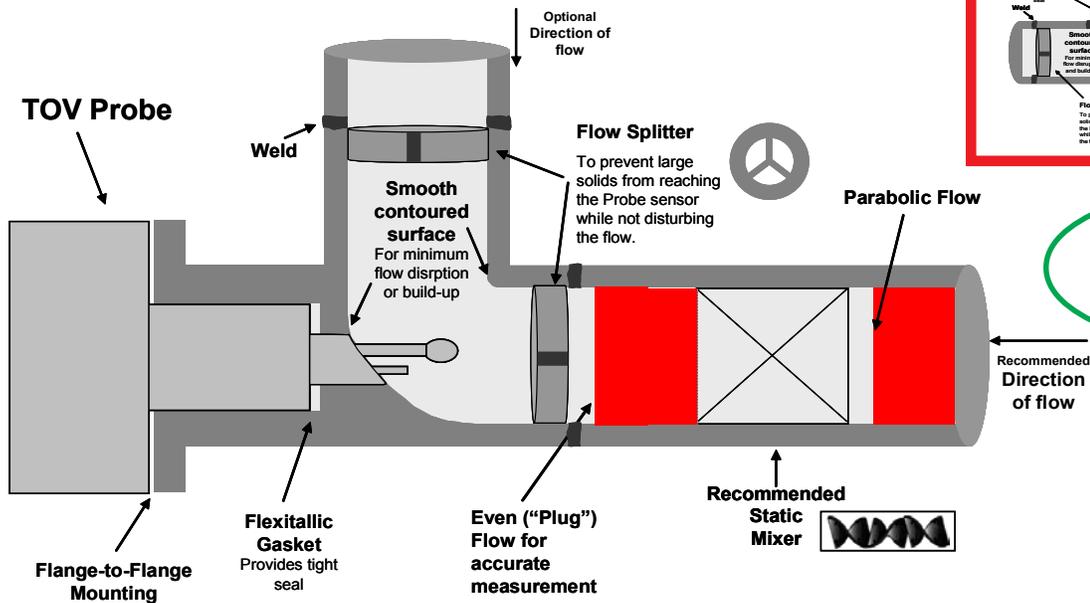
The Adaptor can be designed for jacketed or non-jacketed installations and is not limited by pipeline sizes. It can be designed for TOV installations into either elbow or straight pipeline sections. In vessel installations, a flange is designed for the Probe installation point.

Key Features

- Designed to match the dimensions of the Probe for proper fitting.
- Designed for smooth contour to minimize build-up and process disturbances.
- Probe and Adaptor materials of construction are matched to equal the thermal coefficients of expansion
- The TOV Adaptor requires stringent compliance to detailed drawings to ensure proper fit.
- Adaptor Core and Jacket are designed and manufactured to meet pipe line specifications.
- Mansco Products built Adaptors have all core welds x-rayed per, ANSI 31.3 and jacket welds ultrasonically inspected per B31.3 criteria ASME Section 5.
- Can be designed for any core pipe size or schedule.
- Flow splitters provide Probe protection from solid flow during a process shutdown or freeze-up.
- Mansco Products designed detailed Adaptor drawings are available for customer local manufacture of the Adaptor or Flange.



TOV Pipeline Installation

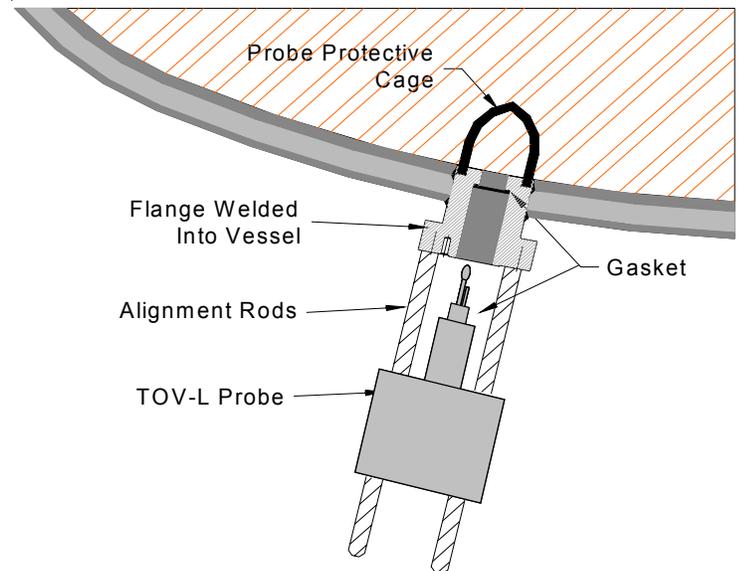


- Elbow installation shown in detail.
- Straightline installations are also available.

- Designed for smooth contour to minimize build-up
- Flow Splitters used for Probe protection
- Optional Jacket not shown
- Mansco Engineers work with the customer to analyze the best installation location in the process.
- A very durable and specifically selected Flexitallic Gasket included with each Probe for each installation

TOVL Vessel Installation

- Designed for smooth contour to minimize build-up
- Mansco Engineers work with the customer to analyze the best installation location in the vessel.
- Protective cage used when extra Probe protection is needed
- A very durable and specifically selected Flexitallic Gasket included with each Probe for each installation



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the TOV viscometer **Rack**

The Mansco Products TOV Rack provides convenient and organized storage for multiple TOV Transducers. For further convenience, the Rack also contains a power outlet and isolation transform and can be located in the DCS room or in the plant environment.

Key Features

- Houses up to four transducers.
- Provides an optimal in-line viscosity monitoring station.
- Contains a convenient power outlet and an isolation transformer.
- The power outlet is located on the front bottom panel that providing convenient access.
- The isolation transformer is in accordance with the incoming power source from the plant.
- An intregal part of the TOV Viscometer System.
- Can be located in the DCS room or in the general plant environment.



specifications

Height:	76.875 in.
Width:	21.063 in.
Depth:	25.050 in.
Weight:	Approximately 300 lbs (with mounted Sola Transformer)
Installation & Mounting:	Shipped from Mansco with Transducers, power outlet, and transformer installed and mounted.
Capacity:	Four (4) Transducer units.
Other:	Unit is shipped in wooded crate for optimal protection and safety. Complete unpacking and installation instructions provided to ensure simplistic installation.



The Mansco Products TOV System™ ... Why the “TOV”



The Most Sensitive and Reliable Device Available: Superior engineering and know-how used in each TOV System provides the most sensitive, accurate, and reliable measurement available.



Provides Real-Time Results: Unlike lab sampling and other methods, the TOV system is a true in-line device providing real time results.



Improves Quality Control: The TOV System is a quality control instrument. Better and tighter control means better quality, better price per production, and, ultimately, better business.



Stand-Alone Device: The TOV can operate with a DCS system or separately from other control devices. In the event of a control system failure the process can continue to operate with confidence of reliable viscosity and temperature measurement.



Increased Operating Efficiency: There are no time delays waiting for lab results resulting in operating inefficiencies and process delays. Real-time control means more higher grade product with less scrap or low grade product. In time, the TOV pays for itself simply through improved quality control.



Developed and manufactured by a proven company with a substantial track record.

- Over 40 years of in-line viscometry experience
- Applications installed throughout the world
- DuPont endorsement
- Superior engineering know-how

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Process Control Comparison

Lab Procedures

Capillaries

Mansco Products TOV System

Low High