WHITE PAPER

Monitoring and Minimizing Packing Leakage from Natural Gas Compressors

A review of the emissions flow measurement implications of regulations effecting the oil & gas industry.

FOX® THERMAL

OIL & GAS | INDUSTRIAL | BIOGAS | WASTEWATER

PURPOSE

Recent regulatory changes place more scrutiny on fugitive emissions of methane in natural-gas applications. This paper will discuss how thermal mass flow meters used for monitoring emissions can help maintain regulatory compliance and improve maintenance performance.

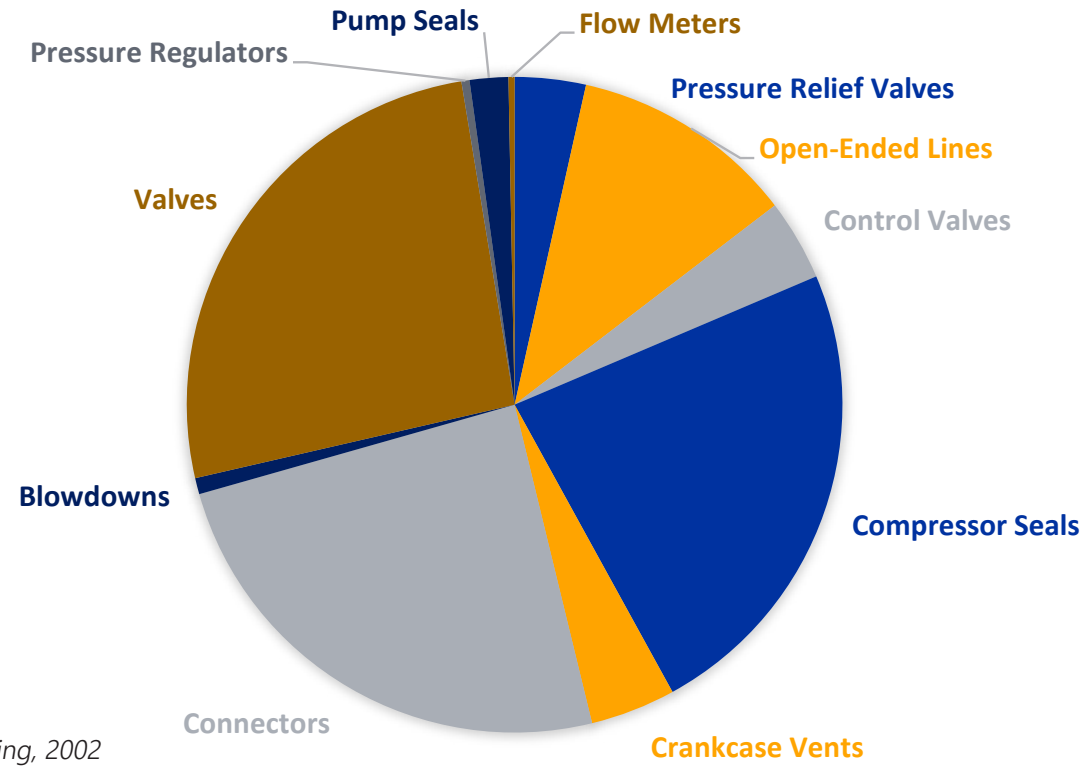
METHANE EMISSIONS REGULATIONS

Methane is a potent greenhouse gas (GHG) — its ability to trap heat in the atmosphere is 25 times greater than that of carbon dioxide, the most abundant anthropogenic GHG. Methane's potency as a GHG means that the potential climate benefits of minimizing methane emissions from natural gas facilities, including fugitive methane emissions from upstream and midstream gas-compressing stations, are highly significant. In addition, minimizing methane leaks during the production, transport and use of natural gas can have a significant impact on revenue for the natural gas industry.

Given methane's environmental impact, U.S. federal entities, such as the Environmental Protection Agency (EPA; www.epa.gov) and the Bureau of Land Management (BLM; www.blm.gov), have increased scrutiny on natural gas facilities, and have been moving toward tighter limits on methane emissions. The Inflation Reduction Act, which became law on August 16, 2022, allocated $850 million to the EPA for implementation of its Methane Emissions Reduction Program (MERP). The MERP provides financial incentives for companies in the oil & gas sector to invest in technologies for reducing the methane emissions footprint of their operations. Also, EPA recently published finalized rules for limiting fugitive emissions from natural gas compressors in 40 CFR 60 subpart OOOO (known as Quad O). The legislative and regulatory pressure to lower methane emissions raises the importance of monitoring and measuring methane emissions. The ability to effectively monitor methane emissions can position compressor fleets for anticipated tighter regulatory requirements.

PACKING LEAKAGE

Natural gas compressors are common in upstream and midstream gas operations for re-pressurizing natural gas as it is transported through pipelines. In reciprocating compressors, methane can leak from valves, flanges and fittings, but the most significant source of gas leakage is the piston-rod packing. Piston-rod packing systems consists of a series of flexible rings that fit around the compressor piston rod to establish and maintain a tight seal around the



Source:
Clearstone Engineering, 2002

rod shaft so compressed gas does not escape the cylinder, while still allowing the rod to move freely. Leakage from packing occurs primarily from around the packing case through the nose gasket, as well as from between the packing cups and from between the rings and shaft. Leaking gases are vented to the atmosphere through packing vents on the flange.

All piston cylinders leak to some extent, even in the case of normal operation of a properly installed, well-aligned piston shaft. EPA estimates that expected leakage could be 11.5 std. ft3/hr. Higher leak rates can result from wear, misalignment of the packing parts, and poor fit of the packing cylinders.

REGULATION OF PACKING LEAKS

Because of the climate impact of high methane emissions, minimizing methane leakage is a key climate objective, and regulatory agencies are increasingly moving toward incentivizing leak limitation and penalizing excessive emissions. Aside from the negative environmental impact, leaks in packing present safety issues for onsite workers and cost money for wasted fuel. Leaks also lead to gas allocation issues and inaccurate fuel consumption tracking. Packing leaks can lead to inaccurate emissions data, during a blowdown event - a scenario that could incur regulatory fines related to environmental emissions. Similarly, misreporting emissions due to leaks also leads to fines. Moreover, measuring leakage allows operators to predict needed repairs early, whereas a major repair discovered too late may mean a difference of 50K in repair costs.

Periodic testing of packing leaks — for example, annual or semi-annual testing – provides only limited information on gas emissions. Monitoring and replacing compressor rod packing systems on a regular basis can greatly reduce methane emissions to the atmosphere and save money. Packing rings can deteriorate over time, increasing leak rates, eventually getting to the point where more frequent

Did You Know?

Fugitive emissions from compressors in all sectors are responsible for approximately 86 Bcf/yr

There are over 45,000 compressors operating in the natural gas industry

Production
32,000 Compressors

Processing
5,000 Compressors

Transmission & Storage
8,500 Compressors

Distribution
0 Compressors

METHANE LOSSES

RECIPROCATING COMPRESSORS

Reciprocating compressor rod packing leaks some gas by design.

- Newly installed packing may leak 60 cubic feet per hour (cf/h)
- Worn packing has been reported to leak up to 900 cf/h

CENTRIFUGAL COMPRESSORS

Centrifugal compressor wet seals leak little gas at the seal face.

- Seal oil degassing may vent 40 to 200 cubic feet per minute (cf/m) to the atmosphere
- A natural gas STAR partner reported wet seal emissions of 75 Mcf/day (52 cf/m)

MEASURE FLOW TO DETECT LEAKAGE INCREASES

Predictive maintenance starts with accurate flow measurement to determine the increase in leaks due to the wear and tear of compressor seals, gaskets, and other fittings.

replacement is economically justified. More frequent ring replacement has the additional benefit of extending the life of the compressor rod.

Equipping compressors with permanent meters to measure emissions can be a better alternative to annual testing for emissions to comply with regulations. Programs aimed at constant monitoring can realize reduced methane emissions, gas savings and extended service life of compressor rods.

FLOW METERS FOR LEAK MEASUREMENT

Typically, gas compressors do not have flow meters installed, and in cases where a flow meter is present, it is usually a single instrument installed on the vent stack to detect methane emissions. A much clearer picture of methane emissions emerges by adding a flow measurement device to each compressor cylinder. A more comprehensive picture of packing leaks in compressor pistons can lead to a return on investment (ROI) that results from identifying losses from leaks, avoiding fines for non-compliance with regulations and from reduced maintenance costs. With emissions regulations likely to continue to tighten, it can be beneficial to have the ability to reference a flow measurement device to determine whether a compressor is meeting emissions regulatory requirements.

FLOW METER REQUIREMENTS

Establishment of packing leak measurement requires careful selection of flow measurement equipment. There are several requirements that flow-measurement devices must meet to be used for monitoring of packing leaks. The first one has to do with installation. Field retrofits are difficult, so easy-to-install flow meters will lower maintenance costs and increase safety.

A second requirement has to do with range of measurement. The flow of gas from leaking cylinder packing is typically small, so a technology is needed that can measure low flow rates that can be as low as 3 scfm or lower.

There are also often regulatory requirements for the flow measurement device. Flow meter accuracy requirements from the EPA are typically at 5%. And finally, it is important to verify that the calibration of the flow meter is not prone to drift (requires frequent recalibration) and that the measurement device does not need additional calculations (such as compensation for temperature or pressure).

CHOOSING THE RIGHT TECHNOLOGY: THERMAL MASS FLOW

Thermal mass flow meters operate by the constant temperature differential method and provide a direct mass flow rate without the need for temperature or pressure compensation.

CHOOSING A MANUFACTURER: BENEFITS OF USING FOX THERMAL MASS FLOW METERS

Fox Thermal has been a leader in thermal mass flow innovation for over 20 years; Fox Thermal was the first manufacturer to offer a thermal mass flow meter using an onboard microprocessor and a digital sensor design. Fox Thermal models FT3, FT4A, and FT4X was designed specifically with gas monitoring for the oil & gas industry in mind. Fox Thermal products are state-of-the-art flow meters offering direct mass flow measurement, exceptional low-flow sensitivity, fast response, and low maintenance requirements.

RUGGED, RELIABLE PERFORMANCE

Fox Thermal manufactures rugged instruments with explosion-proof enclosures housing the instrument electronics. Most models have standard on-board 2 line x 16 character backlit displays that include a configuration panel for field configuration of the meter's settings. Settings such as 4-20mA and pulse output scaling, pipe area, zero flow cutoff, flow filtering or damping, diagnostics, alarms, and data logs - when applicable - may be accessed via the configuration panel.

ACCURACY, SIZING, AND INSTALLATION

Fox Thermal flow meters are very accurate at low flow rates and at high velocities – up to 60,000 SFPM - with a turndown ratio up to 1000:1.

All Fox Thermal models are available in insertion and inline styles and some are available in remote styles. The insertion meter is easily installed with a weld-o-let and compression fitting with the option of a retractor assembly. The inline model is available in ¾-inch to 6-inch sizes and includes built-in flow conditioners that eliminate the need for long, straight pipe runs. Fox Thermal flow meters can be ordered to fit almost any application, even large pipes or complex mixed gases.

The DDC-Sensor™ sensor has the digital platform for greater flow meter programmability and a more robust non-cantilevered RTD design..

ADVANCED DDC-SENSOR™ DESIGN

The DDC-Sensor™ sensor, a Direct Digitally Controlled sensor, is unlike other thermal flow sensors available on the market. Instead of using traditional analog circuitry, the DDC-Sensor™ is interfaced directly to the meter's microprocessor for more speed and programmability.

The DDC-Sensor™ provides a technology platform for calculating accurate gas correlations. The correlation algorithms allow the meter to be calibrated on a single gas in the factory while providing the user the ability to select other gases in the Gas-SelectX® gas menus.

Competitors' sensors utilize fragile, cantilevered elements, whereas the sensor elements of the DDC-Sensor™ are welded to the sensor window at both ends for extra stability and strength. This enhanced design eliminates the sensor element vibration - found most often at high flow rates - which can potentially lead to metal fatigue and failure.

The sensor elements are in direct contact with the process flow. In applications where slag, ice or other foreign particles are traveling down the pipe, cantilevered elements are subject to damage requiring factory repair.

GAS-SELECTX® GAS SELECTION MENU

Models FT4A and FT4X offer three gas menus to choose from. Users can choose from a range of gases in the Pure Gas menu or create a custom gas mix through the combination of gases. Gases can be mixed in 0.1% increments to create a truly custom gas mix to fit the gas composition on-site. This action can be performed on demand and in the field for optimum convenience and to avoid sending the meter back to the factory for a re-calibration service.

Operators can change the programmed gas mix using the configuration panel on the display or by using the FT View™ software whenever the results of gas sample analysis shows a change in gas composition.

Calibration Technician performing an actual gas calibration in the flow laboratory.

ADVANCED DATA LOGGER

Fox Thermal model FT4X comes equipped with an intrinsic data logger for advanced record-keeping and data retention. The data logger records flow rate totals and other events and alarms.

The advanced features of the model FT4X data logger include:

- 40 daily totals (24-hour totals)
- Settable Contract Time defines Contract Day
- Time/date stamped alarm & event logs; 7 year history
- Power off totalizer; power failure creates event log entry

The logs in the model FT4X data logger also give information about the meter's settings and functionality:

- View the meter's gas or gas mix composition
- View the meter's configuration and other meter settings
- View Calibration Validation historical test data
- View and print logs of events and alarms

The data logger can be accessed with the free FT4X View™ Software.

CALIBRATION

All Fox meters are calibrated with NIST traceable flow standards. The Fox Thermal calibration lab employs a wide range of gases, mixtures, temperatures, pressures, and line sizes to simulate actual fluid and process conditions. This approach improves accuracy and minimizes measurement uncertainty in the field.

CALIBRATION VALIDATION

Fox Thermal models FT1, FT4A, and FT4X offer Calibration Validation with CAL-V™ to verify that the calibration of the meter retains its NIST traceable calibration. Providing a Pass/Fail result, CAL-V™ can help to reduce the added cost and inconvenience of annual factory calibrations. If these tests are initiated using the free Fox FT View™ software tool, CAL-V™ Calibration Validation Certificates can be produced at the conclusion of the test. This feature is of particular value for compliance with emissions monitoring applications where periodic calibration validation is mandated.

COMMUNICATION OPTIONS

Fox offers a free software interface, FT View™, to connect via a USB port to a laptop or computer. This software provides complete configuration and remote process monitoring functions allowing the user to adjust meter configuration, evaluate transmitter alarm conditions, collect process data, and view measurements from your PC or control station. Available communication protocols:

- Modbus RTU (RS485)
- BACnet MS/TP (RS485)
- HART
- Profibus-DP
- DeviceNet
- Ethernet Modbus TCP

All digital communication isolated for EMI immunity.

Fox Thermal model FT4X thermal gas mass flow meter and temperature transmitter with advanced data logger.

SUMMARY OF BENEFITS

There are many benefits of thermal gas mass flow meters over other flow measurement technologies and Fox Thermal leads the industry for accuracy, quality, and innovative design. Benefits of Thermal Mass Flow Technology:

- Direct mass flow measurement of air and gases in standard volumetric units (e.g., SCFM or NM3/H) or mass units (e.g., LBS/M or KG/H)
- No additional pressure or temperature compensation required
- Repeatability and exceptionally broad measurement range: up to 1000:1 (100:1 typical)
- Standard linear 4-20mA output proportional to mass flow rate
- Low pressure drop
- No moving parts
- Cost-effective
- Available in insertion, inline & remote styles
- Measures flow rate and temperature

Calibration Validation		
Typical Requirements of Competitive Models	Other Thermal Flow Meters	Fox Thermal flow meter with CAL-V™
Stop the flow*	Required	Not Required
Remove meter from pipe		
Disconnect wires from flow meter		
Look up data on flow meter's calibration certificate		
Measure electrical characteristics with volt ohm meter		
Perform calculations to evaluate flow meter performance		
Set process pressure to manufacturer's calibration pressure		
Connect auxiliarty test equipment and/or test gases to flow meter		

**When using a retractor assembly for calibration validation test*

CONCLUSION

The importance of emissions reductions at industrial sites, including methane leaks at natural-gas production, transport and storage facilities, is growing. Methane leaks from the packing systems at compression stations using reciprocating compressors has been identified as an area of focus for a higher degree of regulatory scrutiny in the present and future. The installation and use of mass flowmeters on natural gas compression stations can improve gas compressor operations by allowing a predictive maintenance approach that minimizes methane leakage, while also saving costs and gas loss.

Disclaimer: Fox Thermal has made every effort to provide an accurate interpretation of the regulations mentioned in this paper; however Fox cannot be held responsible for errors, local differences, or recent changes. Contact the U.S. EPA or other regulatory body for the latest information on these laws and regulations.

FOX THERMAL

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FT4X CAL-V™ CERTIFICATE

CALIBRATION VALIDATION

CAL-V™ Performed on:	September 17 2020	9:39:17 AM
Firmware version:	FT4X V5.9	
Fox Meter Serial Number:	F00010	
CAL-V™ Results:	CAL-V PASS	
CAL-V™:	0.76	
Test Temperature	72.8 F	
Tag #/Meter Location:	Tag #2	
Test performed by:	Patrick	
Additional Comments:	App ID 6506. Test meter #7	

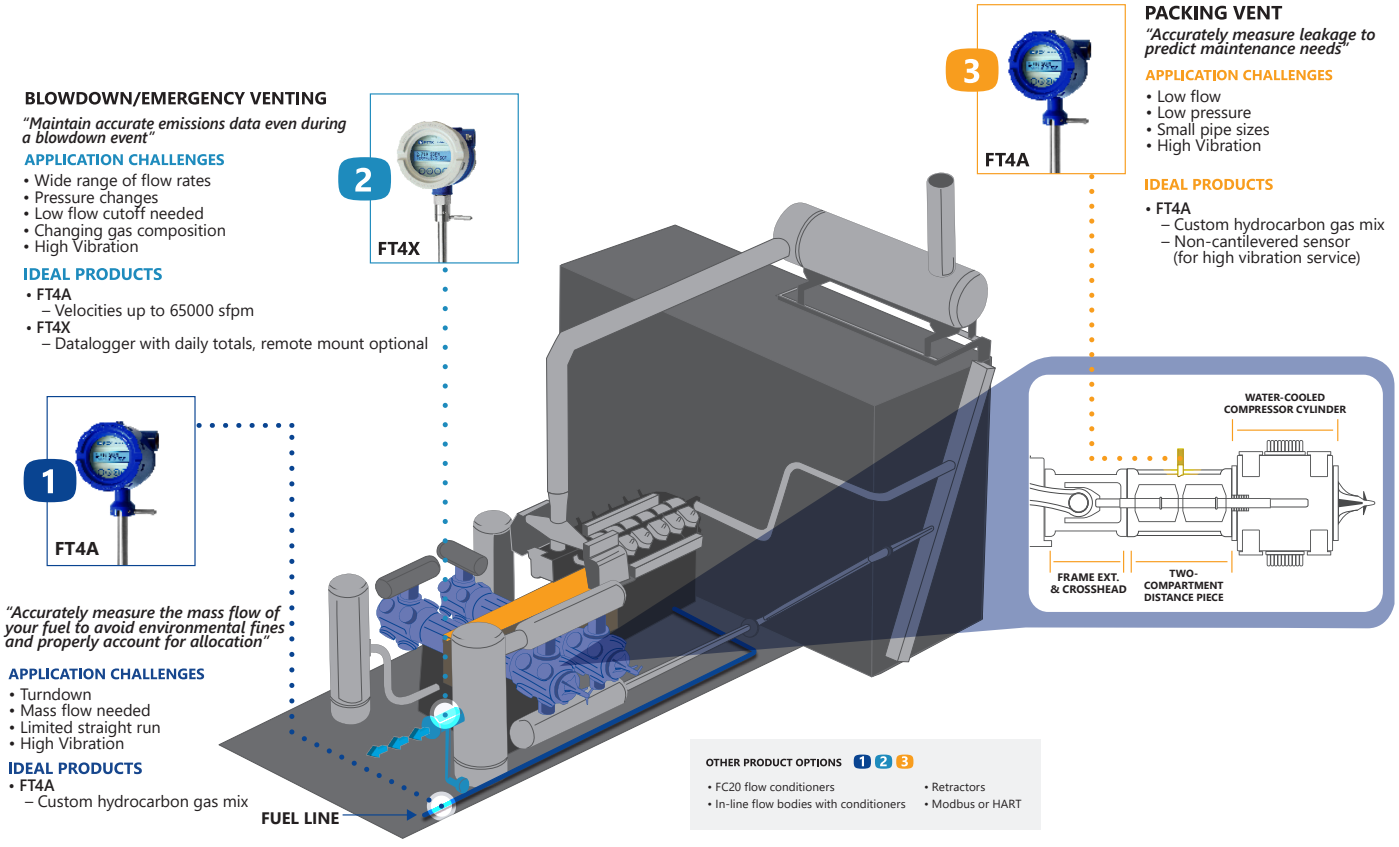
CAL-V™ is a calibration routine that validates the flow meter's calibration accuracy by testing the following:
* Repeatability of sensor
* Repeatability of sensor electronics
* Zero Stability of the meter
* Confirms Calibration Algorithms

At the conclusion of the test, the meter will display a pass/fail message and the CAL-V™ data.
A "pass" result confirms the meter is measuring accurately.
CAL-V™ limits: ± 0 - 0.8 Pass, ± 0.8-1.0 Warning, > ± 1.0 Fail

Configuration:

Pipe Diameter:	1.61 In	**Gas SelectX:**	Single Gas
Customer STP:	70 Deg F @ 750 mmHG	**Methane:**	100%
4-20 mA Range:	0 - 4000 SCFH		
Zero Flow Cutoff:	0 SCFH		
Previous CAL-V:	0.51		
Previous CAL-V:	Pass		
Gross Heating Value[BTU/FT3]:	1014.9		
Density[Kg/M3]:	0.68		

Example of a CAL-V™ calibration validation certificate that can be generated from the free Fox Thermal FT View™ software.



TECHNOLOGY COMPARISON

Compare the Fox thermal mass flow meter equipped with the state-of-the-art DDC-Sensor™ technology, new expanded Gas-SelectX® gas selection menu, CAL-V™ Calibration Validation, and a standard data logger with date and time stamp as the alternative to other technologies.

Review the table below to discover other benefits Fox Thermal gas mass flow meters offer over other flow measurement technologies.

	OTHER TECHNOLOGIES	THERMAL MASS FLOW BY FOX THERMAL
Flow Measurement of gases	Other technologies require multiple instruments to determine the volumetric flow rate at reference conditions.	Direct mass flow measurement of air and gases in standard volumetric units (ie MSCFD, SCFM, or NM3/H) or mass units (ie LBS/M or KG/H). Each meter has the option for the user to select a variety of flow units (see Operating Specs on product datasheets).
Pressure or temperature compensation	Differential pressure flow meters require pressure and temperature compensation.	No additional pressure or temperature compensation is required. This is a time and cost saving measure. No additional calculations or equipment are needed to calculate flow because the meter measures the mass flow rate.
Turndown	Vortex meters are less suitable for low flow rates. DP meters do not have good turndown.	Repeatability and exceptionally broad measurement range: up to 1000:1 (100:1 typical). Whether the flow is at a very high or low velocity, Fox Thermal mass flow meters can measure it.
Pressure Drop	If a DP meter is used to measure low velocity flow, a very small orifice is required, resulting in high pressure drop.	Low pressure drop. The pressure drop of a thermal mass flow meter is negligible.
Moving Parts	A meter with moving parts, like a Turbine meter, will need regular maintenance.	No moving parts which means no problems with wear, binding, etc.
Price	Ultrasonic meters are especially expensive.	Cost effective. Thermal mass flow meters offer a low cost alternative.
Installation	Some meter technologies are complicated and difficult to install, require additional equipment, or long straight pipe run requirements.	Easy to install with insertion and inline configurations. Insertion meters are easy to install, inline meters come equipped with flow conditioners to help reduce the straight run requirements. Communication options available and intrinsic to meter electronics.
Product Selection	Most manufacturers build meters for a single purpose, gas calibration, or application. The customer must sift through pages of specs to find the right meter for their application. This is time consuming and ineffective.	Microprocessor based, field rangeable electronics. Fox Thermal pioneered the use of microprocessors in thermal mass flow meters and continues to create innovative solutions to measurement needs across many industries and applications. Gas-SelectX®, available in models FT1, FT4A, and FT4X, allows the user to change the gas selection in the field. Displays with configuration panels and free software allow users to interact and program the meter in the field. Using the online Product Configurator, the customer can enter process data into the system for an instant Fox Product recommendation: no need to search a list of meters for the one that's right for you!

FOX® THERMAL

Make downtime a thing of the past.

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