Primary Differences Between

# MOVING DIE RHEOMETERS AND OSCILLATING DISC RHEOMETERS

A Publication of

MonTech
Rubber Testing Solutions

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# INTRODUCTION
## History of Use of ODR's and MDR's

The **Oscillating Disc Rheometer (ODR)**, introduced by Monsanto, was once the primary method for attaining cure profiles of any elastomeric compound. Since the instrument's inception, a variety of rheometers have been introduced to the market to aid compounders, chemists, process engineers, and technical experts in understanding cure dynamics and characteristics of their compounds.

The introduction of the **Moving Die Rheometer (MDR)** marked the initial shift away from oscillating disc technology. The MDR's design was both an improvement on ideas brought forth by the ODR, as well as a new innovation in its own right. The MDR introduced rotorless rheological polymer testing with its closed biconical test chamber- which provided new testing capabilities and a higher degree of accuracy and precision than was previously possible, while simplifying testing procedures. However, even with its superior capabilities, the MDR didn't immediately replace the ODR in laboratories and manufacturing facilities.

After years of being the standard in rubber and polymer testing the ODR had become well established among compounders and others in the industry. Many had grown accustomed to working with it, and had built QC and R&D systems and workflows around its data - and had come to accept its limitations. The shift to MDR's also posed a significant change that would require new investment and training which deterred some compounders and molders from adopting it in their testing operations right away.

In an effort to hold on to those who were curious about the expanded capabilities of the MDR but were reluctant to make the switch, improvements were made to the ODR - such as better torque measurements and temperature control. These improvements put the ODR somewhere around the halfway point of the capabilities of the MDR. Other improved versions of the ODR were later released, but none could match the MDR. While this did garner some success and encourage many to stick with the ODR at the time, most ODRs in use today are the original Monsanto R100 units - not the improved versions. (*All of which have long since been discontinued.*)

While it's still somewhat common to find ODR's being used by compounders and rubber manufacturers in the US, most have either switched to the MDR by now - or are giving the switch serious consideration. For many, though, basic questions about the major differences between the ODR and the MDR still remain largely unclear. The purpose of this document is to be a resource for those exploring the shift to the MDR. In this document you will find all the primary differences between the ODR and MDR, to give you a comprehensive picture of how they stack up to one another.

Let's begin.

Difference #1:

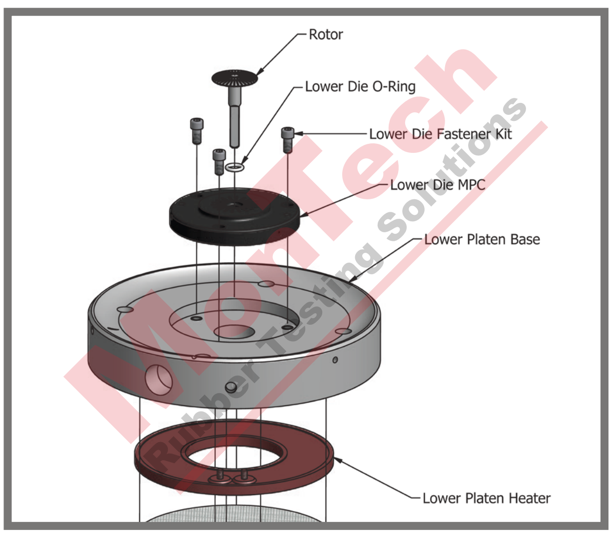
# TEMPERATURE STABILIZATION

# TEMPERATURE STABILIZATION

## Temperature Control Improvements in the Closed Biconical Test Chamber

The primary points of measurement for any cure test are time, temperature, torque and frequency. If temperature is not uniform between each test, this will directly affect the tests' accuracy and repeatability.

The first major difference between the instruments is the heating element. The R100 (below) must heat the platen base, die assembly, and rotor for testing. With its large platen and other components all being heated together, it makes temperature fluctuations less controllable. This, in turn, can affect recovery speeds after the sample is placed into the test chamber, resulting in discrepancies in TS1, TS2, TC 90, and cure time readings. Newer versions of the ODR have attempted to solve this issue with improved heaters and a smaller assembly stack more closely resembling that of the MDR.



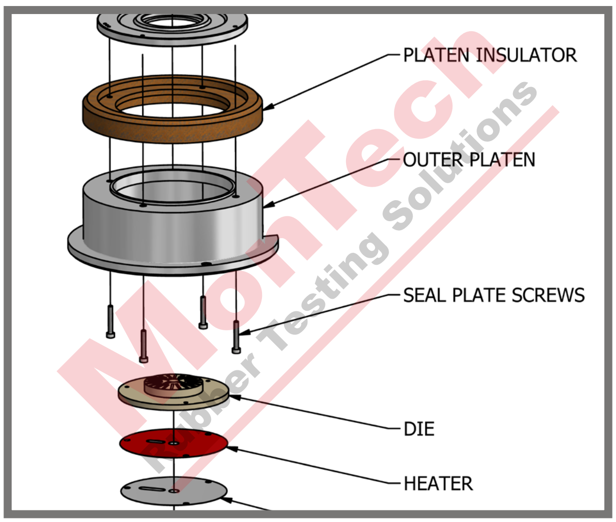

***R 100 Lower Platen Assembly:*** *Lower platen heater must heat platen base, die assembly, and rotor for testing.*

The ODR rotor also plays a significant role in its temperature uniformity. Operators often must remove the rotor to remove the sample and clean any remnants of the sample from the rotor's surface between tests, resulting in heat loss in the rotor.

Since the temperature of the ODR's rotor must be stable to perform tests, any loss of heat between tests must be recovered when it is returned to the die before the next test can be performed. Given that MDRs do not have rotors, temperature recovery is much quicker.

The differences in how the test chambers of the ODR and MDR are designed also play a role in how effectively the instruments can control temperature. Unlike the MDR, ODR's - such as the R100 - do not have an enclosed test chamber. As a result, fluctuations of temperature in the surrounding environment can have an effect on the temperature recovery rate.

The closed biconical test chamber in the MDR loses less heat and provides superior temperature stability, as well as faster temperature recovery, regardless of the surrounding environmental conditions.




***MDR Die Sub-Assembly:*** *Closed biconical test chamber and placement of heating element allow temperature to be more effectively controlled.*

*Next, we will examine another important unit of measurement, and a major difference between ODRs and MDRs: the torque signal.*

Difference #2:

# TORQUE SIGNAL MEASUREMENT

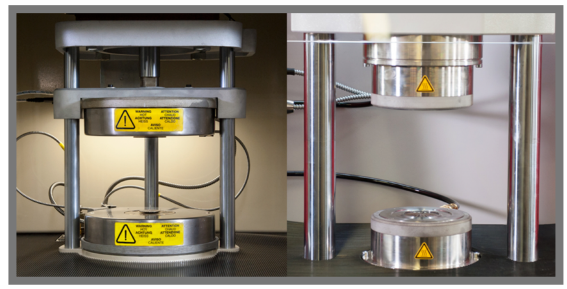
# TORQUE SIGNAL MEASUREMENT
## Design Improvements to Prevent Interference

The most important point of measurement relating to the cure curve is torque. In rheometers, torque is measured using a torque transducer which generates a signal corresponding to its measurements. When plotted on a graph over the duration of a cure test, the signal takes the familiar shape of the cure curve. Both the ODR and MDR have a transducer incorporated in their designs to measure torque. However, between the two instruments there is a difference in where the transducer is placed relative to other components, which has a notable effect on the accuracy of the instruments' data.

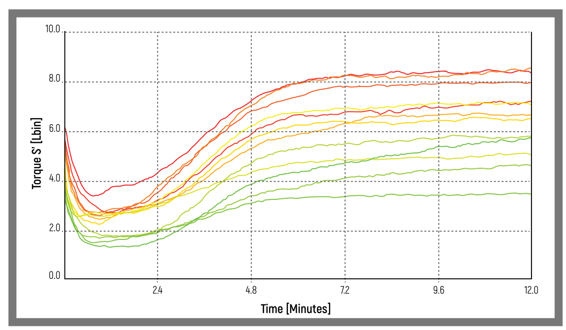
The ODR's transducers are located under the die, either inside or underneath the motor assembly.

Movement of mechanical parts surrounding the ODR's torque transducer can create interference - or noise - in its signal, directly affecting the accuracy of the results. (Fig. 1)

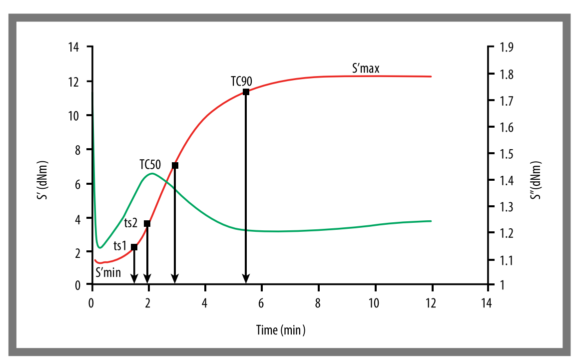
The MDR's torque transducer is located above its dies, isolated from mechanical systems. This design improvement prevents any interference from affecting the torque the signal as the lower die oscillates. (Fig. 2)



*Upper and lower dies of MonTech Upgraded ODR 2000 (Left) and upper and lower dies of MDR 3000 (Right)*




*(Fig. 1) Noisy torque signal from an R100 caused by interference from mechanical systems*



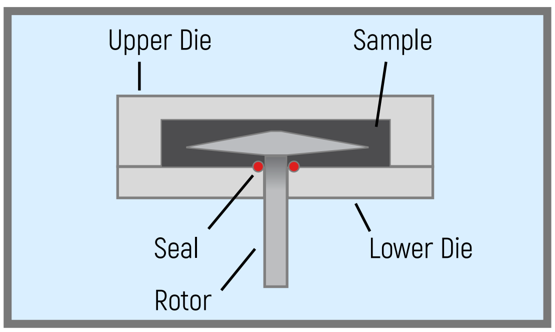

*(Fig. 2) Cure test performed on MonTech MDR 3000*

Difference #3:

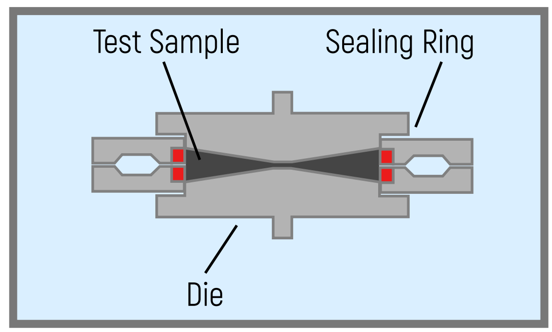
# ROTOR
VS
# BICONICAL DIE

# ROTOR vs BICONICAL DIE
## Other Notable Differences

Outside of temperature loss/recovery, the closed biconical die system on the MDR provides a few other distinct advantages to the rotor and die system used in the ODR. One such advantage is the MDR's ability to maintain a constant shear rate - which is essential for accuracy and repeatability.



*Cross section of ODR's test chamber*



*Cross section of MDR's test chamber*

Maintaining constant shear within the die cavity is achieved with its biconical shape, which evenly distributes shear force to the entire sample as the die oscillates. Because of this key design feature, the MDR is the only type of rheometer capable of maintaining a constant shear rate.

When testing at low temperatures, or with highly viscous compounds, ODR's are also prone to sample slippage within the die cavity. This problem is eliminated* with sealed biconical die system.

Additionally, MDRs typically require less sample material to run a test, as seen below:

*MDR sample requirements: 6g*
*ODR sample requirements: Up to 10 grams*

Using the MDR guarantees a cost reduction by using less sample material - which can be substantial especially when testing expensive compounds.

Lastly, cleaning the MDR biconical die is also much simpler than cleaning the ODR rotor. In the MDR, the sample is placed within a testing film and never comes in direct contact with the dies. This is not the case with the ODR's rotor and die system. Vulcanized rubber can be very difficult to remove, especially in the crevices of the rotor. It is, none the less, necessary to be thorough when cleaning the rotor to prevent cross-contamination of samples from test to test.

** Some specific applications or compounds may require controlling the die cavity pressure*

Difference #4:

# SAFETY

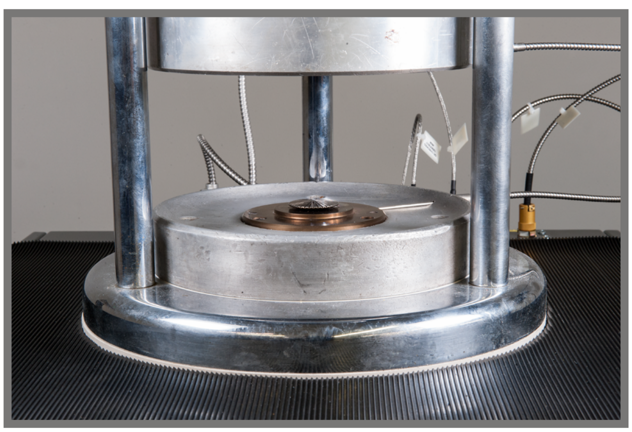
# SAFETY

## Preventative Measures to Increase Operator Safety

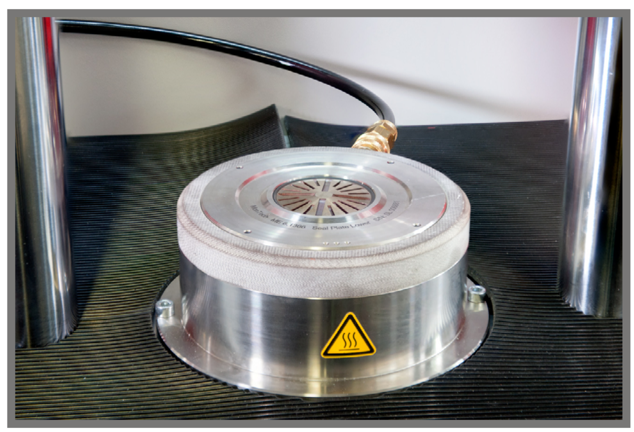
Safety is a major concern when dealing with instruments that can present a real risk of injury. As might be expected, old R100 models have significantly less safety features comparative to newer ODRs and MDRs.

Due to the large size of the ODR platen, placing a sample for testing presents a risk of burns to the forearm. To place the sample and rotor into the R100, technicians must reach over three to four inches of heated platen. Platens are typically heated above 250°F and can immediately cause burns if contact is made with unprotected skin. The smaller size of the MDR's platen, along with the rotorless design present a much smaller risk of accidental burns.

Other safety options included in MonTech MDR's include: safety shields, completely enclosed frames, surge protection, software diagnosis alarms, intelligent motors, and more.



*Lower die of R100. Rotor must be removed after each test to remove sample and clean while both rotor and platen are very hot.*



*Lower die of MDR 3000. Smaller platen size and rotorless design presents less risk during sample removal.*

*Next, we will take a look at the differences in features available for ODR's and MDR's*

Difference #5:

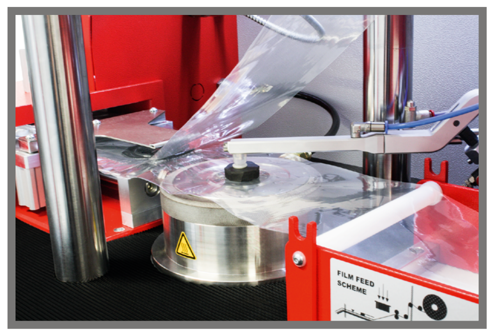
# FEATURES

# FEATURES

## Automation and Additional Testing Capabilities

First, by design, ODR's require user interaction for every test performed. The ODR's rotor often must be removed after testing to remove the sample and then be cleaned before it can be used for the next test when the sample must manually be placed onto the rotor. This makes automated functionality impossible for the ODR. MDR's, on the other hand, can accommodate multiple styles of automation - as there can be little to no required user interaction depending on the build of the unit.

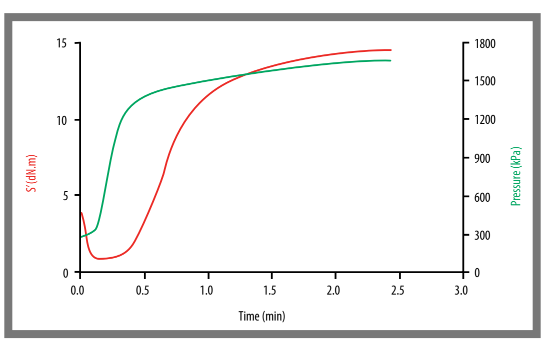
*Automated MDR 3000. Robotic arm lifting test sample from tray to place onto die.*




*Automated MDR 3000. Robotic arm placing test sample onto die.*

Second, the ODR's torque arms are fixed at 0.5° or 3° of arc and because of this, they are unable to measure large amplitudes. Additionally, its data transfer rate is too slow to obtain measurements produced in LAOS testing (i.e. FT Rheology attained using a Rubber Process Analzyer).

Lastly, ODR's are not equipped to measure sponging reactions. Torque arms, or transducers in the ODR only measure torque signals. Measurement of normal force (i.e. the expansion rate of sponging agents) is not possible due to the rotor, die and mechanical setup of ODR's. The MDR's closed test chamber configuration can accommodate these types of measurements.




*Cure test with simultaneous sponging reaction performed on MDR 3000*

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