

A Useful Tool for the Determination of Consistency in Semi-Solid Substances

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Consistency (i.e., thickness or firmness) is the most important characteristic among the many physical properties of a semi-solid substance. The most commonly used test to measure consistency is the cone penetration test as per ASTM D217. Numerous international standards outline procedures for performing these tests on various substances such as petroleum products, food, cosmetics, and other semi-solid materials. The instrument used for determining the consistency and penetration properties of semi-solid substances is called a penetrometer.

Instrument Operation

The operating principle of the penetrometer is straightforward. The penetration measurement is the depths in tenths of millimeters to which a standard penetrant such as a cone or a needle sinks into a semi-solid substance under defined conditions of sample size, penetrant weight, geometry, and time. The softer the sample is then the deeper the penetrant will sink into the sample and thus the higher the penetration number will be. The microprocessor-based digital penetrometer from Koehler Instrument Company shown in *Figure 1* is automated instrument and makes this an even easier test to perform. Operators can choose the time interval they want for the penetrant drop, where the standard time is 5 seconds. The penetration needle or cone is placed at the surface of the sample using either preset values or operator-defined values, and the test can be started with the press of a button. The sample can also be kept at a fixed temperature utilizing the penetrometer bath, which is also available from Koehler. The bath helps in performing tests at a wide range of temperatures. A cooling or temperature stabilization period can also be programmed in the penetrometer by the operator to delay the release of the penetrant into the sample. Once the penetrant is released, it falls into the sample under the influence of gravity.

The penetrometer finds application in a variety of different industries for measuring the consistency of a variety of different products. Each international test standard has been developed with specified penetrants, where each penetrant has a different shape and weight based on the product being tested. *Table 1* lists the different penetrants, test standards, and products tested using the penetrometer. For instance, a hard asphalt or a cosmetic paste may

need a sharp needle with an additional weight to adequately penetrate the sample and give meaningful results. It is important to remember that the penetration measurement is the distance traveled by the penetrant inside the sample under the influence of gravity for a fixed period of time. If the results are too high or too low, then the time of penetration and the weight of the penetrant (1-250 g) can be modified. Typical results are from 50 to 600 penetration units, corresponding to 5 to 60 mm.

The penetrometer is also useful for quality control. For example, for a quality-controlled batch of biscuit dough, the test is performed with a penetrant chosen from Table 1 and the results are noted. Each subsequent batch can then be checked for consistency using the instrument. The test can be run in the laboratory or even on the plant floor, and provides a quick quality control check. The unit can be programmed with higher and lower limits, and then alert the user via audible alarms if the results fall outside the acceptable limits.

Purpose of measuring consistency

Because penetrometers have been in use in the grease industry for a number of years, grease is a good example to consider in explaining the reason for measuring consistency. Greases are available in consistencies ranging from almost fluid to semi-fluid to form block-type greases. Product consistency needs to be appropriate for the application. A grease that is too hard may not feed adequately into areas that need to be lubricated. On the other hand, if a grease is too soft, it may leak away from the area to be lubricated. The pumpability of a grease is also a function of its consistency, with softer greases being pumped more easily.

Thus, it is important to determine the consistency of a product in order for it to be used properly in any given application. As shown above, the example for grease could transcend to other industries as well, such as with the food industry and the processing of the biscuit dough. The use of penetration to measure this property is practical and easy, and can be performed in the field (under battery power) or the laboratory.

Conclusion

This paper describes the versatility of the penetrometer and tests the wide array of products for which it can be used to measure consistency. The automated instrument is important for measuring the thickness or consistency of such products as lubricating greases, dough, chocolate, cosmetic pastes, fruit pulp, silicone, paints, and many other products.

Figure 1 – Microprocessor-Based Digital Penetrometer from Koehler



Table 1 – Penetrants, Test Standards, and Products Tested Using the Penetrometer

Petroleum Industry:

Material	International Test Method	Description of Penetrator
<ul style="list-style-type: none"> • Greases 	ASTM D217, ASTM D1403 IP 50, IP 310 ISO 2137 DIN 51804 FTM 791-311, FTM 791-313	Solid Cone Standard Hollow Cone Quarter-Scale Cone Half-Scale Cone
<ul style="list-style-type: none"> • Semi-Liquid Lubricating Greases 	IP 167 ISO 2137	Perforated Disk
<ul style="list-style-type: none"> • Vaselines • Paraffins (over 150 penetration units) 	ASTM D217, ASTM D937 IP 50, IP 179 ISO 2137 DIN 51580	Standard Hollow Cone
<ul style="list-style-type: none"> • Petrolatum 	ASTM D937 IP 179 ISO 2137 DIN 51580	Solid Cone
<ul style="list-style-type: none"> • Petroleum Waxes • Paraffins 	ASTM D1321 IP 376 DIN 51579	Tapered Needle
<ul style="list-style-type: none"> • Bitumens • Asphalts 	ASTM D5 IP 49 DIN 52010	Standard Needle, 2.5 g

Food Industry:

Material	International Test Method	Description of Penetrator
<ul style="list-style-type: none">• Chocolate• Confectioneries• Yeast	ASTM D5 IP 49 DIN 52010	Standard Needle, 2.5 g
<ul style="list-style-type: none">• Bread	American Institute of Baking, Chicago	Test Ram
<ul style="list-style-type: none">• Putty and Fruit• Viscous Pastes• Cheese		Pin Needle
<ul style="list-style-type: none">• Chocolate• Yeast• Sausages• Meat Products	ASTM D1321 DIN 51579	Tapered Needle
<ul style="list-style-type: none">• Edible Fats• Pudding• Jelly• Yogurt• Mayonnaise	ASTM D217 IP 50, IP 179 ISO 2137 DIN 51580	Standard Hollow Cone
<ul style="list-style-type: none">• Fats (small quantities)	ASTM D1403 IP 310 DIN 51804 Part 2	Quarter-Scale Cone
<ul style="list-style-type: none">• Jam• Marmalade• Ketchup• Mustard• Fruit Preparations	ASTM D217 IP 167 ISO 2137	Perforated Disk Solid Cone
<ul style="list-style-type: none">• Mayonnaise• Mustard• Semi-Liquid Fats and Greases		Conical Perforated Disk

Food Industry cont'd:

<ul style="list-style-type: none"> • Semi-Liquid Fats • Honey 		Hollow Penetration Rod
<ul style="list-style-type: none"> • Yogurt • Cream 		Hollow Plexiglas Cone
<ul style="list-style-type: none"> • Puddings • Gelatin • Jam • Mustard 		Perforated Disk with Cylindrical Holes
<ul style="list-style-type: none"> • Edible Fats • Butter • Margarine • Confectioneries • Candy 	AOCS Cc 16-60 AACC 58-14	Aluminum Cone

Cosmetics Industry:

Material	International Test Method	Description of Penetrator
<ul style="list-style-type: none"> • Lipstick • Compact Powder 	DIN 52010	Standard Needle, 2.5 g
<ul style="list-style-type: none"> • Face and Skin Cream 	ASTM D217, ASTM D937 IP 50, IP 179 ISO 2137 DIN 51580	Standard Hollow Cone
<ul style="list-style-type: none"> • Solid or Semi-Liquid Cosmetic Cream 		Aluminum Micro-Cone

Miscellaneous Items:

Material	International Test Method	Description of Penetrator
<ul style="list-style-type: none"> • Soap 		Test Cutter
<ul style="list-style-type: none"> • Silicone • Rubber • Cement 		Penetration Rod
<ul style="list-style-type: none"> • Pastes • Emulsions • Paints • Putty Fillers 	ASTM D217 IP 50, IP 179 ISO 2137 DIN 51580	Standard Hollow Cone
<ul style="list-style-type: none"> • Paints • Varnishes • Printing Inks 	ASTM D217 IP 167 ISO 2137	Solid Cone Perforated Disk
<ul style="list-style-type: none"> • Rubber Solutions 		Conical Perforated Disk
<ul style="list-style-type: none"> • Soft Pastes • Toothpaste • Printing Inks 		Test Cylinder with Tip
<ul style="list-style-type: none"> • Paste Emulsions • Paints • Varnishes • Potting Compounds • Ceramic Pastes 		Hollow Penetration Rod Plexiglas Penetration Rod
<ul style="list-style-type: none"> • Paints • Varnishes 		Hollow Plexiglas Cone
<ul style="list-style-type: none"> • Viscous Substances • Paints • Varnishes 		Perforated Disk with Cylindrical Holes
<ul style="list-style-type: none"> • Solid Emulsions 	AOCS Cc 16-60 AACC 58-14	Aluminum Cone, 45 g
<ul style="list-style-type: none"> • Pastes 	USDA	Aluminum Cone, 35 g
<ul style="list-style-type: none"> • Heterogeneous Propellants 	ASTM D2884	Magnesium Cone, 15 g