POWDER TESTING CENTER

MODEL PTC-04DM

PRESSING MODES: **SET DENSITY or PRESSURE**

CAPACITY:
3,210 MPa (225 TSI)

DIE TEMPERATURE:
UP TO 300⁰C (570⁰F)

AVERAGE TEST TIME: 10 MINUTES

- **COMPACTIBILITY**
- **DIE WALL FRICTION**
- **COHESIVENESS**
- **Green Strengths**
- **Green Expansions**
- **Bulk Density**
- **Tap Density**
- **Angle of Repose**
- **Compaction Curves**
- **Ejection Characteristics**
- **Crushing Characteristics**

TEST UNIT BASIC SETUP

The PTC consists of three modules: the **testing module** (main front part), the **power module** (back and bottom) and the **bulk powder tester** module (attached to the right column). It interfaces with a driving computer through a USB port. A separate **HEPA vacuum cleaner** unit is usually placed below the bulk powder tester.

The PTC must be connected to a dedicated USB port in a driving computer. The computer, preferably a laptop, is placed on the left side of the PTC. A separate USB hub with 3 or 4 USB ports is attached to the back of the PTC. The hub is used to connect all other devices.

An **electronic micrometer**, mounted on the front of the unit in a micrometer's base, is used for measuring green compact expansions after compaction. It connects to and is powered by the USB hub.

An **electronic scale (mass balance)** is placed on the right of the PTC. It connects to the USB hub. It's power supply can be plugged in an outlet on the back of the PTC.

The **bulk powder tester ("BPT")** can be attached to a column of the testing module (as shown) or mounted on a dedicated stand. It connects to the USB hub. A separate power supply, for the tapping motor, can be plugged in an outlet on the back of the PTC.

The MAXIMUM PRESSING FORCE is 10 metric tons.

EQUIPMENT OPTIONS

POWDER TESTING CENTER MODEL PTC-04DM
- basic unit: test and power modules
- attached bulk powder tester module
- external vacuum cleaner with HEPA filter
- internal microcomputer controller, USB interface
- driving & general compacting/sintering program
- direct micrometer and scale reading software
- user manual in pdf version
- one year limited warranty

Standard (Cold) Test Die Set
- tungsten carbide insert in stainless steel body
- tungsten carbide or steel punches
- may be heated up to 70^{0}C

Cold/Hot Universal Die Set
- interchangeable die cylinders
- ceramic heat insulators
- 300^{0}C maximum test temperature

Die Band Heater & Temperature Sensor
- for use with standard cold dies for up to 70^{0}C
- for use with hot dies for up to 300^{0}C

Electronic Micrometer
- range 0-25 mm/0-1", with SPC and USB adapter

Scale (Mass Balance)
- 0.001 gram readability, with USB adapter

Computer
- laptop with MS Windows 10 Pro
- access to printer

TECHNICAL SPECIFICATIONS

POWER:	
AC Voltage:	100-240 VAC, 50/60 Hz
Max. Power:	650 Watts (approximately)
PTC TEST UNIT:	compaction, green expansions and axial/radial crushing tests
Control:	internal computer board with USB interface, laptop PC
Testing Module:	pressing & control unit, mounted on the Power Module
Power Module:	power unit with stepper motor
Maximum Load:	98.1 kN (22,000 lbf)
Die Temperature:	up to 300^{0}C (570^{0}F)
Pressing Speed:	0.5-1.5 mm/s user selectable
Size W/H/D:	180/584/279 mm (7.1/23/11 inches)
Weight:	23 kg (50 lbs) approximately
Test Compact:	cylindrical pellet 2-16 mm (0.08-0.63 in) long
BPT:	**Bulk Powder Tester**
Control:	internal computer powered by USB
Mounting:	attached to PTC or separate base
Angle of Repose:	inclinometer gravity sensor
Tapping:	selectable, independently powered
Lab Air:	air humidity and temperature sensor
SOFTWARE:	MS Windows compatible for testing and data processing, Manual (pdf)

COLD PRESSING TEST DIE SET

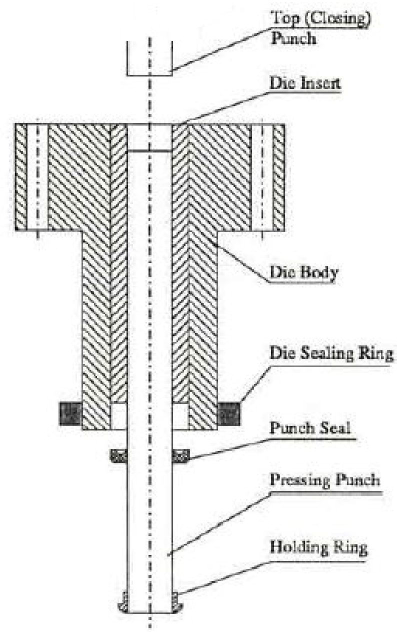
Test dies should be made compatible (die material and surface finish) with working production dies to ensure identical pressing conditions. For compaction friction optimization, one can use test dies made of different materials and various die surface finishes.

Test dies can be made as one piece, with inserts, or with surface coating. The die diameter is selected to have most compaction tests performed within 10-60 % of the maximum pressure (see table below).

The recommended die diameters are from 6.25 mm (0.250 in) to 19.05 mm (0.750 in). The standard compaction length of the test die is 80 mm (3.150 in). The standard pressing punch length is 132.08 mm (5.200 in). These standard sizes will ensure that the pressing punch will always be in contact with the die.

The cold pressing die may be used in a **warm pressing at up to 70⁰C (160⁰F)** when used with a standard band heater. Exceeding the temperature limit can overheat the testing unit (cold dies have no thermal insulation). For a test die made of a steel body with a tungsten carbide insert, overheating would push the insert out during a test.

Test Die installation in the PTC takes around 2 minutes.



COLD/HOT PRESSING TEST DIE SET

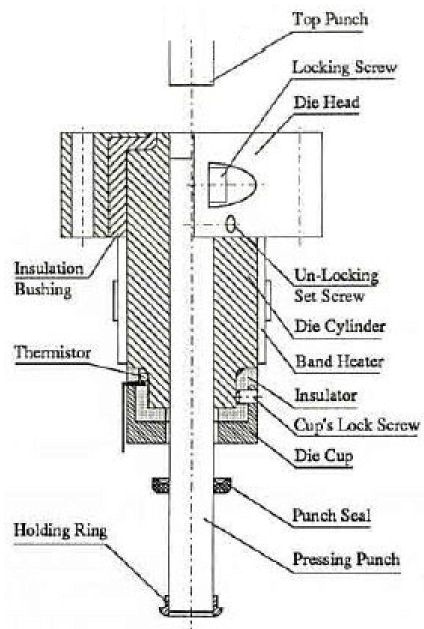
The cold/hot test die consist of a **universal mounting head** and an interchangeable **die cylinder** where a compaction takes place. Any suitable die material may be used (tool steel, steel with tungsten carbide or ceramic inserts, solid tungsten carbide, ...) with corresponding temperature limit for hot pressing. The die cylinder is surrounded with **ceramic heat shields** to limit heat transfer to the testing unit.

Tests may be conducted continuously at various temperatures up to 300⁰C (570⁰F). There are **three user selectable testing options**:

- **no heating**: pressing at room temperature
- **cold powder**: heating the die first, adding cold powder, pressing
- **hot powder**: adding powder, heating the die with powder, pressing.

The die cylinder is heated with a **band heater** (up to 600 W) powered and controlled by the test unit. A temperature sensor provides a continuous temperature readings. **The heating cycle is automatic**. The heating time depends on the testing temperature and the power of the band heater.

Maximum Testing Temperature: up to 300ᴼC (570ᴼF)



STANDARD DIES

Testing should be conducted within the recommended pressure range with the max. limit left for pressing overshots.

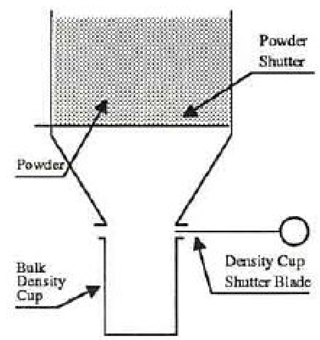
Standard Die Diameter:	Max. Pressing Pressure:	Recommended Pressure Range:
19.05 mm (0.750”)	343 MPa (25 TSI)	34 – 225 MPa (2 – 17 TSI)
12.70 mm (0.500”)	765 MPa (56 TSI)	76 – 500 MPa (5 – 37 TSI)
9.525 mm (0.375”)	1295 MPa (94 TSI)	130 – 845 MPa (9 – 62 TSI)
6.35 mm (0.250”)	3090 MPa (225 TSI)	309 - 2010 MPa (22 – 146 TSI)

OVERVIEW — SUB-TEST #1: PROPERTIES OF THE BULK POWDER

REQUIRED PARAMETERS FOR TESTING

- Powder Name
- Powder Batch (optional)
- Pressing Mode: max pressure or fixed density
- Desired Pressure or Density
- Theoretical Density of the powder mixture
- Desired Compact Size for mass of die filling powder
- Pressure Hold Up time
- Heating Arrangement and Die Temperature

The **SUB-TEST # 1** is conducted with the **Bulk Powder Tester** ("**BPT**"). The **BPT is an independent testing unit** attached to the PTC or mounted on a free standing base.

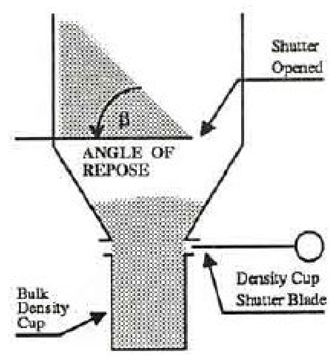


STEP 1: FILLING THE TESTER WITH LOOSE POWDER

The **POWDER TESTER** is detachable from its base for a convenient assembly, filling and cleaning. It is mounted on its base attached to the front of the BPT. The powder mix should fill approximately 75% of the tester.

Required amount of powder mix: approximately 20 cm³.

STEP 2: ANGLE OF REPOSE β OF THE POWDER

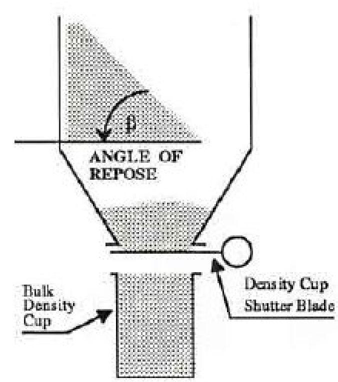


After the **Powder Shutter** is pulled out approximately 10 mm, the powder flows into the **Bulk Density Cup**. The powder left on the shutter forms the **Angle of Repose β**. It represents the actual ***ability*** of the powder to fill uniformly the cavity of a die. Preference is to have β in the 40^o or less range.

The **Angle of Repose** could be measured in several ways and is quite independent from any particular measuring method. The angle is read directly by an inclinometer sensor attached to a dial positioned parallel to the powder surface by an operator.

ADVANTAGE: RELIABLE and REPEATABLE for almost all powders.

STEP 3: BULK (APPARENT) DENSITY ρ_b OF THE POWDER



The **Bulk Density ρ_b** (also known as **Apparent Density)** is the density of a loose powder under the given tested conditions. The method implemented here uses a Bulk Density Cup with a precision measured volume.

The cup is overfilled with powder flowing along the inclined surface. The powder in the cup is separated from the overflow with a thin shutter blade to prevent any accidental and undesirable densification of the powder in the cup. Such extra powder densifications are quite common with other commonly used methods.

ADVANTAGE: ACCURATE, REPEATABLE, and RELIABLE measurements.

STEP 4: TAP DENSITY ρ_{tp} OF THE POWDER

The **Tap Density** is the density of a loose powder subjected to a number of prescribed taps. The number of taps is user selectable. For this test, the Bulk Density Cup with the powder is mounted back into the Powder Tester. The tapping motor taps the entire Powder Tester assembly. When done, the Density Cup with tapped powder is removed and weighed.

POWDER COMPACTING PROCESS is described by 2 distinct phenomena:

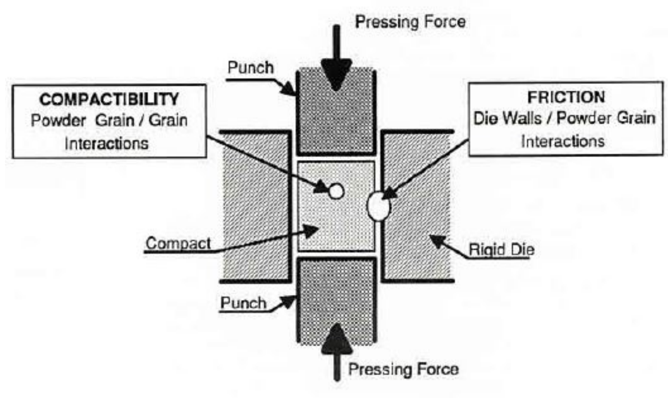
COMPACTIBILITY:

the **ability of a powder to densify** under pressure. For a given material, it is influenced primarily by particle sizes, shapes, and size distribution.

An increase in the **compactibility coefficient** α results in higher green compact density at a given compacting pressure.

DIE WALL FRICTION:

friction interactions between powder grains and the die walls. It is defined as **slide coefficient** η and varies from 0 (infinity friction) to 1 (no friction). It should always be as high as possible.



STEP 1: COMPACTION

The powder mixture is put into the die (cold or heated to a set temperature) and compacted to a desired pressure or density. If needed, the compact may be held in the die under pressure for a specified period of time to allow transformations within the green compact (polymerization, chemical reactions) to finalize.

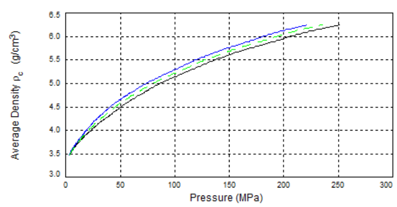


Figure 1. Test compaction pressure: pressing, net, closing. (T152)
In a rigid die, the net (isostatic) cross-section occurs where h=H/2

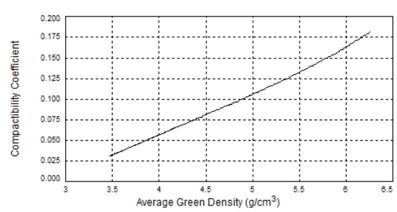


Figure 2. Compactibility Coefficient variations with green density. (T152)

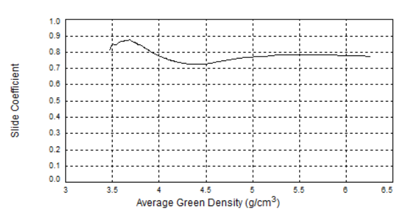


Figure 3. Slide Coefficient variations with green density. (T152)

STEP 2: COMPACT EJECTION

The compact is ejected from the test die by the pressing punch. The **ejection pressure** (punch force per cross section area) and the travel distance during ejection are measured and plotted as the **compact ejection characteristic**.

In the standard configuration, the compact has to travel approximately 5 mm (0.2 in) to the surface of the die. On the plot below, "0" indicates the position of the face of the compact in the die under full load. When the load is released, before ejection, the compact expands within the die in the axial direction as seen on the plot.

The ejection characteristic is the base for calculating:

- **stripping pressure** - peak initial ejection force over compact's friction area (in contact with die)
- **average ejection pressure** - ejection pressure averaged over initial 5 mm of travel
- **ejection (start) pressure overshot** - the ratio of the maximum initial and the average ejection pressure
- **total ejection energy**
- **unit ejection energy** - the ejection energy per unit of the compact's friction surface and per unit of the ejection length

NOTE: The ejection data is **geometry dependent**.

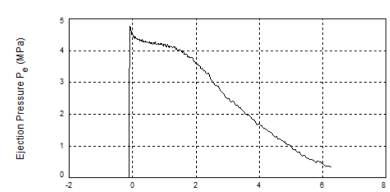
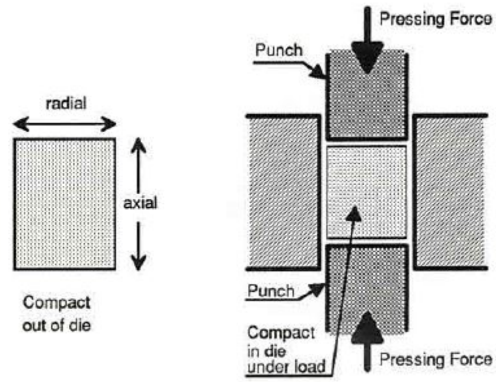


Figure 4. The test compact ejection characteristic. (T152)
The ejection pressure is measured on the ejecting punch.

OVERVIEW — SUB-TEST #3: GREEN COMPACT EXPANSIONS

GREEN COMPACT EXPANSIONS



The **compact height** and **diameter** are measured, after ejection from the die, with a micrometer. These values will depend on the time lapsed after ejection (compacts keep expanding for a short time).

The **expansion coefficients**, calculated as a ratio of dimensions in a free compact and in the same compact in die under full load, are:

- **RADIAL** - the ratio of radial dimensions
- **AXIAL** - the ratio of axial dimensions

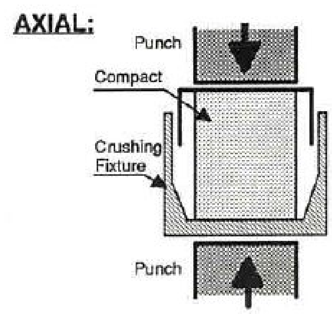
NOTE: The **expansion coefficients are important in tool design**. The axial expansion is typically greater than the radial expansion.

OVERVIEW — SUB-TEST #4: GREEN COMPACT CRUSHING TESTS

AXIAL CRUSHING TEST

The **green compact**, placed in a fixture, **is crushed in axial direction** by the main punches. A rapid readout of the force and compact height change provides data for the **axial crushing characteristic** (below). The maximum crushing pressure - **AXIAL GREEN STRENGHT** - represents a measure of the green strength that holds the compact together during ejection from a die.

A **COHESIVENESS** of a green compact represents the resistance of the compact to cracking and lamination during ejection from a die. It is calculated as a ratio of a green strength and a maximum friction during ejection.

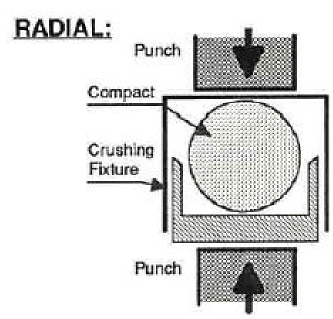


RADIAL CRUSHING TEST

The **green compact** is **crushed along its diameter**. Crushing force and distance data are used to calculate the **radial crushing characteristic** (crushing force over instantaneous crushing contact area) and the **diametral crushing characteristic** (crushing force over half of the cylindrical compact area).

The maximum values in both characteristics are the:

- **RADIAL GREEN STRENGTH**
- **DIAMETRAL GREEN STRENGTH.**



GREEN COMPACT CRUSHING CHARACTERISTICS

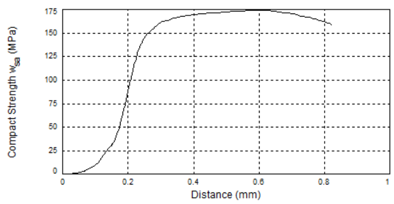


Figure 5. The green test compact axial crushing characteristic. (T152)

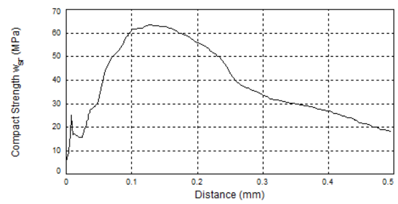


Figure 6. The green test compact radial crushing characteristic. (T152)

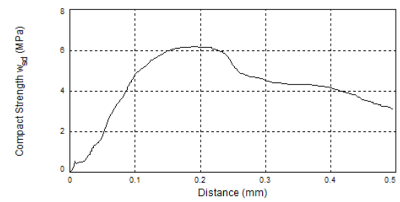
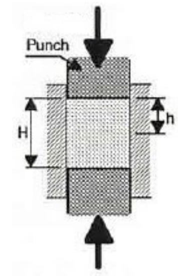


Figure 61. The green test compact diametral crushing characteristic. (T152)



The **test results allow calculations of properties variations within the test compact**. More importantly, with the help of a **Ga** parameter (compact geometry non-dimensional number), local variations in any compact can be determined. For practical reasons, determination of a local green compact density is critical. It allows direct calculations of the local shrinkage and the shape of the end product. Here, **h=0 at closing punch** face and **h=H at pressing punch** face.

The graphical presentations of test results provide bases for:

- **designing compaction and sintering processes**
- **determining optimal pressure during compaction**
- **calculating die dimensions.**

DIE WALL FRICTION AND ISOSTATIC COMPACTION

The slope of the curves in the local properties graphs (below) depends on the slide coefficient (die wall friction). The higher the slide coefficient (lower friction), the lower the slope. The **cross section at h/H=0.5** is not affected by wall friction and represents **ISOSTATIC pressing conditions**. There, the local density is equal to the average density of the compact and the pressure (called **net pressure**) is equal to **ISOSTATIC pressure** for that density.

With no die wall friction, during compaction (plot on the right) the pressing and closing pressure would merge and be equal to the net (isostatic) pressure.

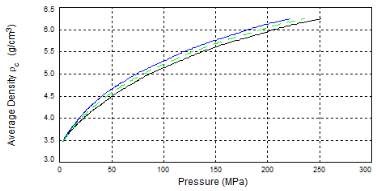


Figure 1. Test compaction pressure: pressing, net, closing. (T152)
In a rigid die, the net (isostatic) cross-section occurs where h=H/2

The **local pressure, density** and **shrinkage** are shown below (h=H at pressing punch face) at **fixed average** compact **densities** listed below each graph. With **NO FRICTION**, all **graph lines would be HORIZONTAL** !

ONE-SIDED PRESSING

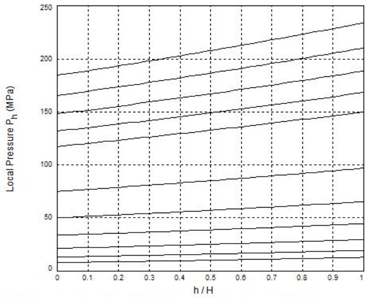


Figure 7. Local pressure distribution in a one-sided pressing. (T3.02)
Valid only for compacts with Ga = 0.0 and ρ = 5.8 at the nominal length H.
The solid lines represent average densities, the dashed lines are compaction curves.
Lines (g/cm³): 4.40 4.60 4.80 5.00 5.20 5.40 5.60 5.65 5.70 5.75 5.80

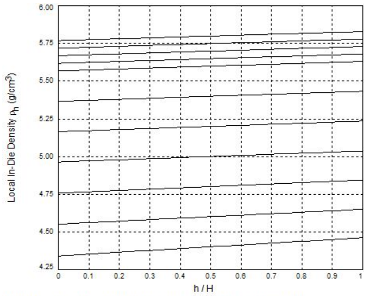


Figure 8. Local density distribution in a one-sided pressing. (T3.02)
Valid only for compacts with Ga = 0.0 and ρ = 5.8 at the nominal length H.
The solid lines represent average densities, the dashed lines are compaction curves.
Lines (g/cm³): 4.40 4.60 4.80 5.00 5.20 5.40 5.60 5.65 5.70 5.75 5.80

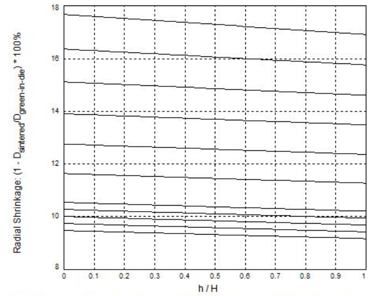


Figure 9. Local Radial Shrinkage during sintering (one-sided pressing). (T3.02)
Valid only when: Ga = 0.0 at the in-die average ρ = 5.8, er = 0.0 , ea = 0.0 .
The solid lines represent local shrinkage at listed below average in-die densities.
Line values from top to bottom (g/cm³): 4.40 4.60 4.80 5.00 5.20 5.40 5.60 5.65 5.70 5.75

DOUBLE-SIDED PRESSING

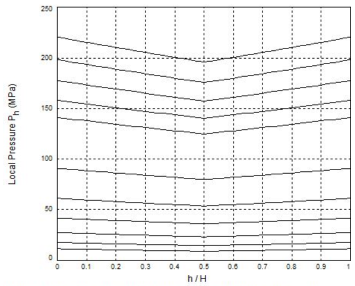


Figure 11. Local pressure distribution in a double-sided pressing. (T3.02)
Valid only for compacts with Ga = 0.0 and ρ = 5.8 at the nominal length H.
The solid lines represent average densities, the dashed lines are compaction curves.
Lines (g/cm³): 4.40 4.60 4.80 5.00 5.20 5.40 5.60 5.65 5.70 5.75 5.80

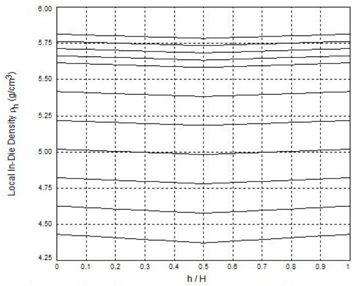


Figure 12. Local density distribution in a double-sided pressing. (T3.02)
Valid only for compacts with Ga = 0.0 and ρ = 5.8 at the nominal length H.
The solid lines represent average densities, the dashed lines are compaction curves.
Lines (g/cm³): 4.40 4.60 4.80 5.00 5.20 5.40 5.60 5.65 5.70 5.75 5.80

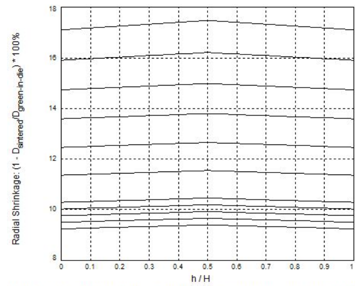


Figure 13. Local Radial Shrinkage during sintering (double-sided pressing). (T3.0
Valid only when: Ga = 0.0 at the in-die average ρ = 5.8, er = 0.0 , ea = 0.0 .
The solid lines represent local shrinkage at listed below average in-die densities.
Line values from top to bottom (g/cm³): 4.40 4.60 4.80 5.00 5.20 5.40 5.60 5.65 5.70 5.75

OVERVIEW — TESTED PARAMETERS AND APPLICATIONS

The **Powder Testing Center** provides basic information necessary in designing and controlling a dry powder compaction process. The testing capability covers a wide range of powders: metallic, ceramic, refractories, nuclear (fuel rods), pharmaceutical, abrasives, explosives, chemicals and others. The testing process is **computer controlled** and **automated**. A typical test takes less than **10 minutes** allowing testing for direct quality control on production lines.

The test results are geometry independent, applicable to rigid-die and isostatic pressing.

TESTING MODES

- **FIXED PUNCH PRESSURE** - pressing to a desired maximum pressing pressure
- **FIXED COMPACT DENSITY/LENGTH** - pressing to a desired in-die average compact density or length
- **FIXED ISOSTATIC PRESSURE** - pressing to a desired isostatic/net pressure

The pressing position and pressure are controlled by precision gauges. A motor brake stops the compaction at a desired point. **The final pressure may be held up for a selected time period before release.**

TYPICAL APPLICATIONS

POWDER QUALITY CONTROL:

- **direct (in-line) quality control** of powder after mixing and before pressing. If tested parameters are out of predetermined limits, the powder should be remixed or rejected
- control of a lubricant content in a powder mixture
- control of a binder content in a powder mixture

PROCESS DEVELOPMENT & OPTIMIZATION:

- determination of an optimum average green density of a compact for new powders
- determination of an optimum lubricant and binder content
- determination of an optimum die material to minimize friction
- determination of control limits on variations for quality control
- determination of temperature effects on compaction parameters

RESEARCH AND DEVELOPMENT:

- new powders and mixtures
- temperature effects on pressing (warm and hot)
- new die materials to minimize wall friction
- new die surface coatings to minimize wall friction
- new binders, lubricants and direct die lubrication methods

TESTED PARAMETERS

POWDER MIXTURE PROPERTIES:

- ✓ **angle of repose** (flowability) - the ability of the powder to fill uniformly a cavity of a die
- ✓ **bulk (apparent) density** of a loose powder
- ✓ **tap density** - the density of a loose powder subjected to prescribed tappings
- ✓ testing environment **humidity** and **temperature**

COMPACTION & GREEN COMPACT PROPERTIES:

- ✓ **compactibility coefficient** - the ability of a powder to densify under a given pressure
- ✓ **slide coefficient** - the measure of frictional interactions at die walls during compaction
- ✓ **stripping pressure** - the ratio of the maximum initial ejection force and the compact's friction area
- ✓ **average ejection pressure** for the test compact
- ✓ **ejection start pressure overshot** - the ratio of the maximum initial ejection pressure and the average ejection pressure
- ✓ **total ejection energy** for the test compact
- ✓ **radial** and **axial** green **expansion coefficients**
- ✓ **cohesiveness of a compact** - crack and lamination resistance
- ✓ **green** test compact **axial strength** during axial crushing
- ✓ **green** test compact **radial strength** during diametral crushing

GENERAL CHARACTERISTICS (GRAPHS):

- ✓ test compaction pressure: pressing, net (isostatic), closing
- ✓ isostatic pressing characteristic
- ✓ compactibility coefficient variations with green density
- ✓ slide coefficient variations with green density
- ✓ ejection characteristic for the test compact
- ✓ axial crushing characteristic for the test compact
- ✓ radial crushing characteristic for the test compact
- ✓ diametral crushing characteristic for the test compact
- ✓ local pressure distribution in a compact
- ✓ local density distribution in a compact
- ✓ local shrinkage perpendicular to pressing direction
- ✓ local shrinkage parallel to pressing direction

Contact us for more information or to request a testing demonstration.