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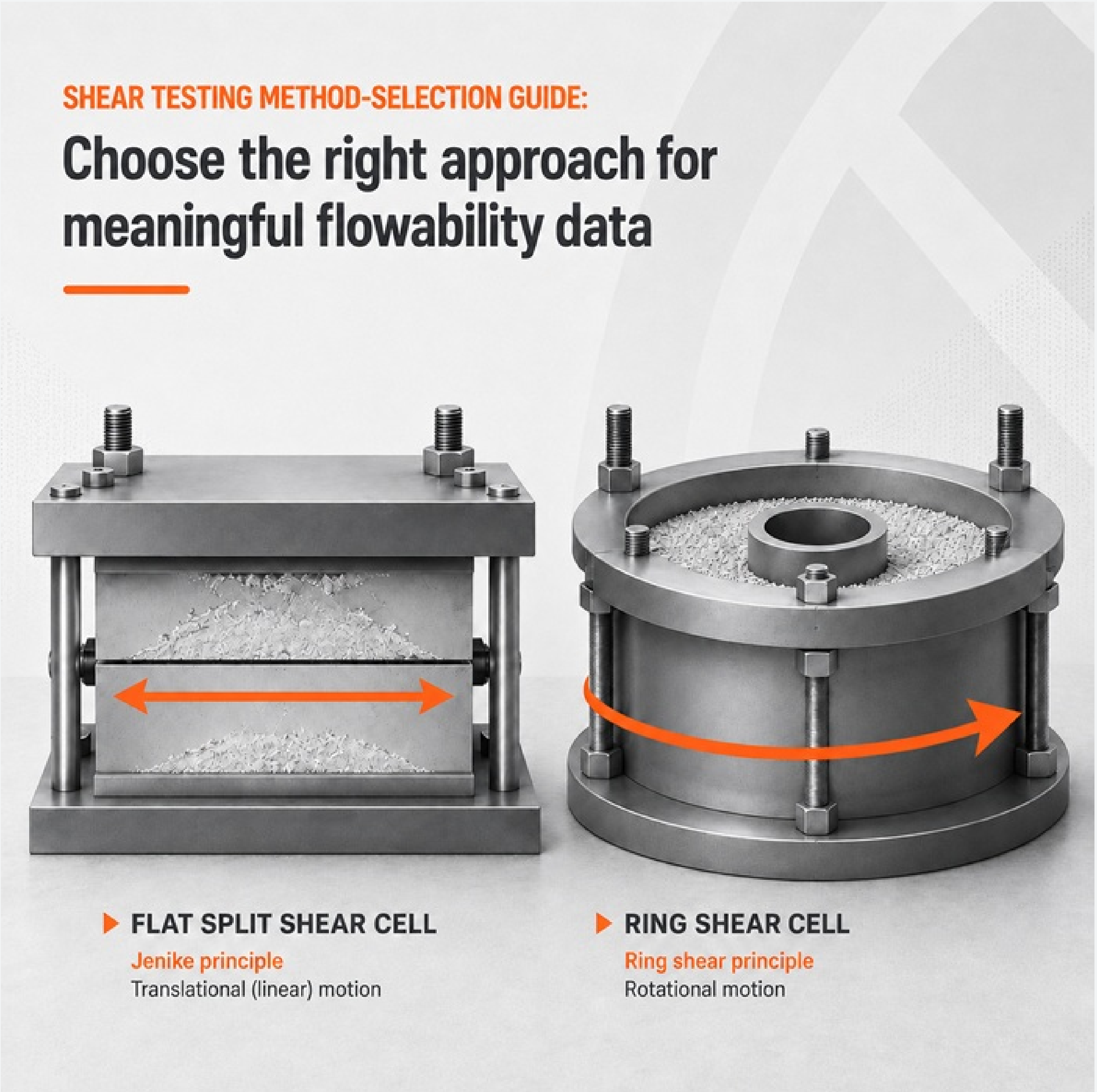

USE THIS GUIDE TO

Define the engineering decision, select the required measurements, check cell and material limits, compare Jenike and ring shear testing, and prepare a defensible laboratory request.

How to Use This Guide

Shear testing can provide material properties for evaluating cohesive arching, ratholing, hopper wall angles, mass-flow conditions, and storage-related strengthening. However, requesting a flowability test is not enough. The method, cell, stress levels, material condition, and outputs must reflect the engineering decision.

1. ENGINEERING DECISION
Define what must be designed, compared, approved, or corrected.
2. REQUIRED DATA
Select flow function, wall friction, bulk density, time consolidation, or a complete design package.
3. MATERIAL LIMITS
Check particle size, shape, sample quantity, representativeness, and handling sensitivity.
4. PROCESS CONDITIONS
Match stress, storage time, temperature, humidity, and material history.
5. METHOD AND CELL
Select a defensible Jenike or ring shear configuration.
6. INTERPRETATION
Connect each result to the decision and state what remains unresolved.

THE FIRST RULE

Select the measurement programme before selecting the instrument.

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Start With the Engineering Decision

Do not begin by asking which tester is better. Begin by defining what must be decided. The instrument becomes relevant only after the required data and representative test conditions are clear.

ENGINEERING QUESTION	PRINCIPAL MEASUREMENTS REQUIRED
Could the material form a cohesive arch?	Flow function, bulk-density relationship, relevant process stresses, and hopper geometry.
Could a stable rathole form?	Flow function, bulk density, bin dimensions, flow pattern, and effective internal friction.
What outlet size is required?	Flow function plus the appropriate hopper-design calculation.
Will the hopper operate in mass flow?	Wall friction against the proposed wall material, hopper geometry, and internal-friction data.
What hopper wall angle or surface is required?	Wall-friction locus for each candidate wall surface.
Will storage make the powder stronger?	Time-consolidated flow functions at representative stress, time, temperature, and humidity.
Did moisture or formulation change handling risk?	Comparative flow functions under controlled and documented conditions.
Can one lot replace another?	Comparative testing with the same method, cell, preparation procedure, and stress programme.
Why does discharge fail only after shutdown?	Time consolidation, environmental history, process stress, outlet geometry, and operating sequence.

DECISION CHECK

Write the decision as one sentence before requesting a test: The results will be used to decide whether or how to...

What the Flow Function Represents

A yield locus describes combinations of normal stress and shear stress at incipient failure for a material prepared at a defined consolidation state. From the yield locus, the unconfined yield strength, f_c, and major principal consolidation stress, σ_1, can be derived.

FLOW FUNCTION

Repeating the measurement at several consolidation states produces the flow function: $f_c = f(\sigma_1)$

The flow function shows how strongly the bulk solid resists unconfined failure after consolidation. It supports cohesive arching and ratholing assessments when combined with the appropriate design method, equipment geometry, and bulk-density data.

Flowability index

The ratio $ff_c = \sigma_1 / f_c$ is commonly used as a flowability index. A larger value indicates easier flow under the tested condition.

COMMON DESCRIPTOR	FLOWABILITY INDEX, ffc
Non-flowing	Less than 1
Very cohesive	1 to 2
Cohesive	2 to 4
Easy-flowing	4 to 10
Free-flowing	Greater than 10

DO NOT USE THE CLASSIFICATION AS THE DESIGN

Terms such as cohesive and free-flowing provide a convenient comparison. They do not directly specify a safe outlet or prove reliable discharge. A powder can also move between classifications as stress, moisture, temperature, formulation, or storage time changes.

Complementary Measurements

Wall friction

Measures resistance as the bulk solid moves over a representative wall coupon. It supports hopper-wall-angle and mass-flow assessment. Test the actual material, finish, orientation, liner, or coating wherever possible.

Bulk density versus stress

Supports stress, capacity, and hopper-design calculations. One freely settled or tapped-density value may not represent the material under process consolidation.

Internal-friction parameters

The effective angle of internal friction and related quantities form part of the Jenike design framework. Derive them consistently from yield loci rather than substituting an angle-of-repose result.

Time consolidation

Measures strength after the specimen has remained under load for a defined period. Use it for shutdown, long residence time, warm storage, humidity exposure, or other storage-related changes.

Minimum data packages

PROJECT PURPOSE	RECOMMENDED MINIMUM PACKAGE
Formulation or lot comparison	Flow function at agreed stresses, bulk density, and controlled sample condition.
Cohesive-arching assessment	Flow function, bulk density, representative process stress, and hopper geometry.
Ratholing assessment	Flow function, bulk density, internal-friction data, bin dimensions, and flow pattern.
Mass-flow assessment	Wall friction against candidate surfaces plus the required internal-friction data.
Full hopper design	Flow functions, wall friction, bulk density, relevant design inputs, and calculations.
Storage or restart problem	Instantaneous and time-consolidated flow functions under representative conditions.

How the Methods Differ

Jenike shear tester

The bulk solid is contained within a circular shear cell divided horizontally into a base and an upper ring. A normal load is applied, and the upper section is displaced linearly relative to the base. The available shear displacement is limited by the cell geometry.

Schulze ring shear tester

The specimen occupies an annular trough. The trough rotates while the lid is restrained against rotation. The relative rotational movement shears the material. Because rotation can continue, the method provides effectively unlimited shear travel.

THE IMPORTANT DISTINCTION

Continuous rotation can make it easier to continue shearing until a steady condition is established. It does not, by itself, determine the available normal-stress range. Normal-stress capability depends on tester design, cell area, load system, resolution, and configuration.

What both methods can provide

- Yield loci and flow functions under defined consolidation conditions.
- Unconfined yield strength and internal-friction parameters.
- Bulk-density information under load.
- Wall-friction measurements with suitable equipment.
- Time-consolidation measurements with an appropriate procedure.
- Data that can feed the established Jenike hopper-design framework.

NOT A UNIVERSAL EQUIVALENCE

The two methods can support the same downstream engineering framework, but they should not be assumed to produce identical values for every powder and test condition.

SELECTION FACTORS 1-6

Method-Selection Matrix

SELECTION FACTOR	JENIKE SHEAR TESTER	SCHULZE RING SHEAR TESTER	ESTABLISH FIRST
Established design use	Directly associated with the original Jenike method.	Produces measurements used within the same general design framework.	Whether a specified or contractual method applies.
Standardized procedure	ASTM D6128.	ASTM D6773 for the Schulze ring shear tester.	Required standard and edition.
Shear movement	Linear displacement.	Continuous rotational displacement.	Whether substantial travel is needed for steady shear.
Shear travel	Finite.	Effectively unlimited.	Risk of incomplete steady-state development.
Operator involvement	Commonly more manual.	Automated systems are widely available.	Required throughput and laboratory capability.
Specimen handling	Multiple preparations may be required across a complete programme.	Automated sequences can reduce intervention, depending on protocol.	Total material needed, including repeats and conditioning.

USE THE MATRIX AS A QUESTION SET

The entries describe practical tendencies. Final suitability depends on the actual apparatus, cell, powder, stress range, and laboratory procedure.

SELECTION FACTORS 7-12

Method-Selection Matrix

SELECTION FACTOR	JENIKE SHEAR TESTER	SCHULZE RING SHEAR TESTER	ESTABLISH FIRST
Small quantities	Smaller cells exist, but geometry and particle size remain limiting.	Very-small-volume cells are available for fine powders.	Actual cell volume and sampling representativeness.
Coarser material	Possible with a suitably large cell that meets dimensional requirements.	Larger cells can accommodate coarser material.	Maximum particle size and distribution width.
Low-stress testing	Depends on load system, cell, resolution, and parasitic forces.	Dedicated low-stress cells may be available.	Lowest representative process stress and usable resolution.
High-stress testing	Depends on apparatus and cell configuration.	Dedicated smaller-area cells can extend the available stress.	Highest representative stress and apparatus limit.
Wall friction	Measured with suitable wall-friction equipment.	Measured with an appropriate wall-friction cell.	Candidate surface, finish, orientation, and stress range.
Time consolidation	Supported using suitable consolidation arrangements.	Supported on the tester or an external bench.	Storage time, stress, temperature, humidity, and number of conditions.

Selection tendencies

A Jenike test may be preferred when a specification requires ASTM D6128, continuity with an established Jenike dataset matters, or the design provider uses a validated Jenike procedure. A ring shear test may be preferred when automated programmes, limited fine-powder quantities, substantial shear travel, or numerous comparative conditions are important.

Particle Size and Cell Selection

A cell must be large enough relative to the particles to create a representative shear zone. Having enough material to fill the cell does not prove that the cell is suitable.

JENIKE DIMENSIONAL CHECK

ASTM D6128 states that the shear-cell diameter must be at least 20 times the maximum particle size of the bulk solid being tested.

ASTM D6773 provides approximate maximum particle sizes for specific Schulze RST-01 cells. Manufacturer guidance adds figures for smaller RST-XS.s configurations. These are cell-specific screening limits, not universal limits for all ring shear testers.

TESTER AND CELL	APPROX. VOLUME	NARROW DISTRIBUTION	BROAD DISTRIBUTION
RST-01, M	900 mL	5 mm	10 mm
RST-01, S	200 mL	2.5 mm	5 mm
RST-01, MV10	220 mL	1 mm	2 mm
RST-01, SV10	85 mL	0.75 mm	1.5 mm
RST-XS.s, XS-Mr	30 mL	Approx. 0.5 mm	Approx. 1 mm
RST-XS.s, XS-Lr	70 mL	Approx. 0.75 mm	Approx. 1.5 mm
RST-XS.s, XS-SV3	3.5 mL	Approx. 0.2 mm	Approx. 0.3 mm

Report the full size distribution, maximum particle size, lumps or agglomerates, and whether particles are brittle, soft, fibrous, flaky, or elongated. The influence of coarse particles depends on more than size alone.

IF A FINE FRACTION IS TESTED

Report the separation method, cut size, mass fraction removed, reason the fines govern the behavior, and whether the result can be applied to the complete material.

Sample Quantity and Stress Range

Convert volume into mass carefully

An initial cell-fill estimate is $m = \rho_b V$, where m is sample mass, ρ_b is representative bulk density, and V is specimen volume. A complete programme normally requires much more than one fill.

- Sample conditioning and discarded preparations.
- Repeat measurements and several consolidation stresses.
- Wall-friction and time-consolidation specimens.
- Moisture, formulation, temperature, or lot variants.
- Archive or confirmation material.

REQUEST THE TOTAL

Ask the laboratory for the total required mass for the complete programme, not only the nominal cell volume.

Match stress to the process

Representative stresses depend on fill height, vessel diameter, bulk density, wall friction, hopper geometry, flow pattern, surcharge, vibration, and the location being investigated. Small feeders and IBCs may require reliable low-stress measurements. Tall silos can require substantially higher stresses.

Low-stress end

Confirm that force resolution, cell area, mechanical friction, and the chosen configuration support the required lowest stress.

High-stress end

Confirm that the normal-load system and selected cell remain within the specified operating limit.

As examples of configuration dependence, the standard RST-XS.s cell is specified at approximately 20 kPa maximum normal stress. A dedicated RST-01 XS cell is intended for higher stresses and is specified at approximately 165 kPa maximum.

DO NOT CONFUSE DISPLACEMENT WITH STRESS

Continuous rotation provides effectively unlimited shear displacement. It does not provide an unlimited normal-stress range.

Control the Material Condition

A measured difference cannot be attributed confidently to formulation or lot when preparation and environmental histories differ. Record the as-received condition and every deliberate conditioning step.

Environment

Temperature, relative humidity, moisture content, atmosphere, exposure time, and any temperature cycling.

Sample history

Age, storage duration, transport, vibration, compaction, aeration, prior flow, and time since sampling.

Preparation

Drying, sieving, deagglomeration, blending, filling method, trimming, preconditioning, and test delay.

Material integrity

Attrition, particle deformation, segregation, electrostatic charging, and loss of volatile components.

Time consolidation must represent the process

A time-consolidation test first consolidates the specimen, holds it under a defined load, and then measures its strength. The selected duration, stress, temperature, and humidity should reproduce the operational question wherever practicable.

- Overnight or weekend shutdowns.
- Maximum silo residence time.
- Warm or humid storage.
- Crystallization, solid bridging, binder migration, or particle deformation.
- Restart after a known period under load.

COMPARATIVE OR REPRESENTATIVE?

An arbitrary 24-hour test can be useful for comparative screening. It should not be presented as a restart simulation unless 24 hours and the applied conditions represent the process.

Results-to-Decision Map

A shear test produces material-property data. Converting those data into a design requires the correct calculation and additional process information.

RESULT	WHAT IT DESCRIBES	WHAT IT SUPPORTS	WHAT ELSE IS NEEDED
Yield locus	Incipient failure under combinations of normal and shear stress.	Strength and friction parameters.	Defined consolidation state and valid fitting procedure.
Unconfined yield strength, fc	Strength of consolidated material when unconfined.	Cohesive-flow assessment.	Major principal stress and process relevance.
Flow function	Strength development across consolidation states.	Arching and ratholing calculations; comparison.	Geometry, stress field, bulk density, and design method.
Flowability index, ffc	Ratio of consolidation stress to unconfined yield strength.	Convenient classification or comparison.	The full flow function for design.
Wall-friction locus	Resistance between powder and a specific surface.	Wall-angle and mass-flow assessment.	Actual surface, finish, orientation, and geometry.
Bulk density relationship	Density under applied stress.	Stress and capacity calculations.	Representative filling and consolidation conditions.
Effective internal friction	Internal friction during steady flow.	Hopper-design calculations.	Consistent derivation and design procedure.
Time-consolidated strength	Strength after storage at rest.	Shutdown and restart assessment.	Representative stress, duration, temperature, and humidity.

RESULTS ARE INPUTS, NOT THE DESIGN

Outlet size, hopper angle, and flow pattern are engineering outcomes. They are not direct instrument readings.

What the Shear Test Does Not Tell You

Mass flow by itself

Mass flow depends on the powder, wall surface, hopper geometry, and design criterion. A flow function alone cannot establish the wall angle.

One universal outlet size

Outlet size depends on the failure mode, geometry, stress conditions, material properties, and design method.

Complete process reliability

Shear testing does not directly reproduce aeration, pneumatic conveying, segregation, electrostatics, screw interaction, impact damage, or high-speed feeding.

Representative sampling

A precise test on an unrepresentative sample gives a precise answer for the wrong material. Segregation can alter the fines fraction and measured strength.

Environmental independence

Humidity, temperature, drying, aging, and handling history can alter behavior. Report the tested condition and its process relevance.

Interchangeable methods

Jenike and ring shear results may agree for some materials and differ for others. A difference does not automatically make one method wrong.

Five interpretation traps

1. ONE ffc VALUE AS A CONSTANT
Always report the associated consolidation stress and condition.
2. THE EASIEST AVAILABLE CONDITION
Fresh, dry powder may not represent storage or processing.
3. A CONVENIENT WALL COUPON
Material designation alone does not define finish, wear, or orientation.
4. IGNORING SHUTDOWN
Continuous flow can succeed while restart after standing fails.
5. COMPARING NUMBERS, NOT PROCEDURES
Preparation, stress programme, cell, environment, and evaluation must also match.

PART 1 - MATERIAL AND PROCESS

Shear-Test Request Worksheet

A. Material identification

INPUT	PROJECT INFORMATION
Material name	
Grade, formulation, or product code	
Batch or lot number	
Supplier or production location	
Safety data sheet available?	
Relevant handling hazards	
Date sampled	
Sampling point and method	
Packaging and transport condition	

PART 2 - CONDITION AND EQUIPMENT

Shear-Test Request Worksheet

B. Material condition

INPUT	PROJECT INFORMATION
Particle-size distribution and maximum size	
Broad or narrow distribution?	
Particle shape; lumps or agglomerates	
Typical bulk density	
Moisture content and sample age	
Conditioning temperature and humidity	
Prior drying, sieving, milling, or deagglomeration	
Representative of process material?	

C. Process and equipment

INPUT	PROJECT INFORMATION
Existing equipment or new design?	
Vessel type, height, and diameter	
Hopper geometry and outlet	
Wall material and surface finish	
Fill level and residence time	
Longest shutdown or storage time	
Operating temperature and atmosphere	
Upstream and downstream process	

PART 3 - PROBLEM AND DECISION

Shear-Test Request Worksheet

D. Observed problem

- ☐ Cohesive arching
- ☐ Funnel flow
- ☐ Irregular or pulsating flow
- ☐ Caking
- ☐ Feeder inconsistency
- ☐ Formulation-related change
- ☐ Ratholing
- ☐ Incomplete discharge
- ☐ Failure after storage
- ☐ Flooding or uncontrolled flow
- ☐ Lot-to-lot variability
- ☐ Unknown flow problem

When does the problem occur?

What do operators see or measure, and what temporary remedy is used?

E. Required engineering decision

Complete: The results will be used to decide whether or how to...

F. Requested measurements

- ☐ Instantaneous flow function
- ☐ Wall friction
- ☐ Effective internal friction
- ☐ Complete hopper-design dataset
- ☐ Method-bridging study
- ☐ Time-consolidated flow function
- ☐ Bulk density versus stress
- ☐ Comparative flowability only
- ☐ Engineering design calculation
- ☐ Laboratory recommendation required

PART 4 - CONDITIONS AND LABORATORY QUESTIONS

Shear-Test Request Worksheet

G. Conditions to include

INPUT	PROJECT INFORMATION
Consolidation-stress range	
Storage duration	
Temperature and relative humidity	
Moisture content	
Batches or formulations	
Candidate wall materials	
Required replicates	
Applicable standard and edition	
Required tester or reference method	
Reporting deadline	

H. Confirm with the laboratory

- ☐ Tester and shear-cell configuration?
- ☐ Complete material or separated fraction?
- ☐ Applied stress range and process basis?
- ☐ Number of repeat measurements?
- ☐ Time consolidation representative?
- ☐ Uncertainty or repeatability information?
- ☐ Cell suitable for maximum particle size?
- ☐ Total sample mass for the full programme?
- ☐ Conditioning and loading procedure?
- ☐ Actual wall surfaces represented?
- ☐ Raw curves and derived results reported?
- ☐ Interpretation or testing only?

Final Review and Technical Basis

Before authorizing the test

A defensible request identifies the decision, material, process condition, relevant stress range, required measurements, appropriate cell, environmental condition, and required engineering interpretation. Resolve any missing item before committing sample and budget.

FINAL QUESTION

Will this programme produce the data needed for the stated decision under conditions that represent the process?

When changing an established test method

1. SELECT REPRESENTATIVE POWDERS
   Cover the relevant range of cohesive behavior.
2. MATCH CONDITIONS
   Use equivalent conditioning, preparation, and stress levels.
3. COMPARE THE UNDERLYING DATA
   Compare yield loci and derived properties, not only the class.
4. INCLUDE REPLICATES
   Separate method effects from ordinary material and test variability.
5. DEFINE ACCEPTANCE IN ADVANCE
   Set the allowable method-to-method difference before reviewing results.
6. REASSESS SPECIFICATIONS
   A limit developed with one method may not transfer unchanged.

Technical basis and references

- ASTM D6128-22. Standard Test Method for Shear Testing of Bulk Solids Using the Jenike Shear Tester.
- ASTM D6773-22. Standard Test Method for Bulk Solids Using Schulze Ring Shear Tester.
- D. Schulze. Technical specifications for the RST Mk II and RST-XS.s shear-cell configurations.
- H. Salehi et al. A comparison between powder flow property testers. Particuology, 2017.
- J. Schwedes. Measurement of flow properties of bulk solids. Powder Technology, 1990.

The numerical guidance applies only to the named configurations. Check the applicable standard and current instrument documentation. When test data are used for equipment design, interpretation by a competent bulk-solids specialist is recommended.

PowderTechnology.info
Independent technical guidance for powder handling, characterization, testing, and process troubleshooting.