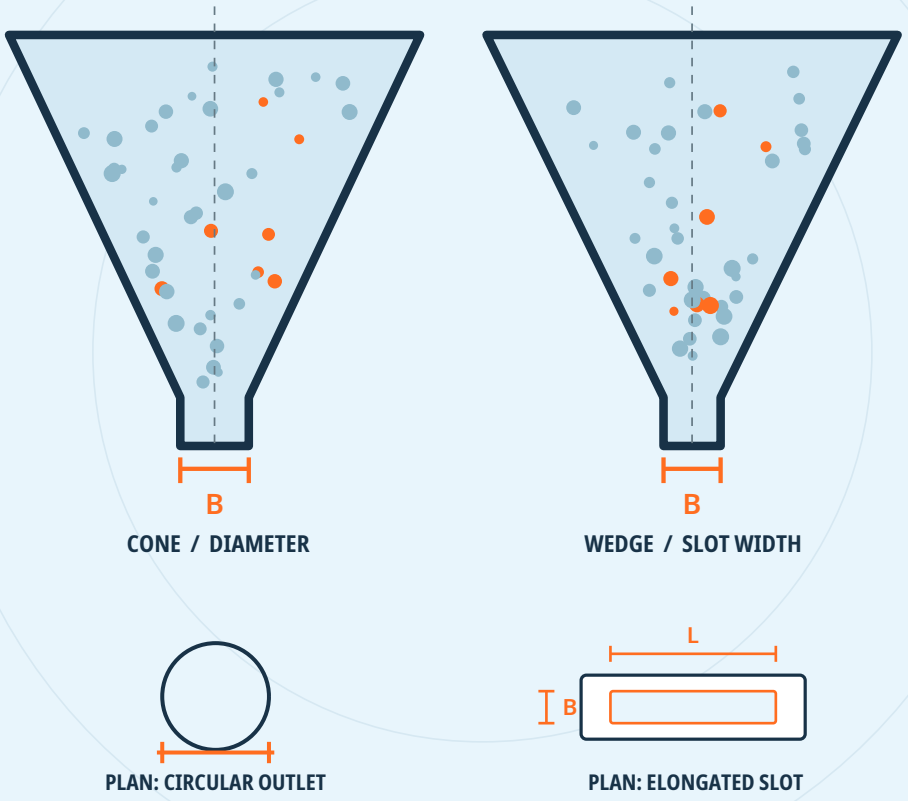
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MONTHLY KNOW HOW / ENGINEERING WORKBOOK

Hopper Design-Check Workbook

Shear Data, Wall Angle, and Outlet Size

Test request · measured data · chart selection · critical opening · release decision



SCHEMATIC · NOT TO SCALE

EDITION 1.1

Deep Field Publishing · November 2026

Use this workbook to document the decision.

Start with the requested test conditions, then transfer measured results into the relevant worksheets. Attach the raw laboratory report, chart reproductions, and equipment drawing.

01 Define the case

Pages 3–4 · Test request and candidate geometry

02 Capture the evidence

Pages 5–7 · Flow data, friction, density and chart selection

03 Calculate

Pages 8–10 · Crossing, iteration and critical opening

04 Close the review

Pages 11–12 · Example and design decision

Project / site / equipment tag

Operating case / unique record ID

Drawing / revision / date

Prepared by / checked by

BEFORE SIGNING OFF

Use a separate record for each material condition or loaded-restart case that may govern. Blank evidence fields remain open actions. **This workbook structures a design check; it does not replace review by a qualified bulk-solids engineer.**

Define the testing package before sampling.

Send the laboratory the operating envelope and the actual wall-contact material. Check the requested deliverables rather than accepting an unexplained flowability class.

Material grade / sample or lot ID

Sampling location / date / representative variation

Moisture / temperature / fines condition

Conditioning, handling, and loaded standstill duration

Expected consolidation range / units / basis

Wall coupon alloy, finish, coating, and service condition

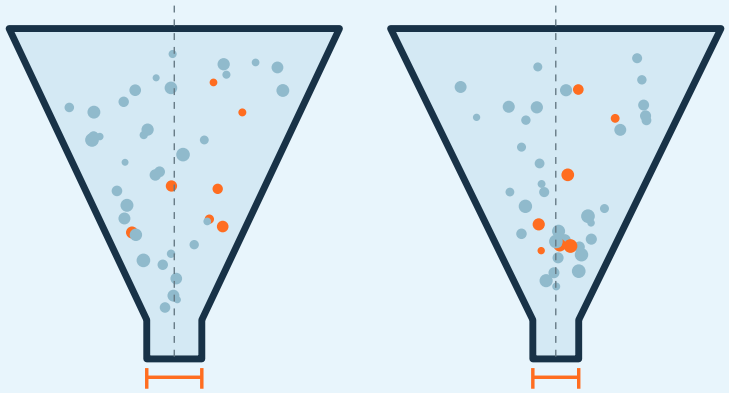
REQUESTED OUTPUTS

- ☐ σ1 and fc pairs, with units
- ☐ Wall yield locus across relevant normal stresses
- ☐ Time-consolidated flow function where applicable
- ☐ Effective internal friction δ
- ☐ Bulk density versus consolidation stress
- ☐ Test method, edition, preparation, and repeatability

Test method / edition / special requirements / exceptions to be reported

Record dimensions that control the calculation.

Work from the current equipment drawing. Distinguish nominal opening dimensions from the clear dimensions available during withdrawal.



CONE / DIAMETER B

WEDGE / SLOT B

Hopper type / drawing

Wall half-angle θ, from vertical

Effective clear B [mm]

Effective slot length L [mm]

Service wall / liner condition

Feeder / gate / restriction

Required rate / continuous duty

Maximum loaded standstill / restart duty

Worst-case fines, humidity, temperature

Clear opening checked on drawing / revision

Plane-flow applicability: Check L > 3B and whether the feeder draws material across the effective length. Record any departures from the idealized geometry.

Enter the measured σ1–fc pairs.

Record separate datasets for immediate flow and loaded restart when both are relevant. Add pages as needed; keep the raw report as the governing source.

A / IMMEDIATE OR REFERENCE CONDITION

No.	σ1 [___]	fc [___]	Comments / ID
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

Dataset A: sample, conditioning, method, report page

B / AFTER DEFINED LOADED STANDSTILL

No.	σ1 [___]	fc [___]	Comments / ID
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

Dataset B: hold duration, load, RH / temperature, report page

Keep the measured stress dependence visible.

Record wall shear and normal stresses for the service coupon. Separately record density versus consolidation stress; these are different stress conditions.

WALL YIELD LOCUS / SERVICE SURFACE

Coupon / surface finish / condition

No.	Wall normal stress [___]	Wall shear stress [___]	Wall-friction angle φ′ [°]	Source / test point
1				
2				
3				
4				
5				
6				
7				

BULK DENSITY VERSUS CONSOLIDATION

No.	Consolidation stress [___]	ρb [kg/m³]	Condition
1			
2			
3			

Low-stress governing wall-friction condition / outlet wall stress basis

Audit: Wall normal stress is not the same as major principal consolidation stress σ1. Identify the density representative of the eventual critical outlet condition and document any interpolation.

Document wall suitability and hopper flow factor.

Use the geometry-specific chart and governing friction inputs. The limiting wall angle is not the final equipment angle.

Chart source / edition / figure number	Cone / plane flow / other geometry
Effective internal friction δ [°] / stress basis	Governing wall-friction angle φ′ [°] / normal stress
Mass-flow limiting half-angle θlim [°]	Proposed half-angle θ [°] / allowance [°]
Selected hopper flow factor ff / chart interpolation	Selected outlet function H / source figure

DECISION AND TRACEABILITY

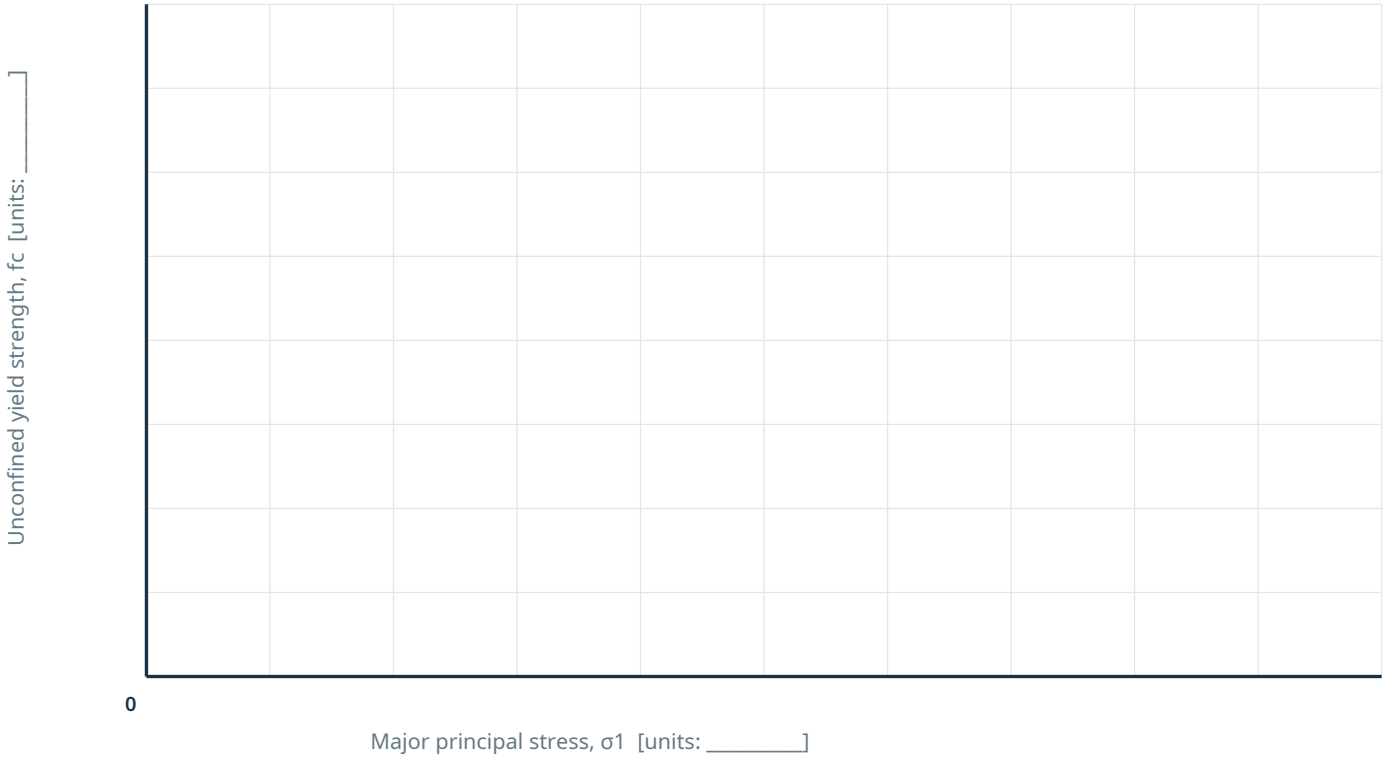
- ☐ Candidate wall angle within evaluated mass-flow region
- ☐ Allowances documented and applicable to geometry

Recalculate if the angle or liner changes: revise the wall limit, ff and H where applicable, then repeat the critical crossing and outlet size calculation.

Plot the flow-function data and hopper line.

Use consistent stress units on both axes. Mark measured points, plot fc = σ1 / ff, and identify all plausible intersections.

Linear axes; both origins at zero. Hopper line passes through (0, 0).



Hopper flow factor ff

Slope 1/ff

σ1,crit [unit]

fc,crit [unit]

Interpolation / fit / crossing count

More than one crossing: Carry all plausible intersections into the outlet calculation, then select the one producing the largest critical dimension. For uncertain or unbracketed crossings, mark the evidence unresolved.

Record chart iterations and select the governing crossing.

If the stress-dependent friction inputs change the flow factor, repeat the intersection until the selected values are consistent with the critical stress range.

FLOW-FACTOR ITERATION RECORD

Iteration	Assumed ff	δ [°]	φ′ [°]	θ [°]	New ff	σ1,crit [unit]	fc,crit [unit]
1							
2							
3							
4							
5							

Governing crossing / source point numbers

Graphical / interpolated crossing uncertainty

Bulk density selected at critical condition [kg/m³]

Curve status: single / multiple / tangent / unbracketed

☐ Measured stress range brackets selected crossing

☐ Friction inputs are consistent with selected ff

Calculate Bcrit, then select the installed opening.

Use the same geometry basis for ff and H. Distinguish the theoretical critical dimension from the actual clear opening and the engineering allowance.

Using bulk density: $$B_{crit} = H(\theta) \times f_{c,crit} / (\rho_b \times g)$$

Using bulk weight density: $$B_{crit} = H(\theta) \times f_{c,crit} / \gamma$$

SI units: $f_{c,crit}$ in Pa; ρ_b in kg/m³; g = 9.81 m/s²; γ in N/m³; B_{crit} in m.

Critical yield strength $f_{c,crit}$ [Pa]	Outlet function H / chart figure
Density ρ_b [kg/m³], or weight density γ [N/m³]	Theoretical critical B_{crit} [m and mm]
Engineering allowance / rationale	Selected equipment dimension [mm]
Installed effective clear dimension [mm]	Slot length L [mm] / L > 3B check (if relevant)

- ☐ Critical outlet check complete
- ☐ Installed clear opening meets selected design dimension
- ☐ Units checked

A completed check: Jenike Example 4(a).

Illustration of how to document the published numerical result. These are theoretical calculations at limiting angles, with a fixed bulk weight density and no added design margin.

Calculation field	Conical geometry	Plane-flow geometry
Effective internal friction δ	50°	52°
Wall-friction angle φ′	24°	26°
Limiting half-angle θ	17°	25°
Hopper flow factor ff	1.28 (Figure 47)	1.17 (Figures 52–53)
Initial assumption to final ff	ff 1.3 to 1.28	28°, ff 1.20 to 25°, ff 1.17
Critical consolidation stress σ1,crit	2,908.1 Pa	2,403.3 Pa
Critical yield force F	3.65 lbf	3.30 lbf
Critical strength fc,crit	2,271.9 Pa	2,054.1 Pa
Outlet function H (Figure 43)	2.27	1.13
Bulk weight density γ	50 lbf/ft³	50 lbf/ft³
Bcrit = F × H / (A × γ), A = 1/13 ft²	2.15423 ft = 657 mm	0.96954 ft = 296 mm

HOW TO APPLY THIS EXAMPLE

The 17° and 25° values are **limiting wall angles**. A project-specific allowance requires revisiting the angle, ff, intersection, H, and critical size. For the plane-flow result, L > 3B requires more than 2.91 ft; Jenike specifies 3 ft. The constant γ is an assumption of the original example.

Record each verdict, the missing evidence, and the owner.

A favorable outlet calculation is one item in the design review. Select one disposition per row. Close out storage, surface condition, withdrawal, ratholing, particle passage, and throughput before final acceptance.

Design check	Disposition	Evidence, limit, or open action
Wall-angle / mass flow	☐ Met ☐ Missed ☐ Insuff.	
Cohesive arching / outlet size	☐ Met ☐ Missed ☐ Insuff.	
Loaded restart / time consolidation	☐ Met ☐ Missed ☐ Insuff.	
Service wall / wear / deposits	☐ Met ☐ Missed ☐ Insuff.	
Active feeder extraction	☐ Met ☐ Missed ☐ Insuff.	
Ratholing / channel stability	☐ Met ☐ Missed ☐ Insuff.	
Discharge rate / coarse-particle passage	☐ Met ☐ Missed ☐ Insuff.	

Final disposition / selected equipment revision

Owner / due date for unresolved action

Prepared by / date

Approved by / date

Technical basis: Jenike, Storage and Flow of Solids, Bulletin 123 (1964/1970), esp. Example 4(a) and Figures 43, 47, 52, 53, 96; Schulze, Powders and Bulk Solids, 2nd ed. (2021); Mehos and Morgan, "Hopper Design Principles," Chemical Engineering (2016); ASTM D6128-22 and D6773-22.

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