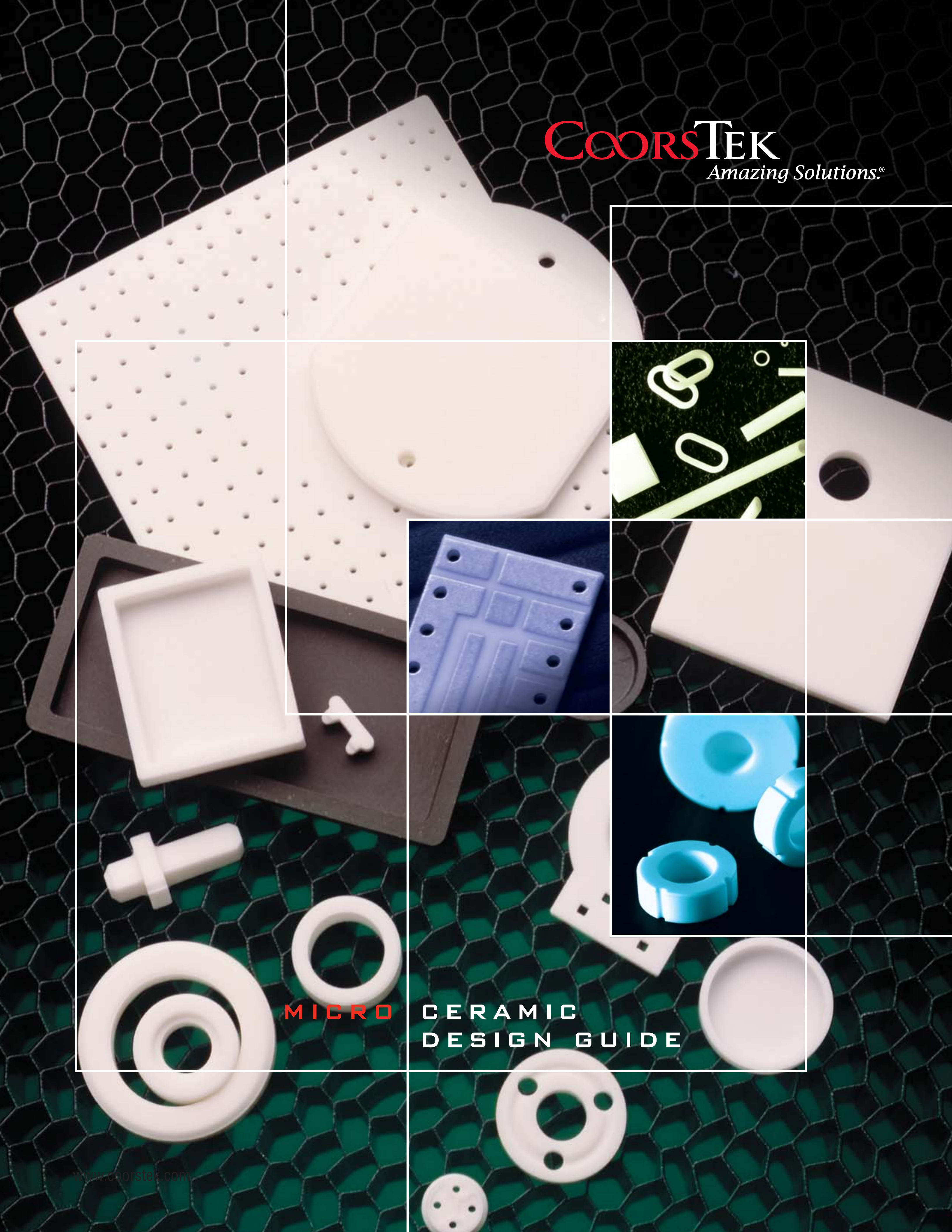


CoorsTek

Amazing Solutions.®

MICRO CERAMIC DESIGN GUIDE

www.coorstek.com

Table of Contents

CoorsTek® manufactures critical components and complete assemblies for semiconductor, automotive, electronics, medical, telecommunications, military, and other industrial applications. Using advanced technical ceramics and other high-performance materials, our solutions enable customers' products to overcome technological barriers and improve performance, especially in demanding or severe service environments.

CoorsTek has a highly qualified staff to assist with material selection and product design. Please contact us today at 303.277.4766 for more information.

For general information about CoorsTek, please visit our website at www.coorstek.com.

I. Scope and Intent

This microceramics technical specification is designed to provide engineers with design guidelines, material property information, inspection methods and quality standards for CoorsTek® dry pressed alumina products. These guidelines will aid in optimizing component design and material selection in order to meet your technical requirements cost effectively.

Consistent properties such as high electrical resistivity, dielectric strength, superior surface finish, high thermal conductivity, tight dimensional control, high strength, chemical corrosion, and radiation resistance have established CoorsTek alumina as the material of choice for a wide variety of electronic and mechanical applications. CoorsTek ceramic materials have superior compatibility with a variety of metallizing paste systems. Our ceramics can also be bonded with glasses, plastics, epoxies, and metals.

NOTE: This document is provided as a general guide for MOST microceramic applications. If your design exceeds defined limits or requires special properties, our specialists may be able to accommodate your requirements. Please contact your CoorsTek Sales Representative or call 303.277.4766 for more information.

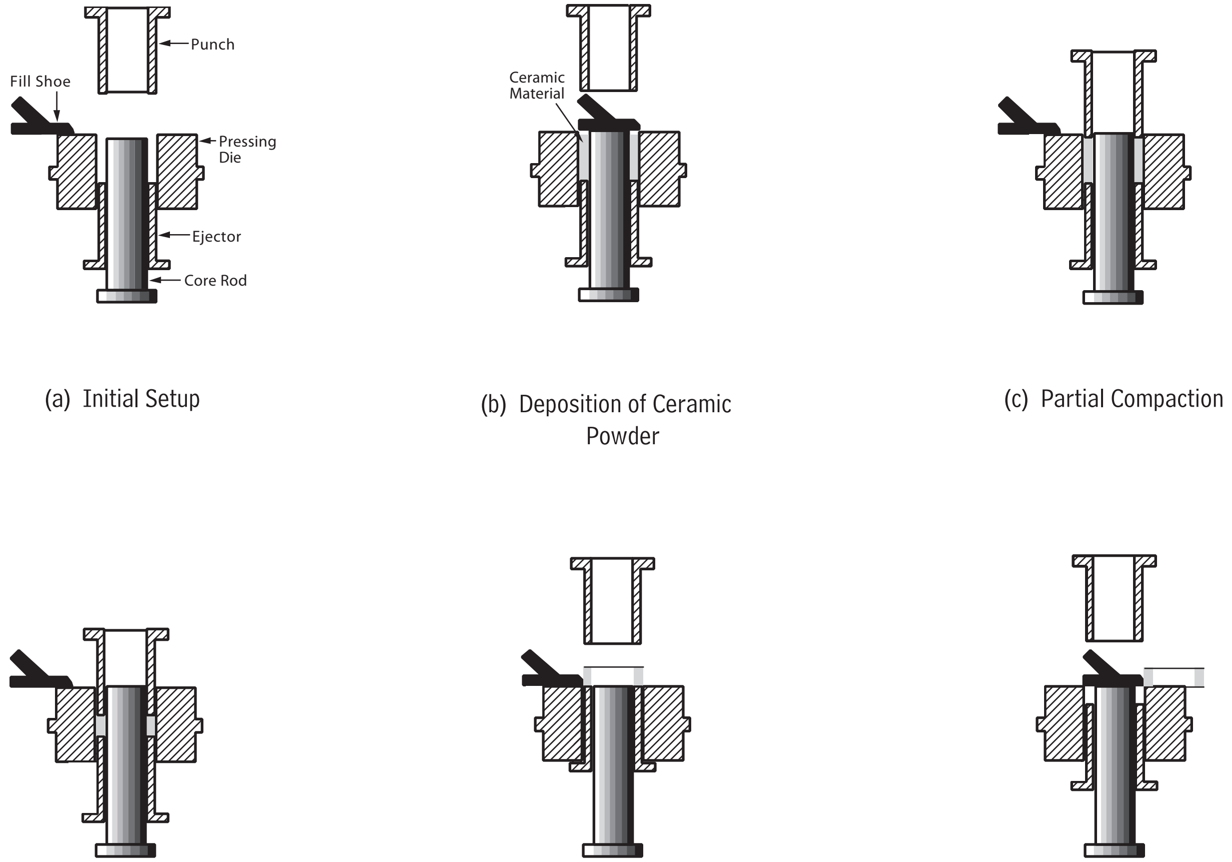
II. Technology Overview

Dry pressing is a method of fabricating ceramic components by compacting flowable powders in a metal die set. This fabrication technology allows parts to be manufactured to precise dimensional specifications and lends itself to high volume production. Dry pressing technology incorporates three basic steps: spray dried powder preparation, pressing and sintering.

Initially, the raw materials (which consist of high purity ceramic powders) are ball-milled with dispersants and water soluble organic binders to achieve proper particle size distribution and slurry rheology. The slurry is then spray dried to form a flowable powder capable of maintaining a desired shape when compacted.

The powder is fed into a precision tungsten carbide or steel die and compressed to achieve the desired shape and size. More specifically, dies consist of the die body, punch, ejector, and, in some instances, one or more core rods. The die assemblies are mounted in either mechanical or hydraulic presses. The fill shoe, which feeds powder into the die cavity from a storage tank, moves over the die and releases spray dried powder into the die cavity. After the fill shoe withdraws, compaction begins when both the punch and ejector simultaneously press the powder in the die. Figure 1illustrates the six steps of the compaction cycle. Pressing pressures typically range from 10-20 Kpsi, depending upon the individual ceramic powder characteristics.

Following the compaction process, the parts are sintered in a high-temperature tunnel kiln. The sintering process brings about several significant changes in the ceramic part: total surface area is reduced, bulk volume is reduced and strength is increased. This process produces polycrystalline, homogeneous parts having the desired physical and electrical properties.



(a) Initial Setup

(b) Deposition of Ceramic Powder

(c) Partial Compaction

(d) Full Compaction

(e) Part Ejection

(f) Transportation of Part (Repeat Cycle)

Fig. 1. Compaction Cycle

III. Design Guidelines

The following design standards represent factors that should be considered to ensure optimal product design and material selection.

A. Material Selection

CoorsTek® offers a variety of alumina materials to meet your application's specific requirements. Table 1 lists a sample of the available alumina materials and corresponding characteristics. Current products include electrical insulators, thick-film microelectronic substrates, lids and covers, resistor components, automotive/industrial sensors, and switches. Additional materials such as zirconias, mullite and steatite are available, and several advanced materials are under development. All CoorsTek materials provide superior physical, electrical and thermal properties. For further assistance selecting the appropriate material for your application, please contact your CoorsTek sales representative.

Table I: CoorsTek® Alumina Materials		
Materials	**Characteristics**	**Typical Applications**
ADO-90 (Nominal 92% Al_2O_3)	An opaque alumina ceramic. This material is ideal for protecting light-sensitive semiconductor devices.	Lids and Covers
AD-94 (Nominal 94% Al_2O_3)	Preferred for most electronic applications. Used where high-strength refractory metallization characteristics are required.	Surge Protectors, Lids and Covers
AD-96 (Nominal 96% Al_2O_3)	Preferred for most electronic applications, commonly used in thick-film metallization techniques	Pressure Sensors, General Electronic Components
AD-995 (Nominal 99.5% Al_2O_3)	The high purity of this material makes it the best choice for low dielectric loss or high dielectric constant applications and chemical resistance.	Microwave Components

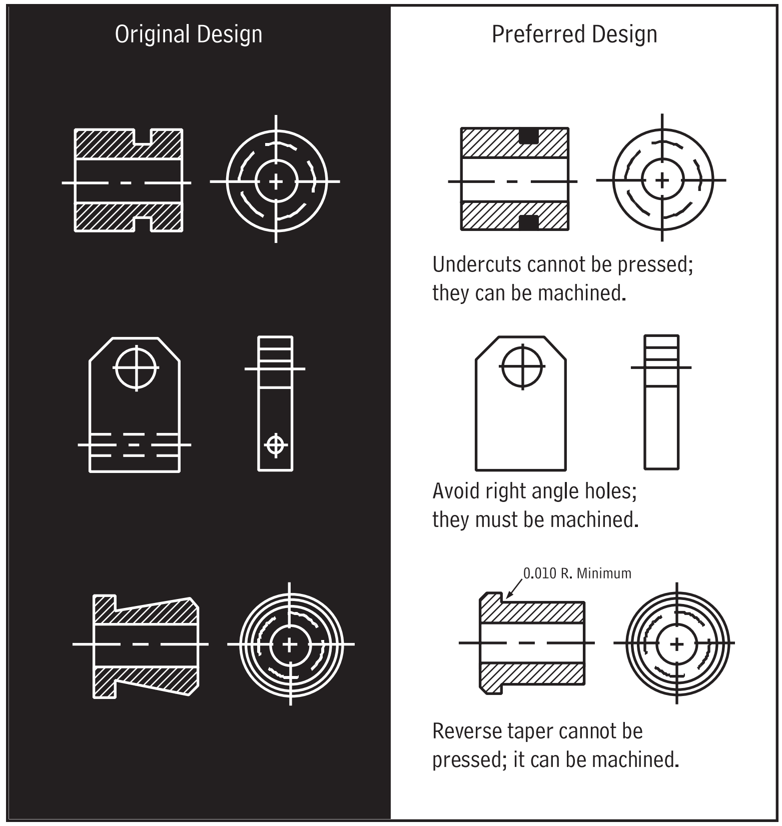
Notes:
1. If your design does not comply with this specification, we may still be able to satisfy your design requirements.
Please contact your CoorsTek sales representative for more information.

B. Designing Parts for Dry Pressing

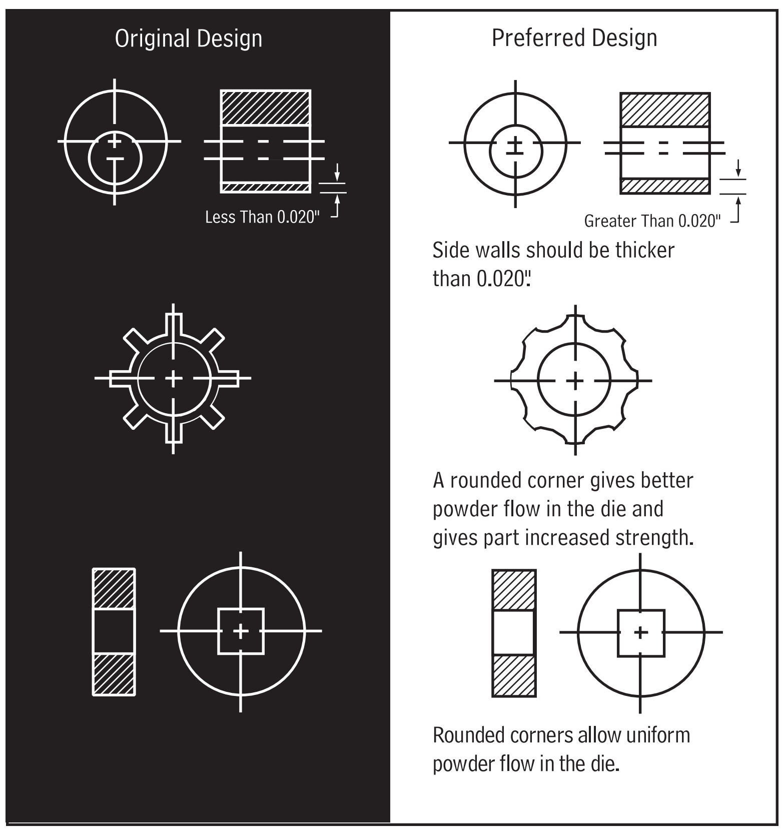
Ceramics can be dry pressed in many shapes, from very simple shapes to complex geometric forms. For maximum economy, however, parts should be designed for symmetry and simplicity. In general, sharp edges and corners, projections, grooves, variable thicknesses, uneven cross sections, and thin walls should be kept to a minimum. When in doubt, consult your CoorsTek sales representative prior to design finalization to ensure optimal ceramic component design.

The advantages of dry pressing can be realized if a few fundamentals are understood and properly employed, resulting in improved designs, simplified tooling, longer die life and lower costs.

1. The part shape must permit ejection from the die. Although most parts can be dry pressed to their desired shapes, some design requirements can be achieved by secondary machining, such as:
    - diametral grooves
    - holes perpendicular to the pressing direction
    - tapers
    - fillets
    - threads

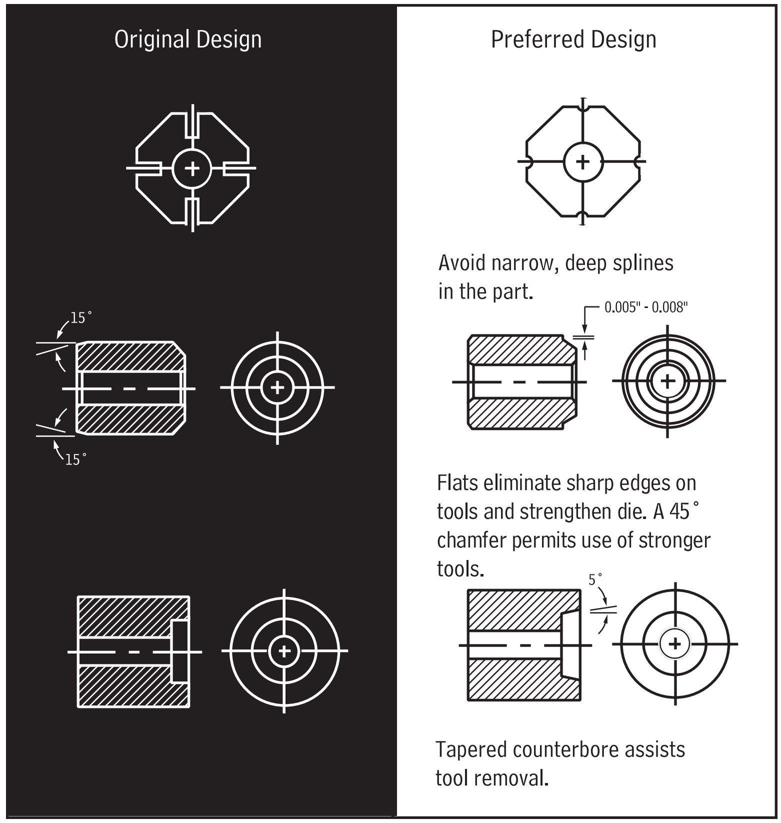


2. The part shape should avoid sharp edges, corners, projections and thin walls to prevent uneven die fill.
    - Sharp edges and corners are regions of high stress which reduce the overall strength of the part.



3. The part shape should permit strong tooling.

    - Simple shapes allow for stronger tooling.
    - Round holes should be used instead of odd-shaped holes.
    - Very small holes should be avoided to eliminate pin breakage.
    - A 45° chamfer on all sides allows for stronger tooling.



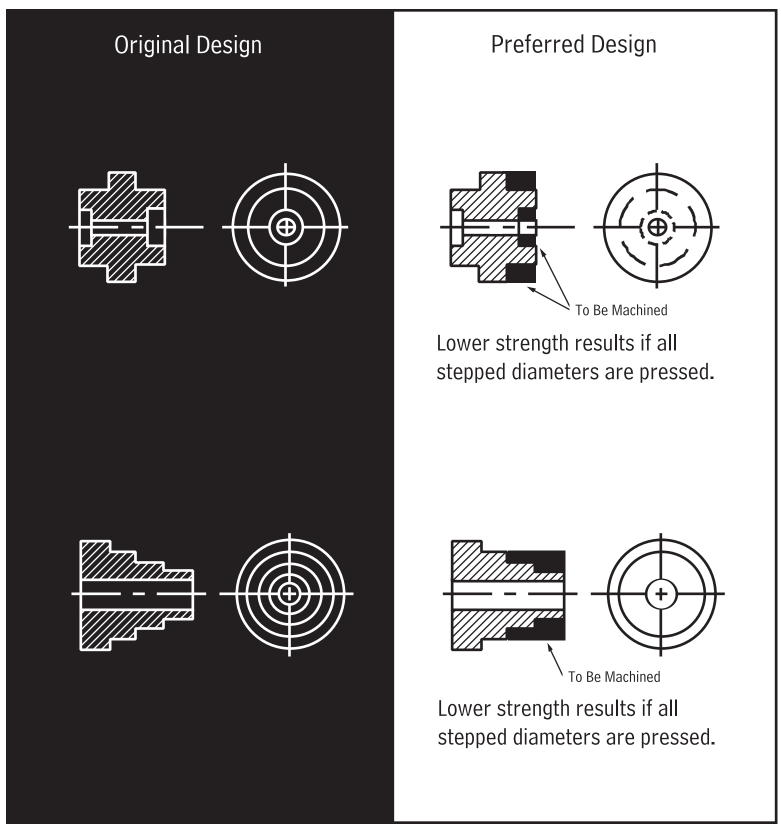
Avoid narrow, deep splines in the part.

Flats eliminate sharp edges on tools and strengthen die. A 45° chamfer permits use of stronger tools.

Tapered counterbore assists tool removal.

4. The part should have as few diametral and axial variations as possible.

    - Strength and uniform density are difficult to maintain when multilevel tooling is used.



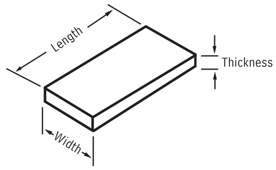
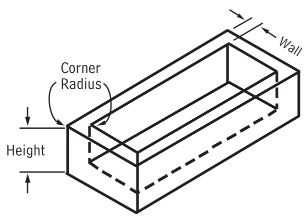
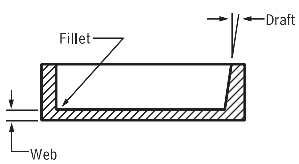
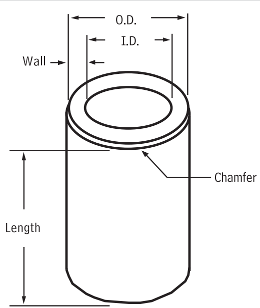
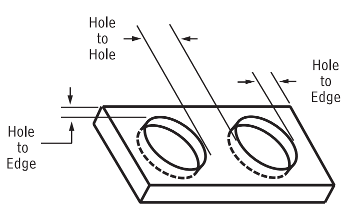
Lower strength results if all stepped diameters are pressed.

Lower strength results if all stepped diameters are pressed.

C. Capabilities and Tolerances

After the sintering process, the ceramic material is referred to as being in the as-fired state. Tables II and III provide as-fired dimensional capabilities and tolerances. For precise tolerances, fine surface finishes and superior flatness, post-fire machining may be required (reference Table IV). Dimensional tolerances should only be specified as tight as is necessary to facilitate assembly and optimum performance.

Table II: Typical As-Fired Capabilities

Typical Part Configuration	Characteristics	Guideline
	Length x Width	Maximum 12 Square Inches
	Thickness	Minimum 0.025" Maximum 2.5"
 	Wall Thickness	Minimum 0.020"
	Wall/Web Thickness Ratio	Typical 1:2
	Corner Radius	Minimum 0.008"
	Fillet	Minimum 0.008"
	Draft Angle	Typical 17°
	Wall Thickness/Height Ratio	Typical 1:4
	Wall Thickness/Length Ratio	Typical 1:5
	Chamfer/Edge Break	Minimum 45° x 0.010"
	Hole Diameter	Minimum 0.015"
	Hole Diameter/Thickness Ratio	Minimum 0.020" NLT Part Thickness
	Hole to Hole	Minimum 0.020" NLT Part Thickness
	Hole to Edge	Minimum 0.020" NLT Part Thickness

Notes:
1. If your design does not comply with this specification, we may still be able to satisfy your design requirements. Please contact your CoorsTek sales representative for more information.
2. NLT = not less than.

Table III: As-Fired Dimensional Tolerances	
Dimensional Criteria	**Tolerances**
Length, Width and Hole Centers	± 1.0% NLT ± 0.003" (±0.08 mm) Standard ± 0.5% NLT ± 0.003" Precision
Thickness	± 3.0% NLT ± 0.002"
Camber	0.003 in./in., NLT 0.003 in.
Edge Breaks	0.015" Max
Fillets	0.015" R TYP
Hole Diameter 0.015" to 0.029" 0.030" to 0.100" > 0.100"	 ± 0.002" ± 0.003" ± 1.0% NLT ± 0.004"
Perpendicularity (X-Y Axis)	≤ 0.003 in./in., NLT 0.002 in.

Notes:
1. If your design does not comply with this specification, we may still be able to satisfy your design requirements. Please contact your CoorsTek sales representative for more information.
2. NLT = not less than.

Table IV: Post-Fired Machining Tolerances	
Dimensional Criteria	**Tolerances**
Length	± 0.0025" Standard ± 0.0010" Precision
Width	± 0.0025" Standard ± 0.0010" Precision
Thickness	± 0.0005" Standard ± 0.00015" Precision
Inside Diameter	± 0.0025" Standard ± 0.0010" Precision
Outside Diameter	± 0.0030" Standard ± 0.0003" Precision (Dia. < 2") ± 0.0010" Precision (Dia. > 2")
Flatness Length ≤ 1" Length > 1" and < 3"	 ± 0.0005 in./in. Standard ± 0.0001 in./in. Precision ± 0.0007 in./in. Standard ± 0.0002 in./in. Precision

Notes:
1. If your design does not comply with this specification, we may still be able to satisfy your design requirements. Please contact your CoorsTek sales representative for more information.

D. Additional Services and Capabilities

1. Design Consultation
   We encourage the design and/or manufacturing engineer to work closely with CoorsTek®. This teamwork improves part design, part yields, efficiency, and overall customer satisfaction.
2. Custom Grinding and Finishing
   For closer dimensional tolerances and special surface finish requirements, CoorsTek offers precision machining processes to meet your most exacting specifications. These in-house capabilities include:
   - Single face grinding/lapping
   - Double face grinding/lapping
   - O.D. and I.D. grinding
   - Edge grinding
   - Honing
   - Polishing
3. Metallizing
   CoorsTek provides refractory metallization (moly-manganese and tungsten metallization), as well as, various thick-film precious metal compositions. Additional, nickel and gold plating and brazing technology for ceramic to metal assemblies. We strive to deliver the prototypes and custom metallized parts in the most cost-effective and timely manner possible.
4. Analytical and Material Testing Services
   The CoorsTek Analytical Laboratory offers a wide variety of services from analytical chemistry to materials testing and detailed failure mode analysis. Trained professionals using the latest techniques and state-of-the-art instrumentation are on hand to provide accurate solutions to fit your particular needs.

IV. Inspection Methods

A. Length/Width

The length and width dimensions are inspected using one or more of the following:

- Anvil micrometers, 0.080" or 0.250" diameter (depending on overall size of the part)
- Dial calipers
- Computer-enhanced optical equipment

B. Thickness

Thickness is measured using an 0.080" or 0.250" diameter anvil micrometer (depending on overall size of the part).

C. Hole Location

The hole location is inspected using a computer-enhanced coordinate measuring system.

D. Surface Finish

Surface finish is measured in microinches with a profilometer using a 0.030" cutoff with a 0.0004" radius stylus.

E. Surface Porosity
Dye penetrant is used to determine surface porosity.

F. Diameter
Inside and outside diameters are inspected using one or more of the following:
- Plug gauge
- Ring gauge
- Micrometers
- Calipers
- Optical methods
- High-precision pneumatic gauge

G. Camber Test Method
Camber is measured using two ground, parallel plates spaced at a fixed distance by the following formula:

D = T + (C x L)

where:

D = the camber distance setting
T = part mode of thickness, where the mode is defined as the value most frequently measured
C = camber value (reference part drawing)
L = part length or maximum outside dimension

Part mode of thickness "T" is established using an 0.250" diameter anvil micrometer. The thickness of each sample piece is measured to the nearest 0.0005" at any point away from the edge. The measured values are plotted (written down) until a mode of thickness value is determined.

Example: For a nominal 2.0" x 1.0" x 0.025" part:

measured mode of thickness **T** = 0.0255"
camber value **C** = 0.003 in./in.
maximum outside dimension **L** = 2.0"

Maximum camber allowed:
D = 0.0255 in. + (0.003 in./in. x 2.0 in.) = 0.0315 in.

To inspect for camber, parallel plates are set at a 45° angle with a gap equal to the "D" value determined in the formula. Parts that pass through the gap under their own weight are acceptable.

H. Visual Inspection Methods for Surface Imperfections
Visual examination for surface imperfections (see page 13 & 14) is performed at an oblique angle, using the unaided eye, under an appropriate light source.

V. Quality Assurance

A. Quality System
The latest measurement and test system technologies assure that customer-specified quality levels are achieved on a continual basis. The CoorsTek® quality system has been successfully audited to MIL-I-45208 Inspection Requirements along with our Metrology group which is qualified to MIL-STD-45662 Calibration System Requirements. Many of our personnel (engineers, technicians, inspectors) have been certified by the American Society for Quality Control. CoorsTek is ISO 9001 registered.

B. Process Overview

The CoorsTek® Quality Program encompasses every aspect of design, production, inspection, and testing processes. Our automated process control overview network controls critical process steps during manufacture. Progressive and innovative, CoorsTek is on the cutting edge of total quality management.

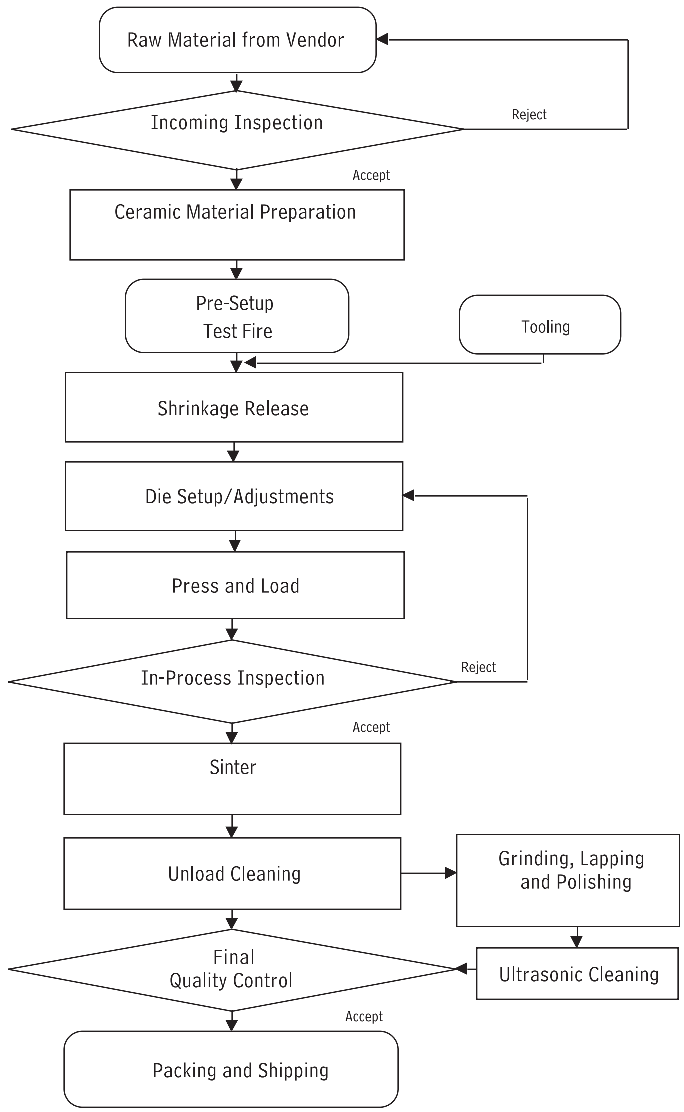
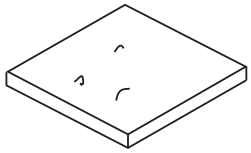
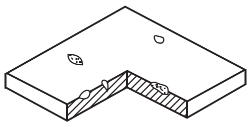
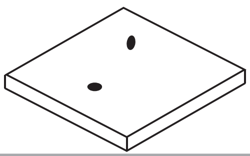
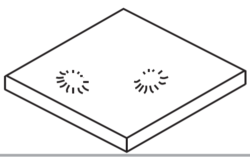
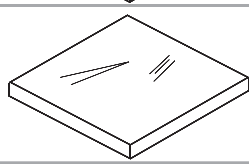
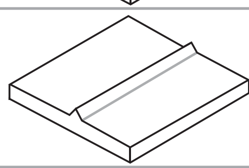
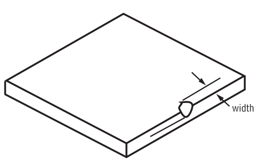
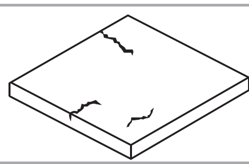
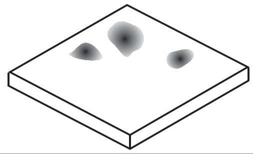
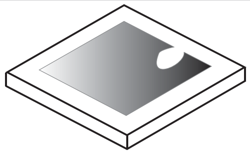
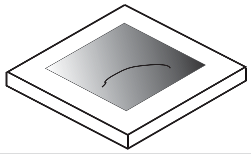
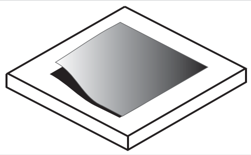
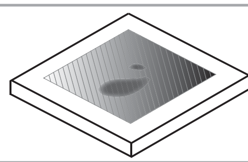
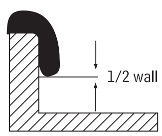
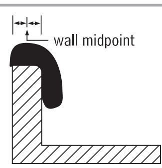


Table VI - Surface Imperfections

Visual Attribute		Acceptance Criteria		
		Ceramic	Metallized*	Epoxy
Burrs/Flashing Fragments of excess material (MBU) or foreign particle adhering to the surface Excessive material/ MBU: OD/ID		None > 0.001" high OD/ID acceptable if within dimensional tolerances	Same as Ceramic	Same as Ceramic
Pits, Holes, and Pocks A deep depression or void		None > 0.010" diameter	None > 0.010" diameter	N/A
Stains, Spots Contamination		None allowed	Metallic Contamination ≤ 0.010" diameter	N/A
Blisters Bubbles or gaseous inclusion at the surface which, if broken, could form a pit, pock, or hole		None > 0.001" high None > 0.012" diameter	≤ 0.010" diameter for a single blister, multiple allowed if ≤ 0.003" diameter; can not reduce seal width by more than 10%; no blisters of plated metals allowed	None allowed in epoxy
Scratches Relatively long, narrow, shallow groove or cut in the surface		None > 0.001" deep	Allowed on surface as long as base material is not exposed	N/A
Bumps, Fins, Ridges Long, narrow protrusion on the surface		None > 0.001" high	None > 0.001" high	N/A
Chips Open - Material broken off along an edge or corner Closed - Material has not broken off or separated		**Open and closed chips allowed to following size limits:** Substrates (Plates) & Other Ceramic up to 0.060" Thickness - 0.015" width, depth not to exceed 50% of part thickness by unlimited length Substrates & Other Ceramics 0.060" to 0.250" Thickness - 0.20" width, depth not to exceed 50% of part thickness up to 0.060" by unlimited length Other Ceramic > 0.250" Thickness - 0.030" width x 0.060" depth x unlimited length		
Cracks Line of fracture without complete separation		None allowed	None allowed in ceramic	None allowed in ceramic
Porous Area An area that will retain dye, and if broken through at the porous area, will show evidence of dye penetration into the body		None allowed	None allowed in ceramic	None allowed in ceramic

Notes:
1. MBU = materials build up
2. UOS = unless otherwise specified

* For further information on CoorsTek metallization capabilities please refer to CoorsTek "Thick-Film Coating Design Guide" (Document #8510-1044)

Table VI - Surface Imperfections....Continued				
Visual Attribute		Acceptance Criteria		
		Ceramic	Metallized	Epoxy
Bare An area not fully covered by metallization, glaze or epoxy. The base material is exposed		N/A	None > 0.010" diameter	Epoxy must cover 50% of wall seal area at any given spot
Lint or Foreign Material		N/A	≤ 0.015" acceptable	None allowed unless approved by customer
Peeling Metallization		N/A	Per tape test, none allowed	N/A
Metallization Pattern Smears or Stains		N/A	Metallization pattern smears - allowable if within pattern tolerances Stains - allowed if parts pass solder/braze test, where applicable	N/A
Epoxy Rundown		N/A	N/A	1/2 the wall height allowed - UOS by customer
Epoxy Thickness		N/A	N/A	Measured at the midpoint of the wall
Sampling Plans Visual/Dimensional Tooled feature verification or destructive test		 C=0 @ 1.5 UOS 3 pieces - regardless of lot size - UOS	 C=0 @ 1.5 UOS 3 pieces - regardless of lot size - UOS	 C=0 @ 1.5 UOS 3 pieces - regardless of lot size - UOS

Notes:
1. MBU = materials build up
2. UOS = unless otherwise specified

Metallization Visual:
Gross visual to be performed at 10x, UOS
Epoxy Visual:
Gross visual to be performed via a ring light magnifier with a diopter 3-10, UOS

VI. Properties

The chart is intended to illustrate typical properties. Engineering data is representative. Property values vary somewhat with method of manufacture, size, and shape of part. This data is not to be construed as absolute an does not construe a warranty for which we assume legal responsibility.

Table VII - Typical Material Characteristics

Characteristics	Unit	Test Methods	ADO-90	AD-94	AD-96	AD-995
Alumina Content (nominal)	Weight %	ASTM-D2442	92	94	96	99.5
Color	–	–	Brown/Black	White	White	White
Nominal Density	g/cm^3	ASTM-C20	3.78	3.70	3.75	3.89
Hardness	–	ASTM-E18, R45N	75	78	82	83
Surface Finish	Mircoinches CLA	Profilometer				
As-Fired		0.030" Cutoff	35	35	35	35
Ground		0.0004" Radius Stylus	20	20	20	20
Lapped		ANSI/ASME B46.1	12	12	12	12
Grain Size	Microns	Intercept Method	–	12	4 - 7	17
Water Absorption	%	ASTM373	nil	nil	nil	nil
Gas Permeability	–	**	nil	nil	nil	nil
Flexural Strength @ 20° C	Kpsi	ASTM-F417	53	51	52	55
Elastic Modulus @ 20° C	10^6 psi	ASTM-C848	45	43	44	54
Poisson's Ratio @ 20° C	–	ASTM-C848	0.24	0.21	0.21	0.22
Coefficient of Linear Thermal Thermal Expansion	10^{-6}/°C	ASTM-C372				
25°- 200° C			7.2	6.3	6.3	7.1
25°- 500° C			7.8	7.1	7.1	7.6
25°- 1000° C			8.4	7.9	8.0	8.3
Thermal Conductivity	W/m°K	ASTM-C408				
20° C			12.6	18	26.0	35.6
100° C			11.3	14.2	20.0	25.9
400° C			7.5	7.9	12.0	12.1
Dielectric Strength	AC Volts/mil	ASTM-D149				
0.025" Thick			540	550	600	580
0.040" Thick			415	425	–	430
Dielectric Constant @ 25° C	–	ASTM-D150				
@ 1 KHz			–	8.9	9.5	9.8
@ 1 MHz			–	8.9	9.5	9.7
Loss Tangent @ 25° C	–	ASTM-D150				
@ 1 KHz			–	0.0002	0.0010	0.0002
@ 1 MHz			–	0.0001	0.0004	0.0003
Loss Factor @ 25° C	–	ASTM-D150				
@ 1 KHz			–	0.002	0.009	0.002
@ 1 MHz			–	0.001	0.004	0.003
Volume Resistivity	ohm-cm	ASTM-D1829				
25° C			$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$
300° C			5.5×10^{10}	9.0×10^{11}	5.0×10^{10}	$> 10^{11}$
500° C			–	2.5×10^{9}	1.0×10^{9}	$> 10^{9}$
700° C			1.7×10^{6}	5.0×10^{7}	4.0×10^{7}	$> 10^{8}$

Note: The chart is intended to illustrate typical properties. Engineering data is representative. Property values vary somewhat with method of manufacture, size, and shape of part. Any suggested applications are not made as a representation or warranty that the material will ultimately be suitable for such applications. The customer is ultimately responsible for all design and material suitability decisions. Data contained herein is not to be construed as absolute and does not constitute a representation or warranty for which CoorsTek assumes legal responsibility. ANY WARRANTY OR REPRESENTATION FOR WHICH COORSTEK IS RESPONSIBLE SHALL BE SUBJECT TO A SEPARATELY NEGOTIATED AGREEMENT.

European Union (EU) Directive on Restriction of Hazardous Substances (RoHS): The EU Directive on RoHS specifies that an electronic product or component may not contain a listed substance except as specifically provided in the directive. CoorsTek ceramic substrates meet the requirements of the Directive.

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