# M.I. what???

A Mineral Insulated (MI) Cable is a metallic cable with ceramic powder insulation packed tightly around the inner wires. Insulators for use in Mineral Insulated Cable production go by many names including **crushable insulators, swageable insulators, preforms, beads, pellets, cores, or blocks**. This is a uniquely engineered product which is designed to crush into a fine powder upon compression by modest forces.

MI Cable is made by stringing ceramic preforms with thermocouple element wires and loading the threaded assembly into a refractory metal sheath. This assembly can then be subjected to a series of drawing operations to reduce the diameter and elongate the part. The end result is a long coil of small diameter cable with a tight packing of ceramic powder to electrically insulate the wires and sheath.

Dimensionally, the requirements are obvious. Tight dimensional control is needed to permit design engineers to adequately predict the finished results. The holes must be properly positioned and accept the wire under all combinations of tolerance limits. The threaded assembly must fit into the sheath in very long lengths. The ends need to be square and smooth to prevent voids which may cause elongation problems. Because the assemblies usually consist of many insulators strung together, length tolerances are not critical, but uniform lengths are easier to use.

## The 3 keys to success: Microstructure, Microstructure, and Microstructure

1) Proper particle size distribution of the starting powder insures that the insulator will be densely compacted to prevent movement of the conductors and excessive elongation.

2) Too high a surface area in the starting powder can result in a fired body with vitrified bonds which fail to crush properly and create large agglomerates that can damage wires. This also leads to wide variation of strengths in the fired parts due to firing inhomogeneity.

3) The starting raw material must not have large grains (>75μ)which promote wire damage during the drawing and elongation process. When the ceramic crushes, it's gotta crush into a fine powder, not an abrasive rock!

OZARK engineers the microstructure by powder processing, not by "finesse" firing. This gives a reproducible microstructure under many firing conditions, and guarantees proper performance in the swaging and drawing operations.

## We voted the Gas Kilns off the Island!

OZARK fires in Electric Kilns designed and furnished specifically for MgO firing. The oxidizing atmosphere guarantees zero carbon, sulfur, and chlorine content in the fired product (with gas kilns….who knows?). The precision control of ramp rates prevents warpage and bad camber results. The kiln uniformity guarantees consistent results.

*Not quite ready to unload!*

## The OZARK difference…

Dimensional problems with crushable insulators are obvious and easily managed. Most performance problems are related to the strength and/or microstructure. OZARK does not depend on firing to develop our microstructure and strength, and are not at the mercy of the variables of the kiln environment such as position, cycle times, etc.. It is impossible to expose every part to the identical thermal environment during firing, so it is very risky to "fire to spec". By designing for a fully fired body, our parts get to the right strength and hardness properties, then quit as fully developed parts.

## That's our final answer!!!

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## INTRODUCTION

OZARK extrudes insulators from MgO, Al2O3, and HfO2 for use in production of mineral insulated thermocouple cable, cartridge heaters, and other high temperature and electrical applications. Extrusion is a ceramic manufacturing technique which produces any shape with a constant cross section and theoretically unlimited length. A mix containing the desired ceramic powder and various organic additives is forced through a die opening configured to give the required geometry which may include holes of precise shape and size. The extrudate is subsequently dried, fired, cut, inspected and packaged for shipment. Precise control of process variables is required to obtain high quality extrusions meeting purity, microstructural, and dimensional specifications.

**CRUSHABLE INSULATORS** - These insulators, also known as preforms or cores, are designed to be easily crushed in the manufacturing operation. They are referred to interchangeably as crushable, soft-fired, or swageable. They may be designed to crush very easily to protect soft platinum components, or with more integrity to improve handling and performance properties. Please refer to the strength specifications.

**HARD-FIRED INSULATORS** – These insulators are meant to be suitable for free standing use without a metallic sheath or support. Standard dimensional tolerances for hard-fired insulators are more liberal. Hard fired extrusions may find other applications in metallurgical, mechanical, and refractory applications.

**MATERIAL/PURITY -** See specifications for purity analysis of standard magnesium oxide and aluminum oxide grades. Other materials are available on request or by custom order.

The following are typical analyses or limits for powders used to produce extruded insulators. All raw materials are high quality fused grain powders which are processed in-house to obtain optimum particle size distributions for end use as crushable or swageable thermocouple insulators.

| CONTENT | CUM MgO | CHM MgO | CTM MgO | CCA $Al_2O_3$ | CUH $HfO_2$ |
|---|---|---|---|---|---|
| MgO (%) | 99.85 | 99.47 | 97.44 | .0003 | ND |
| $Al_2O_3$ (%) | 0.01 | 0.03 | 0.36 | 99.99 | .050 |
| $SiO_2$ (%) | 0.04 | 0.12 | 1.41 | 0.005 | <.02 |
| $Fe_2O_3$ (%) | 0.04 | 0.06 | 0.06 | 0.003 | <.02 |
| CaO (%) | 0.05 | 0.31 | 0.73 | 0.001 | ND |
| B (PPM) | 3 | 25 | <30 | ND | ND |
| Cd (PPM) | <10 | <10 | <30 | ND | ND |
| S (PPM) | <10 | <10 | <10 | ND | ND |
| C (PPM) | <10 | <10 | <10 | ND | ND |

**STRENGTH –** Insulators are fired to uniform mechanical strengths which have been established for optimum handling and swaging characteristics for different applications. The present test standard is the Modulus of Rupture (MOR) test. OZARK offers the following guidelines for MOR spec ranges:

| MOR range | Description | Grades | Recommended Uses |
|---|---|---|---|
| 2000-4000 | soft | SHM, CCA | Platinum thermocouple, >.75" OD thermocouple |
| 3000-6000 | medium soft to medium | CHM, CTM | Thermocouple |
| 4000-8000 | medium | CTM | Thermocouple, coil heater on ID, Cold Core |
| 5000-10000 | medium hard | CTM | Cartridge Wind Core, Cold Core |
| 7000-12000 | hard | BTM | Small OD Cartridge Core, tubular core, spacer stock |

MOR values are psi as measured by a three point flexural beam tester.

# OTC Ozark Technical Ceramics, Inc.

# CD12 / (CA4) - Tech Bulletin
# Extruded Insulators Specs

*The following information indicates some of the principles for acceptable design limits and the most cost-effective design parameters. This is intended as a guide for developing hole sizes and positions for best production efficacy, but external factors may require compromises with production ideals.*

**O.D. (OUTSIDE DIAMETER) –** Nominal O.D. sizes may be specified to the nearest .001" increment from 0.030" to 1.250 inch for crushable insulators, and from 0.030" to about 0.500" for hard fired insulators. OZARK has over 300 round dies in inventory, including most sizes up to 0.5". Modest tool charges (about $200 per inch OD size) may apply for parts over 0.5" if a nearby size is not available.
Non-round parts are made in shaped dies, and there are fewer sizes available in-house. OZARK maintains blanks which can be finished with good turnaround times, at a price of about $300/inch dimension.
Default Tolerances- the larger of +/- .003 inch or one percent of the nominal dimension. The O.D. is determined as the average diameter of the part measured in at least two places. The OD of the lot is considered within spec if the average OD of the lot is within the tolerance limit.

**I.D. (HOLE SIZE) -** The minimum standard hole size is the lesser of .010 inch, or 15% of the OD. Smaller holes ratios can be produced with less control of the hole position. The Maximum hole size is dictated by the wall and web thickness criteria (see table below). Closely spaced holes may result in "teardrop" shaped holes, or web knitting problems.

Default Tolerances- .002 inch plus 2% of the nominal hole size. Example: For a .050 hole size, the hole tolerance is computed at .003 inch, because .002 + (2% x .050) = .003. The hole size is defined as the largest pin gage size (to the nearest .001 inch) that slides freely through the part.

**CONFIGURATION and BOLT CIRCLE -** Standard configurations are defined by having equal web and wall spacings. Symmetric designs are preferable, but not mandatory.

Thin webs and walls lead to misshapen holes due to the tendency to collapse into the neighboring hole. Insulator shape cannot be guaranteed for wall or web thickness less than the hole size. The minimum size limit for wall and web thickness is 50% of the neighboring hole size. Large holes may result in loss of roundness and potential for thin webs and/or walls. The following table indicates the suggested hole size for a standard geometry as a multiple of the O.D.

| NUMBER OF HOLES | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| IDEAL I.D. = O.D. X | .333 | .200 | .188 | .171 | .156 | .142 | .131 | .122 |
| MAXIMUM I.D.÷ O.D. | .700 | .286 | .268 | .243 | .220 | .200 | .183 | .169 |

Any other configuration may be specified within fabrication limitations. Center holes may be added, and unequal hole sizes may be specified. Please contact us with your request for optimum design specifications for special configurations.

**LENGTH –** Any nominal length may be specified between 0.5 and 9.5". There is a premium for lengths under 2" or over 8", and for L/D ratios over 30. If your specs permit a small percentage at a shorter length, then the production yield will improve by the reworking of chips and small flaws.

Default Tolerances- There are no standard specifications for length unless requested by the user. Normally parts are cut in three-inch and/or four-inch lengths within +0.25 / -0 inch tolerance.

**STRAIGHTNESS -** Camber is inspected by rolling the insulators between plates of glass set at the maximum permissible spacing as determined by the operating spec and the nominal length of the parts.

Default Tolerances- The default tolerance for crushable thermocouple insulators is .003 in/in. The default tolerance for heater grade products is .006 in/in. All hard fired insulators are on a "best efforts" basis unless otherwise specified, and OZARK recommends a design cushion of .005 in/in.

**TWIST -** Twist is overchecked by spot inspection of samples for the lot.

Default Tolerances- Crushable insulators may have up to 5 degrees/inch. Heater products are to average less than 20 degrees per full length. Hard fired insulators may be up to 10 degrees/inch.

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