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Standard Classification for Advanced Ceramics[1]

This standard is issued under the fixed designation C 1286; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This classification covers a system by which advanced ceramics may be classified. The system has been devised to cover all types of advanced ceramics in the forms of inorganic precursors for ceramic powder production, powders, granular forms, fibers, whiskers, platelets, single crystals, consolidated polycrystalline ceramics, amorphous (glassy) and composite materials, and components in block and coating forms. The structure of the classification system is coded to be machine readable.

1.2 The classification system has been developed through an international collaboration under the auspice of the Versailles Advanced Materials and Standards Project (VAMAS) Technical Working Area 14, and with support from the Commission to the European Communities, ASTM Institute of Standards Research, and the Japan Fine Ceramics Association. Its construction was based on the results of an international survey of requirements among manufacturing and user industries, and recommendations provided at an international workshop held at Ispra, Italy, in June 1990.

1.3 The present range of products that is encompassed by the term *advanced ceramics* or one of its synonyms is enormous in breadth, and complex in chemistry, form, processing route, and property attributes. Normally, there are close interlinks between these factors. It has therefore been impossible to devise a simple hierarchial scheme, such as that used in IEC 672 for electrotechnical ceramics for insulators. The system developed and incorporated in this classification is novel in many respects to encompass all foreseen requirements and purposes, and all raw and manufactured materials and applications. It has great flexibility and is amenable to computer recognition and programming.

1.4 *System Constraints*—It is not the purpose of this classification to specify how the system shall be used. The user is able to define the coding combination and the level of detail to suit a particular purpose. This classification provides only a flexible framework within which this might be done.

1.4.1 The classification system includes only those ceramic products defined and designated by ceramic manufacturers, trade associations, and professional societies as advanced ceramics (see 3.1.1). On this basis, the classification system does not cover:

1.4.1.1 Elemental carbon, except for specific ceramic forms such as diamond, vitreous carbon, and chemical vapor deposit (CVD) graphite;

1.4.1.2 Elemental silicon, elemental germanium, and other elemental or compound semimetallic (intermetallic) substances other than when they form an integral component of, or precursor for, an advanced ceramic;

1.4.1.3 Traditional ceramics based on clay, including: porcelains; whitewares; sanitary wares; floor and wall tiles;

1.4.1.4 Unshaped and shaped refractories and bulk glasses for tonnage applications; and

1.4.1.5 Flat or container glass.

1.4.2 This classification provides a classification system framework that allows comparison and correlation of collected data/information with that gathered under other classification systems, such as the Standard Industrial Classification (SIC) code and the international convention on the Harmonized Commodity Description and Coding System. The SIC is the statistical classification standard underlying all establishment-based U.S. Federal economic statistics classified by industry. The SIC code covers the entire field of economic activities and defines industries in accordance with the composition and structure of the economy. The Harmonized System, an international system designed to standardize commodity classification for all major trading nations, in a relational way is similar to the SIC system.

1.4.3 Currently, advanced ceramics are not represented as a specific code field in either the SIC or the Harmonized System, but are included in other categories where other material classes dominate and in which the advanced ceramics comprise only a small fraction of the end products of the classification.

1.4.4 This standard recognizes the relationship between classification systems, but does not present a detailed crosswalk between individual system fields. This relationship is illustrated by the following examples:

1.4.4.1 In structural applications, advanced ceramic products are found in motor vehicle parts and accessories (SIC 3714), steam, gas, and hydraulic turbines (SIC 3511), motors and generators (SIC 3621), aircraft engines and parts (SIC 3724);

1.4.4.2 In mechanical applications, advanced ceramic products appear in cutting tools (SIC 3545), ball and roller bearings (SIC 3562), pumps and pumping equipment (SIC 3561), and

[1] This classification is under the jurisdiction of ASTM Committee C-28 on Advanced Ceramics and is the direct responsibility of Subcommittee C28.91 on Nomenclature.

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fabricated metal products (SIC 3499); and

1.4.4.3 Applications in electronics are found in electronic capacitors (SIC 3675), semiconductors (SIC 3674), electronic resistors (SIC 3676), and electronic components, not elsewhere classified (SIC 3679).

1.5 For related information, see Reynard,[2] Cotton,[3] Schneider,[4] and *Standard Industrial Classification Manual*.[5]

2. Referenced Documents

2.1 *ASTM Standards:*

C 1145 Terminology of Advanced Ceramics[6]

3. Terminology

3.1 Definitions—For definitions of terms not included here, see Terminology C 1145.

3.1.1 *advanced ceramic*—a highly engineered, high-performance, predominantly nonmetallic, inorganic, ceramic material having specific functional attributes.

3.1.1.1 Discussion—This definition has been adopted by the Versailles Advanced Materials and Standards Project (VAMAS) Technical Work Area 14 on classification of advanced technical ceramics. It is recognized that the specific functional attributes result from the rigorous control of composition, processing, and the detailed regulation of highly refined or characterized raw materials during manufacture. Advanced ceramics are known by several alternate pseudonyms such as advanced technical ceramics, engineered ceramics, fine ceramics, etc.

3.1.2 *classification element*—a single term in a classification field.

3.1.3 *classification field*—a set of terms related to one independent aspect or feature of the classification.

3.1.4 *code*—an alphanumeric string with a prescribed definition in terms of material attributes.

3.1.5 *coding element*—a part of a code from one classification field.

4. Significance and Use

4.1 This classification provides a framework whereby all advanced ceramic products can be classified for a variety of purposes, including commercial statistics, market surveys, R&D expenditures, inventories, billings/invoices, specifications, bar coding, material property databases, etc.

4.2 To describe fully the diversity of ceramic materials in various stages of manufacture, it is essential to link chemical composition, form, processing conditions, material properties, and applications in any required combination. The system allows any full or partial combination of these elements to be employed in any sequence for any desired purpose. The elements are described individually in the following sections. Annex A1 through Annex A5 provide a coding scheme and thesaurus for each classification element of the system. Annex A1 through Annex A4 also give a flowchart for the construction of the code for specific classification elements.

4.3 The user should select from the classification fields those relevant to his requirement, and place these in a prescribed order. Examples of some possible combinations are described in Appendix X1.

5. Basis of Classification

5.1 *Introduction*—Since the intention is to provide a capability for classifying any combination of fields in any sequence appropriate to user needs, each field is separately identified by a unique initial letter code:

A = Application
C = Chemcial character
P = Processing method
D = Property characteristics or data
R = Product origin

Note that the form of the product is closely related to chemistry, and is incorporated in the chemistry code.

5.1.1 For the purposes of computer recognition, a strict sequence of classification elements is not required, but for other purposes, such as manual preparation of trade statistics or material specifications, the sequence of classification elements should be chosen and fixed as preferred.

5.1.2 In the following description of code structures, the variable characters in the code are:

X = any appropriate single upper case letter coding character.
n = any appropriate single numeric coding character.

5.2 *Classification Elements for Application Type*—The coding format for this field is *Annn*. The initial character to denote the start of the *application* string is *A*. This is followed by a three-digit number code as listed in Annex A1 for the application areas. In the list, applications are separated into, initially, a hierarchial series of areas by the principal physical function of the product as defined by:

5.2.1 Electrical insulation;

5.2.2 Electronic/ionic conduction;

5.2.3 Mechanical, including wear, at or near ambient temperature;

5.2.4 Thermal, where dimensional stability at raised temperature, heat insulation, heat conduction, or resistance to thermal shock are the principal application features;

5.2.5 Thermomechanical, where both external mechanical loads and elevated temperatures are involved;

5.2.6 Nuclear, where the component plays either an active or a passive nuclear role;

5.2.7 Optical, where the component plays a functional role as an optical element in reflection, refraction, transmission, or absorption of electromagnetic radiation;

5.2.8 Chemical, including biomedical, where the component is employed for handling melts, chemicals, solutions, or atmospheres because of its resistance to attack by them, and in the case of biomedical materials, a degree of bioinertness;

[2] Reynard, K. R., "Proceedings of Workshop on Classification of Advanced Ceramics," Ispra, June 1990, Elsevier, London, published in Ceramics International, 1993, 19(1), 1 et seq.

[3] Cotton, J. W., Everill, J. B., "Report to VAMAS TWA14—A Unified Classification System for Advanced Technical Ceramics," British Ceramic Research Ltd Report to VAMAS TWA14, November 1992.

[4] Schneider, S. J., Ed., "Final Report of VAMAS Technical Working Area 14, Classification of Advanced Technical Ceramics," VAMAS Report No. 15, ISSN 1016-21866, July 1993.

[5] *Standard Industrial Classification Manual*, Executive Office of the President, Office of Management and Budget, National Technical Information Service, Springfield, VA, Order No. PB 87-100012, 1987.

[6] *Annual Book of ASTM Standards*, Vol 15.01.

5.2.9 Magnetic, where the component possesses properties allowing a functional magnetic role.

5.2.10 The first digit of the three-digit code is given to correspond to the principal physical function, listed in 5.2.1 through 5.2.9. The subsequent digits are nonhierarchial, and follow the listing in Annex A1.

NOTE 1—It may not always be possible to assign a particular product to one of the listed codes. In such a case, the use of the code representing *other* applications should be employed.

5.3 *Classification Elements for Chemical Character*:

5.3.1 This field contains information relating to chemistry and form, and is identified by the letter C. Annex A2 details the field coding method to describe chemistry and form. Due to the relatively complex chemistry and the likelihood of the presence of a number of compounds and forms, this part of the coding system is required to be particularly versatile. The chemical character code should contain at least three essential items of information:

5.3.1.1 Identifier letter (C);

5.3.1.2 Overall form of the item, that is, powder, fiber, monolithic, etc; and

5.3.1.3 Numerical identification of the chemical formula or material type.

5.3.2 Subsequent coding items may be included to identify the form and chemistry of minor constituents. In these cases the form descriptors also act as separators between related compounds.

5.3.3 *Options for Numerical Codes*:

5.3.3.1 The complexity of the chemistry associated with advanced technical ceramics places a heavy responsibility on the numerical coding system used to describe it. A number of options are given to accommodate chemical formula, individual compounds, form descriptors, and to identify purity and compositional range.

5.3.3.2 The options are based on a four-digit code to denote chemical formula or material type and form. A list of code numbers and associated definitions are given in Annex A2.

5.3.4 *Procedures for the Definition of Chemical Purity or Purity Range*:

5.3.4.1 *Procedure 1*—The inclusion of a fifth digit indicating the quantity of the material defined by the preceding four-digit code. The fifth digit would indicate the mass percentage concentration in accordance with the following:

1 ≤ 1 %
2 > 1%, ≤ 10 %
3 > 10 %, ≤ 30 %
4 > 30 %, ≤ 50 %
5 > 50 %, ≤ 70 %
6 > 70 %, ≤ 90 %
7 > 90 %, ≤ 99 %
8 > 99 %

If the value is undefined or undefinable the character may be omitted.

5.3.4.2 *Procedure 2*—The inclusion of purity or concentration level in parentheses (. . .) following the four-digit code. The use of this option should be governed by a set of rules as follows:

(*1*) The sole presence of a number within the parentheses indicates the % of the material present. For single constituent strings this figure would define the purity level; for multiple items, that is, where the chemical character is described in the long form, this would denote composition.

(*2*) The presence within the parentheses of < or > followed by a number indicates the maximum or minimum content of the constituent. For example, (<90) indicates maximum content 90 % and (>99.9) indicates minimum 99.9 % content (probably used to signify purity).

(*3*) The presence within the parentheses of two numbers separated by a hyphen indicates a range of composition. For example, (95–98.5) indicates that the material contains between 95 and 98.5 % of the constituent in question. In its simplest form the chemical character code would have the following appearance:

CWBnnnn

where WB identifies the material as fiber blanket and nnnn defines its composition. The format for the chemical character coding could however have the appearance:

CEBxxxx7MEyyyy2MBzzzz1

or:

CEBxxxx(>90)MEyyyy(0.5–4.5)MBzzzz(0.5)

This would indicate that the material was a powder (<100μ diameter) of a compound xxxx (90–99 %) physically mixed (ME) with a chemical compound of yyyy (1–10 %) and zzzz (<1 %).

5.4 *Classification Elements for Processing Method*—The initial character indicating *process* type is *P*. It is followed by a two-digit numerical code selected from the semi-hierarchial list given in Annex A3. Each of the codes represents a description of a single process at a particular stage in the manufacture of a product. If more than one identifiable process is needed to classify a product, the process code is repeated as required:

PnnnPnnnPnnn . . . . . .

5.5 *Classification Elements for Property Characteristics or Data*—Many ceramic products are developed for specific property attributes appropriate to particular end uses. If it is required to provide a classification element to define the *properties* or *characteristics*, this is done using a code with an initial letter *D* (data). This is followed by a string of 3 to 6 numerical characters defined according to the matrix in Annex A4. The first of the numerical characters defines the property class, the second and third defines the property type within that class. The fourth and subsequent characters identify either a value class for the property when measured in accordance with a specified test procedure. If the particular generic property feature cannot be classified in a consistent or well-recognized numerical form, but is a material attribute, this is indicated by using only the first three characters.

5.5.1 If more than one property characteristic is required, the code D is repeated, that is, DnnnDnnnnnDnnn. . . . . represents three property features of particular relevance.

NOTE 2—It is envisaged that property classification elements could be replaced by a more-detailed data base when this is desired, the other classification elements being employed to define uniquely the ceramic product application chemistry, processing, and any other feature of the material or component. *The property measurements used for the classification system, shall wherever possible, be measured and reported in*

accordance with approved national or international standards.

5.6 *Classification Elements for Product Origin*:

5.6.1 This field is uniquely identified by the initial letter R. The field is intended to identify the place and date of product manufacture, as defined by codes listed in Annex A5.

5.6.2 The code for the place of manufacture is based on the international telephone code and consists of a country and city (or local region) numeric identifier string. The date of manufacture is identified by a 2-digit number corresponding to the month (January = 01; December = 12) and by a 4-digit number correspondidng to the year (19yy; 20yy).

5.6.3 The coding format for this descriptor will be:

Rnnnnbbbbxxyyyy

where nnnn is the country code, bbbb is the local area code, xx is the month code, and yyyy is the year code.

5.7 *Other Classification Fields*:

5.7.1 While not included as a part of this classification, additional classification elements may be employed for further features associated with a product as required by the application of the classification, for example, manufacturer name, date of entry of information, statistical data by category, applicable test methods, related other classification codes, etc. If it is desired to include such information, the classification elements should be constructed from agreed tables of codes in the following form:

Xnnn

where X is a unique initial classification field character, and nnn is a three-digit code from the agreed table. In this form, the additional classification elements remain unique and machine readable.

6. Use of the Classification System

6.1 *Introduction*:

6.1.1 The classification system in its entirety represents a fairly complex matrix, the size of which, if the system is used in its entirety, would be unattractive from the user's point of view.

6.1.2 The system has been designed to accommodate all likely inputs in each of the prescribed fields. It is recognized, however, that it is unlikely that the classification system will be used at this level. It is envisaged that:

6.1.2.1 Only a limited number of fields will be used, hence the field identifiers should be readily recognized.

6.1.2.2 Within those fields the information used may be limited to only a few items, hence the order of information should be logical.

6.1.2.3 With use, the regularly encountered items such as specific chemical types will become familiar, hence sectors of the code, such as chemical character, should scan easily.

6.1.2.4 For ease of use, coding lists should be accessible by both item and code.

6.2 *Examples*—Appendix X1 provides examples that are intended to illustrate some of the ways in which the classification system may be used to describe a range of materials and applications.

7. Keywords

7.1 advanced ceramics; advanced ceramic applications; advanced ceramic classification; advanced ceramic database

ANNEXES

(Mandatory Information)

A1. APPLICATION CLASSIFICATION FIELDS

A1.1 This field is uniquely identified by the initial letter *A*.

A1.2 The classification list for applications of advanced technical ceramics is given in Table A1.1. The list is composed of a hierarchy of application types grouped as follows. To assist in the identification of the appropriate class and code as determined by its principal function, an alphabetical index is given in Table A1.2.

NOTE A1.1—Since the application range for advanced ceramic products is widening rapidly, this list may not include recently developed applications. Until the classification is updated, the most appropriate *other* identification should be employed where there is any doubt.

Code No	Application type
100 to 199	Passive electrical applications
200 to 299	Active electrical applications
300 to 499	Mechanical applications
500 to 599	Thermal and thermomechanical applications
600 to 699	Nuclear applications
700 to 799	Optical applications
800 to 899	Chemical applications, including biomedical applications
900 to 949	Magnetic applications
950 to 999	Other applications

A1.3 Some applications may not appear to fall uniquely into a single category listed above by virtue of employing several advantageous features. An example would be chemical plant pump rotating shaft seal. This performs a mechanical function in a chemical environment and is listed under mechanical applications. An index is provided to assist location in the list.

A1.4 A flowchart for construction of the code for applications, which is to be used in conjunction with this annex, is shown in Fig. A1.1.

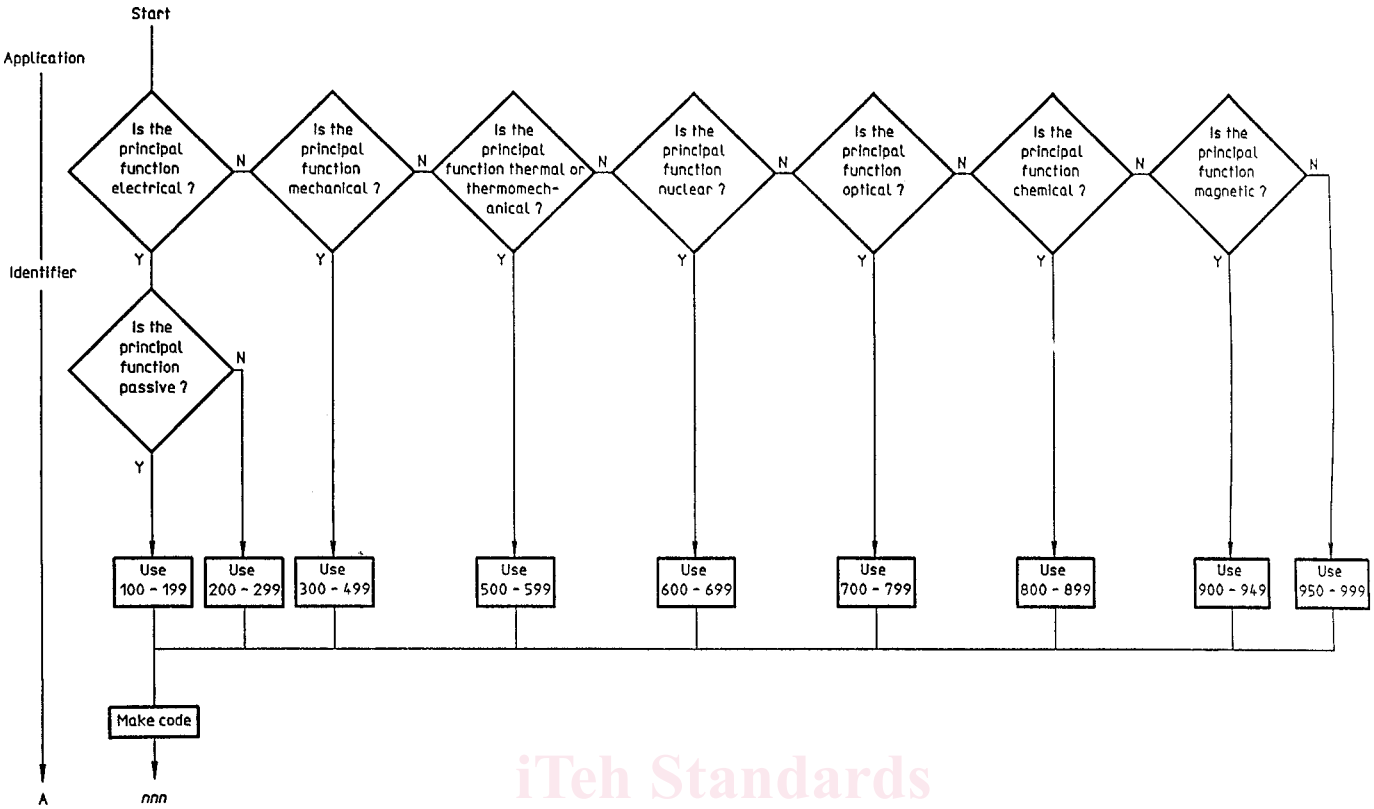

FIG. A1.1 Flowchart for Construction of the Code for Applications

TABLE A1.1 Classes of Applications

100 to 199 Passive Electrical Applications	
Power insulators:	
101	Structural electrical power insulators
102	Small low-tension electrical insulators (for example, standoff insulators, bus bar supports, terminal blocks)
103	Spark plug insulators
104	Igniter insulators
105	Glow plug insulators
106	Eyelets and cable cleats
107	Bushes, sleeves—up to 200°C
108	Bushes, sleeves—above 200°C
109	Aerial insulators
110	Low-power coil formers
111	High-power coil formers
112	Precision coil formers
113	Coil formers for high-frequency applications
114	Coil formers for high-temperature applications
115	Low-power fuse bodies
116	High-power fuse bodies
117	Vacuum envelopes
118	Vacuum leadthroughs
119	Electrical insulators for use in vacuum
120	Other electrical components for use in vacuum
139	Other power electrical insulators
Insulators for electronics:	
140	Substrates for electronic components, monolithic, including pin-grid arrays
141	Multilayer interconnects for electronic circuits, including pin-grid arrays
142	Heat sinks
143	Power semiconductor housings
144	Resistor cores
169	Other electronic packaging applications
Microwave insulators:	
170	Radomes and missile nosecones
171	Windows for use in microwave devices
172	Absorbers and attenuators for microwave devices
173	Phase shifters for use in microwave devices
174	Other applications in microwave devices
199	Other passive electrical applications
200 to 299 Active Electrical Application	
Ohmic electrical conductors:	
201	Ohmic heating elements
202	High-frequency susceptors
203	Electrodes
204	Igniters, jet engine
219	Other ohmic electrical conducting applications
Ionic conductors:	
220	Battery electrolytes
221	Fuel cell electrolytes
222	Gas detectors
223	Exhaust oxygen sensors
224	Molten metal oxygen sensors
229	Other ionic conducting applications
Capacitor applications:	
230	Monolithic single-layer capacitors
231	Multilayer chip capacitors
239	Other capacitors
Non-ohmic electrical conductors:	
240	Varistors
241	Thermistors
242	Attenuators
243	Applications based on superconducting ceramic components
249	Other non-ohmic electrical conductors
Piezoelectric applications:	
250	Microphone membranes, including telephone handsets
251	Loudspeaker membranes, including telephone handsets
252	Other buzzers and vibrators
253	Force, pressure, and acceleration transducers
254	Sonar emitters and detectors
255	Impact igniters
256	Mechanical actuators
257	Motor elements

TABLE A1.1 *Continued*

258	Ink-jet printer heads
259	Resonators
269	Other piezoelectric devices
270	Electrostrictive devices
280	Pyroelectric devices
299	Other functional electrical devices
	300–499 Mechanical Applications
Milling and crushing machinery:	
301	Mill linings
302	Milling media
303	Other mill parts
304	Pestle and mortar linings for grinding soft materials
305	Pestle and mortar linings for grinding hard materials
309	Other milling or crushing applications
Agricultural applications:	
310	Agricultural implements for soil working
311	Agricultural pulverising nozzles
319	Other agricultural applications
Wear-resistant facings for plant and machinery:	
320	Shot blast nozzles
321	Pipelines and cyclones
322	Chute linings
323	Food processing applications
324	Mould and die liners
325	Crushing rolls
326	Slideways, wear-resisting pads
329	Other wear-resistant facings
Ballistic applications:	
330	Ballistic armour
331	Ballistic projectiles
339	Other ballistic applications
Material cutting applications:	
340	Indexable inserts for cutting and machining of hard alloys
341	Indexable inserts for cutting and machining ferrous metals
342	Indexable inserts for cutting and machining nonferrous metals
343	Inserts for rock drilling
344	Paper, tape-cutting knives
345	Domestic knives
346	Scissors and shears
347	Tool dressing components
359	Other material cutting applications
Material shaping applications:	
360	Cold die parts
361	Extrusion and drawing dies
362	Wire drawing cones
363	Dies for hot processes
364	Stamping dies and roller dies
369	Other material shaping applications
Pump applications:	
370	Vanes and impellers for pumps
371	Rotating shaft seals (stationary or rotating components)
372	Hydraulic plungers and cylinders
373	Pump bearing sleeves
374	Pump shafts
375	Pump housings
379	Other pump applications
Valve and tap (faucet) applications:	
380	Tap (faucet) valve faces, single-lever action
381	Tap (faucet) valve faces, multiple-lever action
382	Tap (faucet) valves, for water, other
383	Pneumatic valves
399	Other valve facings for noncorroding liquids
Guides for thread, paper, tape, etc.:	
400	Thread spinning nozzles
401	Friction disks for thread texturing
402	Thread guides
403	Guides, runners for paper handling
404	Applications in printer heads
405	Guides and other components for magnetic tape transport
419	Other thread, paper, or tape guide applications
Bearing applications:	
420	Plain bearing sets
421	Roller bearing sets
422	Precision balls for bearings
423	Precision rollers for bearings

TABLE A1.1 *Continued*

424	Thrust bearing sets
439	Other bearing applications
Precision jigs and metrological devices:	
440	Sizing rings
441	Gage blocks
442	Jigs
443	Vee blocks
444	Surface plates and angle plates
459	Other precision tooling applications
Sport goods:	
460	Shoe studs
461	Golf-club inserts
462	Fishing-rod ring liners
463	Ice-skate blades
469	Other applications in sports goods
499	Other mechanical applications
	500 to 599 Thermal and Thermomechanical Applications
Temperature-resistant electrical applications:	
501	Thermocouple insulators and sheaths
502	Coiled wire heating element supports
503	Supports for rod heating elements
504	Insulators for lamp elements
505	Resistance thermometer element bases
506	Lamp holders
509	Other temperature-resistant electrical applications
High-temperature materials processing applications:	
510	Applications in hot metal immersion probes
511	Muffle tubes for furnaces
512	Saggars for material processing
513	Kiln furniture (ware support) for high-temperature processing
514	Pins for refractory insulation
515	Furnace rollers, runners, and guides
516	Burner parts
517	High-duty heat exchangers
518	Low-duty heat exchangers
519	High-temperature gas valves
520	Weld pool rings
521	Welding nozzles
522	Welding jigs
523	Casting tubes for molten metals
524	Shell moulds
525	Casting cores
526	Filters for liquid metals
527	Break rings for the continuous casting process
528	Crucibles for metal melting and handling
529	Other liquid-metal handling applications
539	Other high-temperature materials processing applications
Aerospace applications:	
540	Rocket nozzles
541	Ablation shields
542	Jet engine petals/nozzles
543	Brake disks
549	Other aerospace applications
Domestic applications:	
550	Domestic cooker tops
551	Cookware
559	Other domestic applications
Reciprocating engine applications:[A]	
560	Cylinder blocks in reciprocating engines
561	Pistons and piston crowns in reciprocating engines
562	Fuel injector nozzles for reciprocating engines
563	Precombustion chambers for reciprocating engines
564	Piston pins
565	Applications in exhaust valves
566	Cam followers
567	Cylinder liners
568	Exhaust port liners
569	Exhaust pipe liners
570	Turbocharger rotors
571	Turbocharger stators
572	Turbocharger housing
573	Fuel injection pins
574	Diesel particulate filters
579	Other reciprocating engine applications
Applications in turbine engines:	

TABLE A1.1 *Continued*

580	Rotors and blades for gas turbines
581	Stators for gas turbines
582	Combustion chambers for gas turbine application
583	Fuel injectors for gas turbines
584	Regenerators and heat-exchanger components for gas turbines
585	Thermal barrier coating of metallic components
586	Shrouds and shroud components
589	Other gas turbine applications
599	Other thermal and thermomechanical applications
	600 to 699 Nuclear Applications
601	Nuclear fuel elements
602	Element separators in nuclear applications
603	Moderators in nuclear applications
699	Other nuclear applications
	700 to 799 Optical Applications
Reflective applications:	
701	Telescope mirrors
702	Synchrotron mirrors
709	Other reflective applications
Non-optical structural components for optical systems:	
710	Optical benches
711	Ferrules for fiber optics
719	Other structural components for optical applications
Laser components:	
720	Laser waveguides
721	Laser rods
729	Other components for lasers
Optical window applications:	
730	Windows for optical wavelengths
731	Windows for infrared wavelengths
739	Other optical window applications
Lamp envelopes:	
740	High-power lamp envelopes
741	Envelopes for high-pressure sodium vapor lamps
749	Other lamp envelopes
Active optical components:	
750	Optical modulators
759	Other active optical components
799	Other optical applications
	800 to 899 Chemical and Biomedical Applications
Laboratory chemical equipment:	
801	Crucibles and boats for laboratory use
802	Funnels for laboratory use
803	Filter media for laboratory use
809	Other laboratory ware applications
Chemical plant applications:	
810	Tower packing in large-scale chemical plant
811	Vessels and pipes in large-scale chemical plant
812	Floats and tubes in large-scale chemical plant
813	Ball valves in large-scale chemical plant
814	Flowmeter applications
815	Gas percolation elements
819	Other chemical plant applications
Chemical moulding parts:	
820	Rubber dipping formers
829	Other mould components
Filter bodies and materials:[B]	
830	Filter elements for liquid media, monolithic
831	Filter elements for gaseous media, monolithic
832	Ceramic filter membranes
839	Other filter applications
Catalysts and catalyst supports:	
840	Ceramic catalysts
841	Catalyst supports, granular
842	Catalyst supports, plate
843	Catalyst supports, monolithic honeycomb, including vehicle exhaust applications
849	Other chemical applications
Biomedical applications:	
861	Orthopedic biomedical implants
862	Dental implants
863	Vascular biomedical implants

TABLE A1.1 *Continued*

899	Other biomedical implants
	900 to 949 Magnetic applications
901	Cores for loudspeakers and microphones
902	Components for transducers
903	Components for microwave devices
904	Components for coils
905	Components for yokes
906	Components in flyback transformers
907	Components for data recording heads
908	Nonmagnetic components for data recording heads
909	Magnets for motors
949	Other magnetic applications
	950 to 999 Other Applications[C]

[A] See 843 for vehicle exhaust catalyst supports.
[B] Filters for molten metals are coded 526.
[C] In the formulation of this coding scheme the codes 950–999 are available for other applications to be identified by user demand.

TABLE A1.2 Alphabetical Index to Applications Classification

Ablation shields, aerospace	541
Abrasion resistant applications, miscellaneous	343
Abrasives	
linings for process plant for	321
Absorbers, microwave devices	172
Acceleration transducers, accelerometers	253
Actuators, piezoelectric	254
Aerial insulators	109
Aerospace applications	540–549
Agricultural implements	
nozzles	311
for soil working	310
Angle plates, precision	444
Applications, miscellaneous	950
Armour, ballistic	330
Attenuators	
electrical	242
microwave devices	172
Ballistic armour	330
Ballistic projectiles	331
Balls	
for bearings	422
for milling	302
Ball valves, chemical plant	813
Battery electrolytes	220
Bearings	
miscellaneous	439
Bearing sets	
plain	420
roller	421
thrust	424
Biomedical applications	851–899
Biomedical implants	
dental	852
miscellaneous	899
orthopedic	851
vascular	853
Brake disks, aerospace	543
Break rings, continuous casting	527
Burners, parts for	516
Bus bar supports	102
Bushes	
above 200°C	108
up to 200°C	107
Buzzers	252
Cable cleats	106
Cam followers	564
Capacitors	230–239
monolithic	230
multilayer	231
miscellaneous	239
Casting, continuous, break rings for	527

TABLE A1.2 *Continued*

Casting cores	525
Casting tubes, for metals	523
Catalyst supports	
granular	841
monolithic, honeycomb, vehicle exhaust	843
plate	842
Chemical applications	800–849
miscellaneous	849
Chemical plant components, large scale	810–819
Chute linings	322
Circuits, electronic, interconnects	141
Coatings, thermal barrier,	
for metallic components	585
Coiled wire heating element supports	502
Coil formers	
high frequency	113
high power	111
high temperature	114
low power	110
precision	112
Coils, magnetic components for	904
Cold-die parts	360
Combustion chambers, gas turbines	582
Cooker tops, domestic	551
Cookware	550
Conductors	
electrical, ohmic	200–219
electrical, non-ohmic	230–239
ionic	220–229
Cones, wire-drawing	362
Continuous casting, break rings for	527
Cores	
casting	525
for resistors	144
Crucibles for metal melting	528
Crushing rolls	325
Cutting, materials	340–359
Cyclones	321
Cylinder blocks, reciprocating engines	560
Cylinder liners, reciprocating engines	567
Cylinders, hydraulic	372
Data-recording heads	
magnetic components for	907
nonmagnetic components for	908
Dental implants	852
Dies,	
cold	360
drawing	361
extrusion	361
for hot processes	363
liners	324
roller	364
stamping	364
Diesel engines	
particulate filters	574
precombustion chambers for	563
Drawing dies	361
Electrical applications	
active	200–299
active, miscellaneous	299
passive	100–199
passive, miscellaneous	199
Electrical devices, functional,	
miscellaneous	299
Electrical insulators	101–139
Electrodes	203
Electrolytes	
batteries	220
fuel cells	221
Electronic components, substrates for	140
Electronic packaging, miscellaneous	
applications	169
Electrostrictive devices	290
Element separators, nuclear	601

TABLE A1.2 *Continued*

Envelopes, lamps	740–749
Exhaust gas catalyst supports	843
Exhaust gas sensors	223
Exhaust pipe liners	569
Exhaust port liners	568
Exhaust valves, reciprocating engines	565
Extrusion dies	361
Eyelets, electrical	106
Faucets (taps), valve faces (water)	380–382
Fiber optics, ferrules for	711
Filter applications, chemical,	
miscellaneous	839
Filter elements	830–839
gaseous media	831
liquid media	830
Filter media, laboratory	803
Filters	
diesel exhaust particulates	574
for liquid metals	526
membranes	832
Fishing-rod ring inserts	462
Flow meter applications	814
Flyback transformers, magnetic	
components for	906
Food processing, applications in	323
Force transducers	253
Formers, rubber dipping	820
Friction disks for thread texturing	401
Fuel cells, electrolytes for	221
Fuel injectors	
gas turbine	583
reciprocating engine	
nozzles	562
pin valves	573
Funnels, laboratory	802
Furnace components	
guides	515
kiln furniture	513
muffles, tubes	511
rollers	515
runners	515
saggars	512
Fuse bodies	
high power	116
low power	115
Gas detectors	222
Gas percolation elements	815
Gas turbines (see also Jet Engines)	
combustion chambers	582
components for	580–589
fuel injectors	583
heat-exchanger components	584
igniters	204
miscellaneous applications	589
regenerators	584
rotors	580
shrouds	586
stators	581
Gas valves, high temperature	519
Gage blocks	441
Glow plug insulators	105
Golf club inserts	462
Grinding, pestles and mortars	304–305
mill liners	301
Guides	
furnaces	515
magnetic tape	405
paper handling	403
thread	402
Heat-exchanger components	
gas turbines	584
high duty	517
low duty	518

TABLE A1.2 *Continued*

Heating elements, ohmic	201
Heating element supports	
coiled wire	502
rods	503
Heat sinks, electronic	142
High-temperature processing	510–539
kiln furniture	513
saggars	512
Honeycomb catalyst supports	843
Housings	
power semiconductor	143
pumps	375
turbochargers	572
Hydraulic cylinders	372
Hydraulic plungers	372
Hydrophones	252
Ice-skate blades	463
Igniter insulators	104
Igniters, impact	255
jet engine	204
Immersion probes, hot metal	510
Impact igniters	253
Impellers	370
Implants	
biomedical	851–899
dental	852
miscellaneous	899
orthopedic	851
vascular	853
Indexable inserts, machine tools	340–342
Ink-jet printer heads	258
Inserts, rock drilling	343
Insulation, refractory pins for	514
Insulators, electrical	
aerials	109
fuse bodies	115–116
glow plug	105
igniter	104
lamp elements	504
low tension, small	102
spark plug	103
structural power, large	101
thermocouples	501
vacuum envelopes	117
vacuum leadthroughs	118
vacuum, use in (degassable)	119
Ionic conductors	220–229
Jet engines (see also Gas turbines)	
nozzles	542
petals	542
Jigs	442
Kiln furniture	513
Knives	
domestic	345
paper cutting	344
tape cutting	344
Laboratory ware	801–809
miscellaneous	809
Lamp elements, insulators	504
Lamp envelopes	
high power	740
high pressure sodium vapor	741
miscellaneous	749
Lamp holders	506
Lasers	
components for	720–729
waveguides	720
Liners, linings	
chutes	322
cyclones	321
cylinder	567
dies	324

TABLE A1.2 *Continued*

exhaust pipe	569
exhaust port	568
mills	301
moulds	324
pestle-and-mortar, for grinding soft materials	304
pestle-and-mortar, for grinding hard materials	305
pipes	321
process plant	321
Loudspeakers	
magnetic cores for	901
piezoelectric membranes for	251
Machine tools	
indexable inserts for	340–342
slideways	326
Magnetic applications	900–949
loudspeaker cores	901
microphone cores	901
miscellaneous	949
Magnetic tape, guides	405
Mechanical actuators	256
Mechanical applications	300–499
miscellaneous	499
Metallic components, thermal barrier coatings for	585
Metals, liquid, handling	523–529
casting tubes for	523
miscellaneous	529
Microphones	
magnetic cores for	901
piezoelectric membranes for	250
Microwave devices	
absorbers	172
attenuators	172
magnetic components or	903
miscellaneous	179
phase shifters	173
windows	171
Milling media	302
Mills	
linings	301
miscellaneous parts for	303
Mirrors	
synchrotron	702
telescope	701
Missile nosecones	170
Moderators, nuclear	602
Modulators, optical	750
Mortar linings, for grinding	304–305
Motors, parts for	
magnets	909
piezoelectric elements	257
Moulds	
liners	324
miscellaneous, chemical applications	829
rubber dipping formers	820
shell	524
Non-ohmic conductors, miscellaneous	249
Nozzles	
agricultural	311
fuel injection	532
fuel injection, control pins for	572
jet engines	542
rockets	540
shot or grit blast	320
thread spinning	400
welding	521
Nuclear applications	600–699
miscellaneous	699
Nuclear fuel elements	601
Optical applications	700–799

TABLE A1.2 *Continued*

miscellaneous	799
Optical benches	710
Optical modulators	750
Orthopedic implants	851
Oxygen sensors	
exhaust gas monitors	223
for molten metal	724
Paper-cutting knives	344
Petals, jet engine	542
Phase shifters, microwave devices	173
Piezoelectric applications	250–269
miscellaneous	269
Pin-grid arrays, electronic substrates	140–141
Pins, for refractory insulation	514
Pipe linings, abrasion resistant	321
Pipes, chemical plant	811
Piston crowns, reciprocating engines	561
Piston pins	564
Pistons, reciprocating engines	561
Plungers, hydraulic	372
Pneumatic valves	383
Power insulators	101
Precision tooling, miscellaneous applications	459
Precombustion chambers, reciprocating engines	563
Pressure transducers	253
Printer heads	
piezoelectric components for	258
wear-resistant components for	404
Projectiles, ballistic	331
Pumps	370–379
bearing sleeves for	373
housings	375
impellers for	370
miscellaneous applications in	379
shafts for	374
vanes for	370
Pyroelectric devices	280
Radomes	170
Reciprocating engines, components for	560–579
miscellaneous applications in	579
Regenerators, gas turbines	584
Resistance thermometers, element bases	505
Resistor cores	144
Resonators, piezoelectric	259
Rock drilling, inserts for	343
Rocket nozzles	540
Roller bearing sets	421
Roller dies	364
Rollers	
for bearings	421
furnace	515
Rolls, crushing	325
Rotating shaft seals	371
Rotors	
gas turbine	580
turbocharger	569
Rubber dipping formers	820
Runners	
furnace	515
paper handling	403
Saggars, for material processing	512
Scissors	346
Seal rings, for pumps	371
Semiconductors, housings	143
Shaft seals, rotating	371
Shafts, for pumps	374
Shears	346
Sheaths, thermocouple	501
Shell moulds	524
Shoe studs	460
Shot blasting, nozzles	320

TABLE A1.2 *Continued*

Shrouds, gas turbine	586
Sizing rings	440
Sleeves, electrically insulating	
above 200°C	108
up to 200°C	107
Slideways	326
Sonar emitters and detectors	254
Spark plug insulators	103
Sports goods, applications	460–469
miscellaneous	469
Stamping dies	364
Stators	
gas turbines	581
turbochargers	570
Substrates, for electronic components	140
Superconducting ceramics, applications	243
Supports	
bus bar	102
coiled wire heating elements	502
kiln furniture	513
rod heating elements	503
Surface plates	444
Susceptors, high frequency	202
Synchrotron mirrors	702
Tape-cutting knives	344
Taps, valve faces (water)	380–382
Telescope mirrors	701
Terminal blocks	102
Thermal applications	500–599
miscellaneous	599
Thermal barrier coatings	585
Thermistors	241
Thermocouple insulators	501
Thermocouple sheaths	501
Thermometers, resistance, element	
bases for	505
Thread guides	402
Thread spinning nozzles	400
Thread texturing, friction disks	401
Thrust bearing sets	424
Tool dressing components	347
Tower packing, chemical plant	805
Transducers	
force, pressure, acceleration	251
magnetic components for	902
Tubes, chemical plant	812
Turbochargers	
housings	572
rotors	570
stators	571
Vacuum devices, insulating components	119
Vacuum envelopes	117
Vacuum leadthroughs	118
Valve facings	380–399
miscellaneous, noncorrosive liquids	399
miscellaneous, water	382
taps (faucets)	380–381
Valves	
ball, chemical plant	813
exhaust, reciprocating engines	565
high-temperature gas	519
miscellaneous, water	382
pneumatic	383
Vanes, for pumps	370
Varistors	240
Vee blocks	443
Vessels, chemical plant	811
Vibrators, piezoelectric	252
Water faucets (taps)	380–382
Waveguides, laser	720
Wear-resisting pads	326
Weld pool rings	520
Welding jigs	522

TABLE A1.2 *Continued*

Welding nozzles	521
Windows	
infrared wavelengths	731
microwave devices	171
miscellaneous	739
optical	730
Wire drawing	
cones	362
dies	361
Yokes, magnetic components	905

A2. CHEMICAL CHARACTER DESCRIPTOR FIELDS

A2.1 Introduction

A2.1.1 This field contains information relating to chemistry and form, and is uniquely identified by the letter *C*.

A2.1.2 Due to the relatively complex chemistry of advanced technical ceramics and the likelihood of the presence of a number of compounds and forms, this part of the classification system is required to be particularly versatile. The chemical character code contains at least three essential items of information in the following order:

A2.1.2.1 The initial identifier letter *C*;

A2.1.2.2 The overall form of the item, that is, powder, fiber, monolithic, composite, etc., expressed as one or two upper case letters; and

A2.1.2.3 A numerical identification of the chemical formula (of the major constituent at least).

A2.1.3 Subsequent classification items may be included in the coding string to identify the purity of the major component, and the form and chemistry of minor constituents. In these cases the form descriptors also act as separators between related compounds.

A2.1.4 A flowchart for construction of the code for chemical character, which is to be used in conjunction with this annex, is shown in Fig. A2.1.

A2.2 Form

A2.2.1 The form descriptors, which also act as separators in the chemical character coding, are given in Table A2.1.

A2.3 Four-Digit Codes for Simple Chemical Compounds

A2.3.1 Table A2.2 gives a four-digit code to be used for the description of chemical components of precursors, powders, and ceramic products where composition in simple chemical compound form is to be described. Table A2.2 lists the most common metal ions, including those of variable valency, and nine commonly met simple radicals. Individual codes are obtained by combining the metal ion of appropriate valency from the list on the left-hand side of the table with the required radical given at the top of the table. Each combination of metal ion and radical is identified by a unique number. The four-digit codes are arranged in accordance with the following heirarchy:

Code Number	Radical
0001 to 0099	Elements
0101 to 0199	Boride
0201 to 0299	Carbide
0301 to 0399	Nitride
0401 to 0499	Oxide
0501 to 0599	Fluoride
0601 to 0699	Silicide
0701 to 0799	Phosphide
0801 to 0899	Sulphide
0901 to 0999	Iodide

A2.3.2 In the majority of cases requiring classification by detailed chemistry it will be possible to describe an advanced technical ceramic material in terms of these codes. However, the list is not exclusive, and the metal ion description *other* may be used for metallic species not appearing in Table A2.2. For single-species anions not appearing in the table, refer to four-digit codes 1000 to 1999, for two-species of anion see Codes 2000 to 2999, and for more complex compounds see Codes 3000 to 3999.

A2.3.3 It is apparent from the matrix of codes for simple binary compounds that many of the possible code numbers will be rarely used; indeed several of the codes are redundant through impossible combinations, for example, carbon carbide, or through thermodynamic considerations (instability).

A2.3.4 For atomic species that exist wth more than one valency separate rows are provided in the matrix for each valency state. In this way the matrix can provide codes that differentiate between, for example, CeO_2 and Ce_2O_3, or FeO and Fe_2O_3. In some cases, employing simple valencies is not possible. In such cases the formula is quoted after the code number in Table A2.2, but would not be employed in the use of the code. In other cases, a series of two or more compounds may be formed from the same species. This classification does not attempt to separate them with individual codes, but represents them either in the form A_xB_y or in the form AB_y.

A2.3.5 If the component is not normally solid at ambient temperature this is noted in the matrix table (Table A2.2) as (g) for gaseous, (l) for liquid. If the chemical normally has water of crystallisation that would be removed in forming a ceramic product, this is indicated by (h) (for hydrated).

A2.3.6 Substoichiometry of compounds is accommodated in one of two ways:

A2.3.6.1 By the inclusion of a leading character (*N* for nonstoichiometric) in the code. *N* does not appear as a character in the form descriptor, and therefore would not be