# Recommended Practices for Material Identification and Density

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# 1   Introduction

Most CAD systems allow the assignment of a material (and associated properties) to parts. Exchanging the information about the material the part is made of provides additional intelligence to the exchange and broadens the scope for interoperability with applications beyond the pure CAD world.

Exchanging the material information allows the receiver e.g. to pull detailed material information from his database. This information is important in applications like engineering analysis or CAM.

Of the many properties a material can have, one of the most vital is the density information. Using the density value interpreted from the STEP file, the receiving system can potentially calculate the mass (and weight) of the solid model(s), and distinguish between the center of geometry and the center of gravity.

This document provides in **chapter 4** a basic approach to exchange information regarding material information and density on an informational basis. The data will be included as 'general properties', i.e. basically as string values. The importing system may decide whether to import the information provided as real values for further computation, or as user attributes.

STEP itself provides a far more powerful mechanism to transfer material information, which allows to attach a far greater range of material attributes, includes the capability to version the material, and is also harmonized between a number of APs, such as AP203, AP209, AP210 and AP214. This approach, referred to as "material as product", is presented in **chapter 5**.

# 2   Scope

The following are within scope of this document:

- Assignment of a material to solid models
- Definition of the density value for this material

Note: It is possible to assign a different material resp. density to each part that may be present in the CAD model.

The following are outside the scope of this part:

- Assignment of other material properties, such as Young's Modulus, etc. to a solid model.

# 3   Fundamental concepts

Particular concepts of interest within the scope of this recommendation are described in the following sections.

## 3.1   Material

The material from which a part is made is one of its basic properties. The material is both defined by and defines the possible use and the manufacturing process for the respective part. Hence the material information is of vital use for many applications.

On a basic level, a material is defined by its name and a unique identifier, which can e.g. be used to pull more detailed information from a material database.

Within STEP, especially AP209 and AP214 provide a very detailed concept to represent the material, and assign a wide variety of properties to it. Both the simple approach ('general

property') and the more sophisticated approach harmonized with AP209 and the PDM schema are presented in the chapters below.

### 3.2  Mass

The mass of an object is a fundamental property of the object; a numerical measure of its inertia; a fundamental measure of the amount of matter in the object.

The primary Système Internationale or SI unit for mass is "kilogram" (kg). Other commonly used units for mass are "gram" (gm), "pound" (lb), "slug" and "tonne".

STEP allows for definition of SI units such as "kilogram" as well as conversion between SI units and other units, such as "pound" (1 kg = 2.2064 lbs)

### 3.3  Density

Density is calculated as the mass of the solid model divided by the volume. Density is one of the material properties associated with solid models.

## 4  Material and Density as General Property

This approach (in short terms referred to as "material as property") is based on the requirement to have a simple approach to exchange general part properties on a very basic, i.e. informational, level. In the context of this document, material and density are regarded as such general properties.

> **Important Note:** This approach has been agreed on between the members of the CAx-IF for exchanging such information on a basic level. The CAx-IF is aware that this approach is not interoperable with the implementation in other APs, such as AP209 and the PDM schema, which is given in chapter 5, and hence not interoperable.
>
> The justification for this decision are: (i) The detailed approach requires much more work to exchange the same information, and (ii) some 'pure' CAD systems are not capable of handling the material as individual part, including versioning and other information.

### 4.1  Material name and id

In this context, the material is treated as a general property of the part. This is reflected in the structure given below, which uses the respective approach given in STEP:
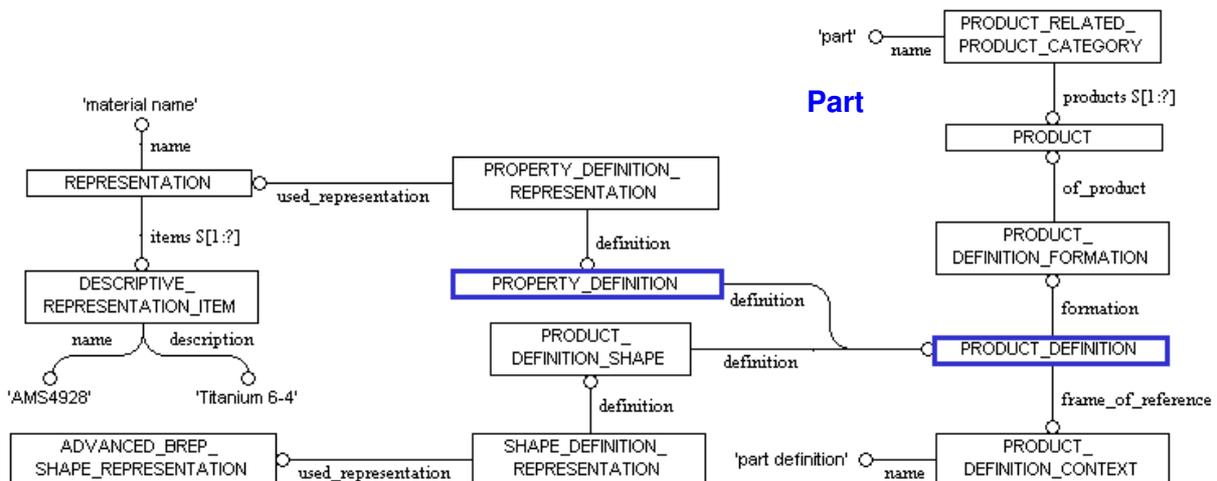


**Figure 1: Representing the material as general property of the part**

In some CAD systems it is possible to assign properties to individual solids within a part, i.e. sub-shapes. The general property approach in STEP supports this by using shape_aspect. The figure below shows the same structure as above, but with the additional usage of shape_aspect:
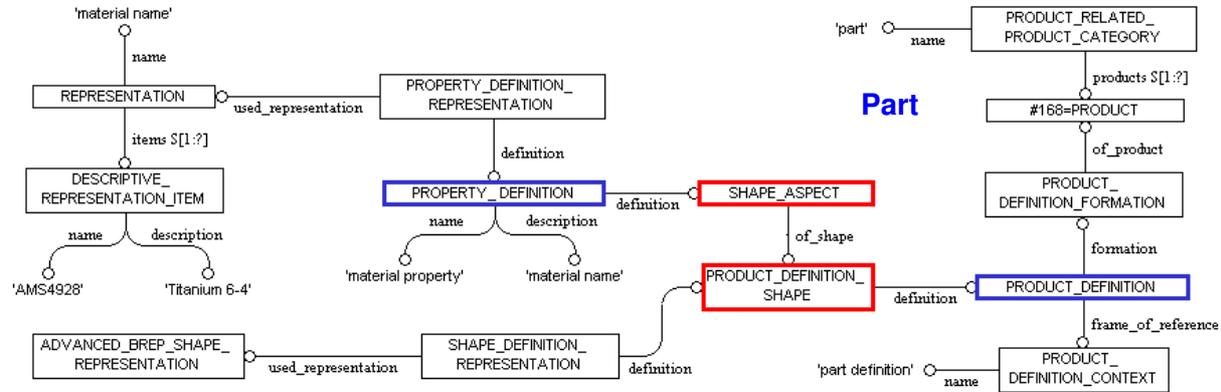


**Figure 2: Representing the material as general property of a sub-shape of the part**

**Agreement:** Only those CAD systems supporting the assignment of properties to individual sub-shapes should export the structure using shape_aspect. The best way in any case is to export shape_aspect only if there is in fact more than one sub-shape for the part.

Both approaches, with and without shape_aspect, should be supported on import.

### 4.1.1  property_definition

The property_definition states what kind of property is assigned.

| Attribute | Type | Population |
|---|---|---|
| **name** | label | 'material property' |
| **description** | text (optional) | 'material name' |
| **definition** | characterized_definition | product_definition for the product defining the part |

### 4.1.2  representation

Collects the items defining the property in scope.

| Attribute | Type | Population |
|---|---|---|
| **name** | label | 'material name' |
| **items** | set of representation_items | The measure_representation_item defining the density |

### 4.1.3  descriptive_representation_item

This item defines the id and name of the material used.

| Attribute | Type | Population |
|---|---|---|
| **name** | label | *the material id* (here: 'AMS4928') |
| **Description** | text | *the material name* (here: 'Titanium 6-4) |

### 4.1.4  Instantiation example

```
/* Giving the material (Titanium) as a general part property */

#250=PROPERTY_DEFINITION('material property','material name',#170);
#251=DESCRIPTIVE_REPRESENTATION_ITEM('AMS4928','Titanium 6-4');
#252=REPRESENTATION('material name',(#251),#162);
#253=PROPERTY_DEFINITION_REPRESENTATION(#250,#252);
```

## *4.2  Density*

Within the simple approach, the density is just another general part property, which is, technically, independent from the material assigned. The structure used to reflect this in the STEP file is therefore almost identical:
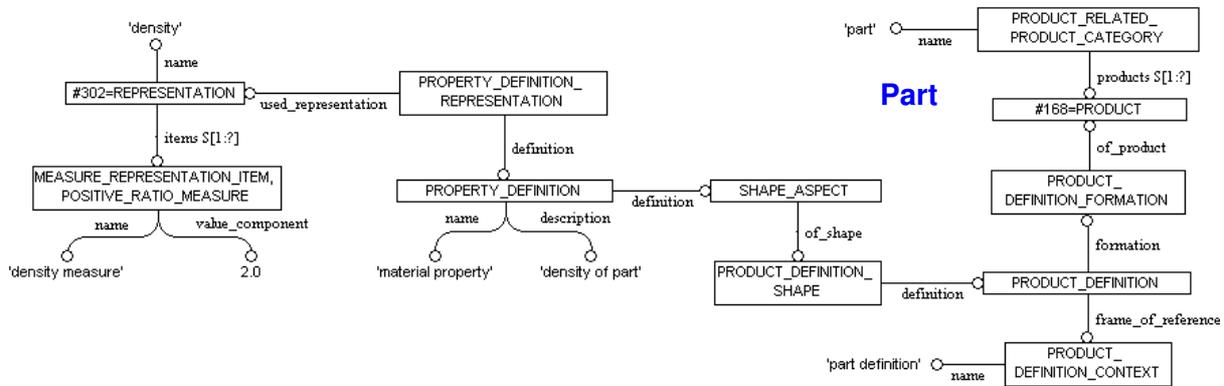


**Figure 3: Representing the density as a general property of the part**

**Note** that the same as said in section 4.1 with regard to the assignment of properties to sub-shapes of a part using shape_aspect applies here.

### 4.2.1  property_definition

The property_definition states what kind of property is assigned.

| Attribute | Type | Population |
|---|---|---|
| **name** | label | 'material property' |
| **description** | text (optional) | 'density' |
| **definition** | characterized_definition | product_definition for the product defining the material |

### 4.2.2  representation

Collects the items defining the property in scope.

| Attribute | Type | Population |
|---|---|---|
| **name** | label | 'density' |
| **items** | set of representation_items | The measure_representation_item defining the density |

4.2.3   measure_representation_item

This item defines the numerical value and unit for the density.

| Attribute | Type | Population |
|-----------|------|------------|
| **name** | label | 'density measure' |
| **value_component** | measure_value | The positive_ratio_measure with the numerical density value |
| **unit_component** | unit | The unit in which the density value is represented. |

4.2.4   Instantiation example

```
/* assignment of density (2.0) to the material */

#300=PROPERTY_DEFINITION('material property','density',#170);
#301=MEASURE_REPRESENTATION_ITEM('density meas-
ure',POSITIVE_RATIO_MEASURE(2.0),#500);
#302=REPRESENTATION('density',(#301),#162);
#303=PROPERTY_DEFINITION_REPRESENTATION(#300,#302);

/* Mass and Density unit definitions for the unit context */

/* Mass unit [Pounds] Note: 1 kg = 2.206 lb */
#400=(MASS_UNIT() NAMED_UNIT(*) SI_UNIT(.KILO.,.GRAM.));
#401=DIMENSIONAL_EXPONENTS(0.E0,1.E0,0.E0,0.E0,0.E0,0.E0,0.E0);
#402=MASS_MEASURE_WITH_UNIT(MASS_MEASURE(4.536E-1),#400);
#403=(CONVERSION_BASED_UNIT('POUND',#402)MASS_UNIT()NAMED_UNIT(#401));

/* Density [lb/inch3] */
#500=DERIVED_UNIT((#501,#502));
#501=DERIVED_UNIT_ELEMENT(#403,1.);
#502=DERIVED_UNIT_ELEMENT(#155,-3.);

#503=NAME_ATTRIBUTE('POUND PER CUBIC INCH',#500); /* optional */
```

# 5   Detailed Material Identification

The basic assumption behind the approach presented below (in short terms referred to as "material as product") is the fact that the material, from which a part is made, is a part itself, which can have its individual versions and documents assigned to it. Hence, on the AIM level, the material is represented as a product which is linked to the part via a make-from-relationship. For details, see also the PDM Schema Usage Guide v4.3, section 4.5.3.

## 5.1   Material representation

In the following sections, the STEP entities which are relevant within this scope are listed. Only those attributes involved in the definition of the material are listed.

The figure below illustrates the structure in the STEP file:
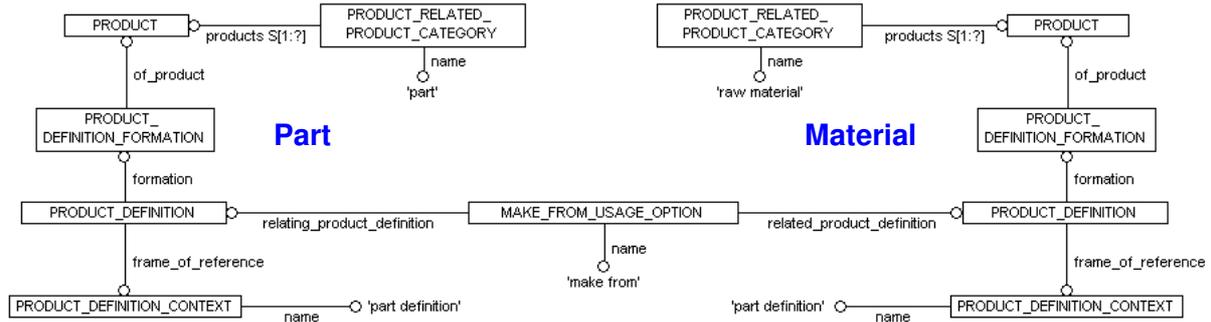
**Figure 4: Assignment of a material to a part**

**Note** that this relationship is established on the product level, i.e. one material per part. For CAD systems supporting the assignment of different materials to different sub-shapes of a part, it is possible to support this also in the "material as product" approach, using configurations. However, this is rather complicated and will be reflected in a later edition of this document.

### 5.1.1  Product

The material is represented as a `product`, and the attributes are populated with the respective information:

| Attribute | Type | Population |
|---|---|---|
| **id** | identifier | "Unique" id, e.g. catalogue number |
| **name** | label | Name of the material |
| **description** | text (optional) | Additional description for the material |

### 5.1.2  Product_related_product_category

The `product_related_product_category` is used to distinguish between the part and the material it is made from.

| Attribute | Type | Population |
|---|---|---|
| **name** | label | 'raw material' |
| **products** | set of `product` | References to all product entities that define a material |

**Note:** In AP209, the permissive list of materials includes 'isotropic material', 'anisotropic material', 'filament assembly', 'discontinuous fiber assembly' or 'stock core'. Since this document applies to CAD implementations, the value 'raw material' should be used to avoid conflicts with AP214.

### 5.1.3  Make_from_usage_option

The `make_from_usage_option` is a subtype of `product_definition_relationship`, and defines the `make_from_relationship`.

| Attribute | Type | Population |
|---|---|---|
| **id** | label | A unique identifier for the relationship |
| **name** | identifier | 'make from' |
| **description** | text (optional) | |

| relating_product_definition | product_definition | Represents the part manufactured from the related_product_definition |
|---|---|---|
| related_product_definition | product_definition | Represents the raw or semi-finished material |
| ranking | real | A relative ranking value. A lower value indicates a higher preference. |
| ranking_rationale | text | Explains the reason for the ranking. |
| quantity | measure_with_unit | This attribute records the number of resultant parts that can be made from the source part. |

The use of this entity allows for an extensive definition of the relation between the manufactured part and the "source part", i.e. the material. Using the ranking attribute, several materials can be assigned to a part with different priorities to identify the preferred material. The quantity allows to give information on how many parts can be manufactured from the material, if the material is interpreted as a source part, e.g. a sheet of metal.

As the CAx-IF is currently mainly focuses on the transfer of material name and id, the following values for the ranking and quantity are suggested:

- ranking = 1.0
- ranking_rationale = '' (empty string)
- quantity = 1

### 5.1.4  Instantiation example

```
/* Definition of the material (Titanium) as a product */

#250=PRODUCT('AMS4928','Titanium 6-4','',(#167));
#251=PRODUCT_RELATED_PRODUCT_CATEGORY('raw material','',(#250));
#252=PRODUCT_DEFINITION_FORMATION('1','LAST_VERSION',#250);
#253=PRODUCT_DEFINITION_CONTEXT('part definition',#164,'design');
#254=PRODUCT_DEFINITION('part definition','',#252,#253);

/* Establish the make_from_relationship */

#275=MAKE_FROM_USAGE_OPTION('Assign AMS4928 to CUBE','make
from','',#170,#254,1.0,'',#276);
#276=MEASURE_WITH_UNIT(COUNT_MEASURE(1),#277);
#277=NAMED_UNIT(#278);
#278=DIMENSIONAL_EXPONENTS(0.0,0.0,0.0,0.0,0.0,0.0,0.0);
```

### *5.2  Density as General Property*

Even within the "material as product" approach, there are different ways to represent its properties. One way is to transfer density as a general property of the part defining the material (see section 5.1). This approach is harmonized with the PDM schema and other APs that do not have the material property specific entities used in section 5.3.

The figure below illustrates the structure in the STEP file:
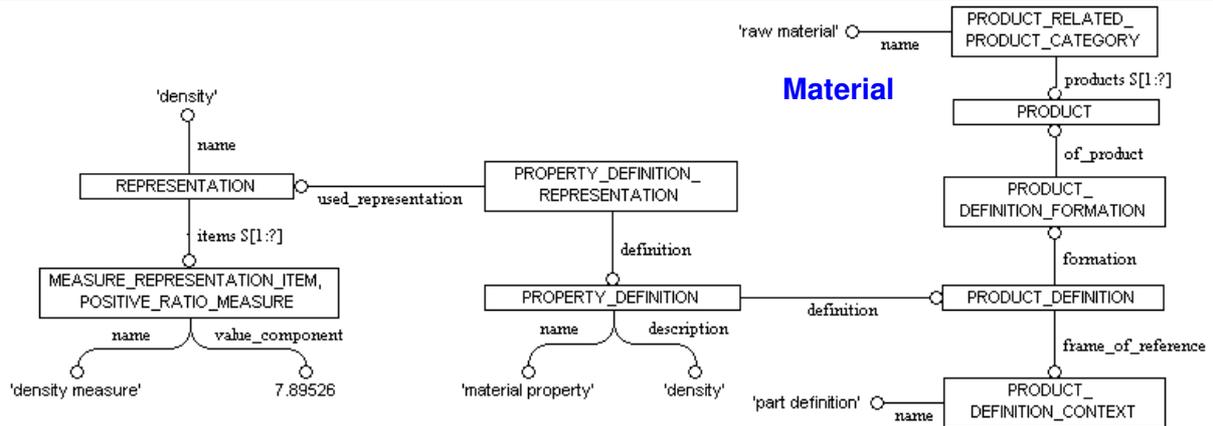
**Figure 5: Assignment of the density as general property to the material**

> **Note** that compared to the simple approach given in section 4.2, the only difference in the structure is the fact the `property_definition` no longer points to the part, resp. its shape, but references the `product_definition` of the material.
>
> Since the `product` defining the material does not have any sub-shapes, the usage of `shape_aspect` does not apply here.

For a listing and explanation of the included STEP entities, see section 4.2.

## 5.3  Density as Material Property

In APs such as AP209, which because of their scope need a far more detailed and comprehensive material representation, a more sophisticated system of material properties is implemented. With regard to density, this includes the physical fact that the density of a part is also dependent on its temperature.

The figure below illustrates the definition of a density of "2.0" at a temperature of 20°C:
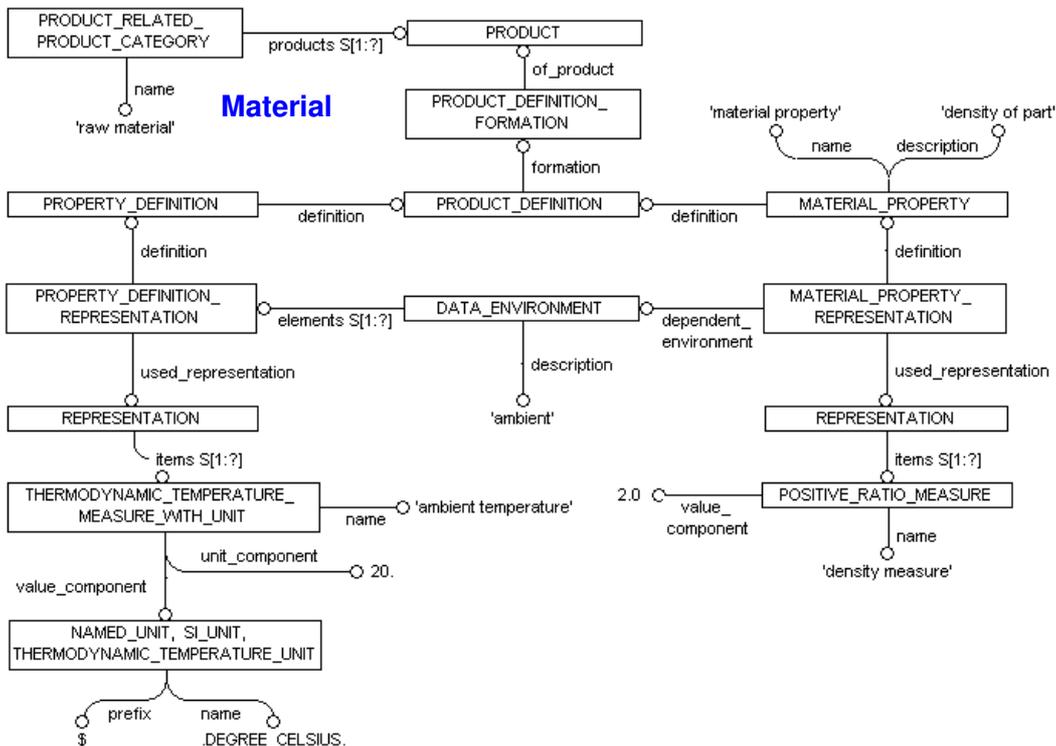
**Figure 6: Density as material property including ambient temperature**

Although the CAx-IF Agreement prefers the "material as property" approach, the information given in this section is harmonized with the appropriate working groups and can therefore be seen as a valid recommended practice. For details on the entities used here, please refer to the AP209 Implementation Guidelines.

## 5.3.1  Instantiation example

```
/* Assignment of density (2.0) to the material */

#300=MATERIAL_PROPERTY('material property','density of part',#254);
#301=MATERIAL_PROPERTY_REPRESENTATION(#300,#302,#310);
#302=REPRESENTATION('density',(#303),#162);
#303=MEASURE_REPRESENTATION_ITEM('density meas-
ure',POSITIVE_RATIO_MEASURE(2.0),#500);

#310=DATA_ENVIRONMENT('#310','ambient',(#353));

/* Definition of default room temperature as environment */

#350=PROPERTY_DEFINITION('ambient condition','temperature',#254);
#351=MEASURE_REPRESENTATION_ITEM('ambient tempera-
ture',THERMODYNAMIC_TEMPERATURE_MEASURE_WITH_UNIT(20.),#450);
#352=REPRESENTATION('temperature',(#351),#162);
#353=PROPERTY_DEFINITION_REPRESENTATION(#350,#352);

/* Mass and Density unit definitions for the unit context */

/* Mass unit [Pounds] Note: 1 kg = 2.206 lb */
#400=(MASS_UNIT() NAMED_UNIT(*) SI_UNIT(.KILO.,.GRAM.));
#401=DIMENSIONAL_EXPONENTS(0.E0,1.E0,0.E0,0.E0,0.E0,0.E0,0.E0);
#402=MASS_MEASURE_WITH_UNIT(MASS_MEASURE(4.536E-1),#400);
#403=(CONVERSION_BASED_UNIT('POUND',#402)MASS_UNIT()NAMED_UNIT(#401));

/* Temperature unit definition */

#450=(NAMED_UNIT(*) SI_UNIT($,.DEGREE_CELSIUS.) THERMODY-
NAMIC_TEMPERATURE_UNIT());
#451=DIMENSIONAL_EXPONENTS(0.E0,0.E0,0.E0,0.E0,1.E0,0.E0,0.E0);

/* Density [lb/inch3] */
#500=DERIVED_UNIT((#501,#502));
#501=DERIVED_UNIT_ELEMENT(#403,1.);
#502=DERIVED_UNIT_ELEMENT(#155,-3.);
#503=NAME_ATTRIBUTE('POUND PER CUBIC INCH',#500);  /* optional */
```

# 6  Part21 File Example

This section presents Part 21 file instantiation examples of the concepts discussed. The files are provided separately in an AP214 and AP203 conformant way. The differences relate to application protocol specifics. These specifics do not relate to the capability described in this document, i.e. the files are exactly identical in respect to the entities discussed herein.

Figure 6 shows a part model represented in the Part21 file. It is comprised of a cube with a side length of 100 inches.
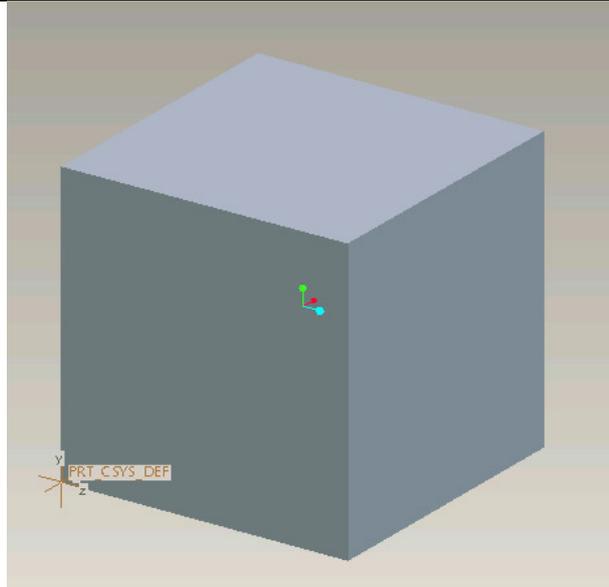
**Figure 7: Part used to illustrate the assignment of density**

## 6.1 Using "Material as Property", conforming to AP214 IS

Changes related to assignment of density property can be seen in RED.

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION((''),'2;1');
FILE_NAME('CUBE','2004-07-16T',('cax-if'),(''),'','','');
FILE_SCHEMA(('AUTOMOTIVE_DESIGN { 1 2 10303 214 1 1 1 1 }'));
ENDSEC;
DATA;
#2=DIRECTION('',(1.E0,0.E0,0.E0));
#3=VECTOR('',#2,1.E2);
#4=CARTESIAN_POINT('',(0.E0,0.E0,0.E0));
#5=LINE('',#4,#3);
#6=DIRECTION('',(0.E0,1.E0,0.E0));
#7=VECTOR('',#6,1.E2);
#8=CARTESIAN_POINT('',(1.E2,0.E0,0.E0));
#9=LINE('',#8,#7);
#10=DIRECTION('',(-1.E0,0.E0,0.E0));
#11=VECTOR('',#10,1.E2);
#12=CARTESIAN_POINT('',(1.E2,1.E2,0.E0));
#13=LINE('',#12,#11);
#14=DIRECTION('',(0.E0,-1.E0,0.E0));
#15=VECTOR('',#14,1.E2);
#16=CARTESIAN_POINT('',(0.E0,1.E2,0.E0));
#17=LINE('',#16,#15);
#18=DIRECTION('',(0.E0,0.E0,1.E0));
#19=VECTOR('',#18,1.E2);
#20=CARTESIAN_POINT('',(0.E0,0.E0,0.E0));
#21=LINE('',#20,#19);
#22=DIRECTION('',(0.E0,0.E0,1.E0));
#23=VECTOR('',#22,1.E2);
#24=CARTESIAN_POINT('',(0.E0,1.E2,0.E0));
#25=LINE('',#24,#23);
#26=DIRECTION('',(0.E0,0.E0,1.E0));
```

```
#27=VECTOR('',#26,1.E2);
#28=CARTESIAN_POINT('',(1.E2,1.E2,0.E0));
#29=LINE('',#28,#27);
#30=DIRECTION('',(0.E0,0.E0,1.E0));
#31=VECTOR('',#30,1.E2);
#32=CARTESIAN_POINT('',(1.E2,0.E0,0.E0));
#33=LINE('',#32,#31);
#34=DIRECTION('',(1.E0,0.E0,0.E0));
#35=VECTOR('',#34,1.E2);
#36=CARTESIAN_POINT('',(0.E0,0.E0,1.E2));
#37=LINE('',#36,#35);
#38=DIRECTION('',(0.E0,-1.E0,0.E0));
#39=VECTOR('',#38,1.E2);
#40=CARTESIAN_POINT('',(0.E0,1.E2,1.E2));
#41=LINE('',#40,#39);
#42=DIRECTION('',(-1.E0,0.E0,0.E0));
#43=VECTOR('',#42,1.E2);
#44=CARTESIAN_POINT('',(1.E2,1.E2,1.E2));
#45=LINE('',#44,#43);
#46=DIRECTION('',(0.E0,1.E0,0.E0));
#47=VECTOR('',#46,1.E2);
#48=CARTESIAN_POINT('',(1.E2,0.E0,1.E2));
#49=LINE('',#48,#47);
#50=CARTESIAN_POINT('',(0.E0,0.E0,0.E0));
#51=CARTESIAN_POINT('',(1.E2,0.E0,0.E0));
#52=VERTEX_POINT('',#50);
#53=VERTEX_POINT('',#51);
#54=CARTESIAN_POINT('',(1.E2,1.E2,0.E0));
#55=VERTEX_POINT('',#54);
#56=CARTESIAN_POINT('',(0.E0,1.E2,0.E0));
#57=VERTEX_POINT('',#56);
#58=CARTESIAN_POINT('',(0.E0,0.E0,1.E2));
#59=CARTESIAN_POINT('',(1.E2,0.E0,1.E2));
#60=VERTEX_POINT('',#58);
#61=VERTEX_POINT('',#59);
#62=CARTESIAN_POINT('',(1.E2,1.E2,1.E2));
#63=VERTEX_POINT('',#62);
#64=CARTESIAN_POINT('',(0.E0,1.E2,1.E2));
#65=VERTEX_POINT('',#64);
#66=CARTESIAN_POINT('',(0.E0,0.E0,0.E0));
#67=DIRECTION('',(0.E0,0.E0,1.E0));
#68=DIRECTION('',(1.E0,0.E0,0.E0));
#69=AXIS2_PLACEMENT_3D('',#66,#67,#68);
#70=PLANE('',#69);
#72=ORIENTED_EDGE('',*,*,#71,.T.);
#74=ORIENTED_EDGE('',*,*,#73,.T.);
#76=ORIENTED_EDGE('',*,*,#75,.T.);
#78=ORIENTED_EDGE('',*,*,#77,.T.);
#79=EDGE_LOOP('',(#72,#74,#76,#78));
#80=FACE_OUTER_BOUND('',#79,.F.);
#81=ADVANCED_FACE('',(#80),#70,.F.);
#82=CARTESIAN_POINT('',(0.E0,0.E0,0.E0));
#83=DIRECTION('',(0.E0,-1.E0,0.E0));
#84=DIRECTION('',(1.E0,0.E0,0.E0));
#85=AXIS2_PLACEMENT_3D('',#82,#83,#84);
#86=PLANE('',#85);
#87=ORIENTED_EDGE('',*,*,#71,.F.);
#89=ORIENTED_EDGE('',*,*,#88,.T.);
#91=ORIENTED_EDGE('',*,*,#90,.T.);
#93=ORIENTED_EDGE('',*,*,#92,.F.);
#94=EDGE_LOOP('',(#87,#89,#91,#93));
```

```
#95=FACE_OUTER_BOUND('',#94,.F.);
#96=ADVANCED_FACE('',(#95),#86,.T.);
#97=CARTESIAN_POINT('',(0.E0,1.E2,0.E0));
#98=DIRECTION('',(-1.E0,0.E0,0.E0));
#99=DIRECTION('',(0.E0,-1.E0,0.E0));
#100=AXIS2_PLACEMENT_3D('',#97,#98,#99);
#101=PLANE('',#100);
#102=ORIENTED_EDGE('',*,*,#77,.F.);
#104=ORIENTED_EDGE('',*,*,#103,.T.);
#106=ORIENTED_EDGE('',*,*,#105,.T.);
#107=ORIENTED_EDGE('',*,*,#88,.F.);
#108=EDGE_LOOP('',(#102,#104,#106,#107));
#109=FACE_OUTER_BOUND('',#108,.F.);
#110=ADVANCED_FACE('',(#109),#101,.T.);
#111=CARTESIAN_POINT('',(1.E2,1.E2,0.E0));
#112=DIRECTION('',(0.E0,1.E0,0.E0));
#113=DIRECTION('',(-1.E0,0.E0,0.E0));
#114=AXIS2_PLACEMENT_3D('',#111,#112,#113);
#115=PLANE('',#114);
#116=ORIENTED_EDGE('',*,*,#75,.F.);
#118=ORIENTED_EDGE('',*,*,#117,.T.);
#120=ORIENTED_EDGE('',*,*,#119,.T.);
#121=ORIENTED_EDGE('',*,*,#103,.F.);
#122=EDGE_LOOP('',(#116,#118,#120,#121));
#123=FACE_OUTER_BOUND('',#122,.F.);
#124=ADVANCED_FACE('',(#123),#115,.T.);
#125=CARTESIAN_POINT('',(1.E2,0.E0,0.E0));
#126=DIRECTION('',(1.E0,0.E0,0.E0));
#127=DIRECTION('',(0.E0,1.E0,0.E0));
#128=AXIS2_PLACEMENT_3D('',#125,#126,#127);
#129=PLANE('',#128);
#130=ORIENTED_EDGE('',*,*,#73,.F.);
#131=ORIENTED_EDGE('',*,*,#92,.T.);
#133=ORIENTED_EDGE('',*,*,#132,.T.);
#134=ORIENTED_EDGE('',*,*,#117,.F.);
#135=EDGE_LOOP('',(#130,#131,#133,#134));
#136=FACE_OUTER_BOUND('',#135,.F.);
#137=ADVANCED_FACE('',(#136),#129,.T.);
#138=CARTESIAN_POINT('',(0.E0,0.E0,1.E2));
#139=DIRECTION('',(0.E0,0.E0,1.E0));
#140=DIRECTION('',(1.E0,0.E0,0.E0));
#141=AXIS2_PLACEMENT_3D('',#138,#139,#140);
#142=PLANE('',#141);
#143=ORIENTED_EDGE('',*,*,#90,.F.);
#144=ORIENTED_EDGE('',*,*,#105,.F.);
#145=ORIENTED_EDGE('',*,*,#119,.F.);
#146=ORIENTED_EDGE('',*,*,#132,.F.);
#147=EDGE_LOOP('',(#143,#144,#145,#146));
#148=FACE_OUTER_BOUND('',#147,.F.);
#149=ADVANCED_FACE('',(#148),#142,.T.);
#150=CLOSED_SHELL('',(#81,#96,#110,#124,#137,#149));
#151=MANIFOLD_SOLID_BREP('',#150);
#152=DIMENSIONAL_EXPONENTS(1.E0,0.E0,0.E0,0.E0,0.E0,0.E0,0.E0);
#153=(LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.MILLI.,.METRE.));
#154=LENGTH_MEASURE_WITH_UNIT(LENGTH_MEASURE(2.54E1),#153);
#155=(CONVERSION_BASED_UNIT('INCH',#154)LENGTH_UNIT()NAMED_UNIT(#152));
#156=DIMENSIONAL_EXPONENTS(0.E0,0.E0,0.E0,0.E0,0.E0,0.E0,0.E0);
#157=(NAMED_UNIT(*)PLANE_ANGLE_UNIT()SI_UNIT($,.RADIAN.));
#158=PLANE_ANGLE_MEASURE_WITH_UNIT(PLANE_ANGLE_MEASURE(1.745329251994E-
2),#157);
```

```
#159=(CONVERSION_BASED_UNIT('DEGREE',#158)NAMED_UNIT(#156)PLANE_ANGLE_UNIT(
));
#160=(NAMED_UNIT(*)SI_UNIT($,.STERADIAN.)SOLID_ANGLE_UNIT());
#161=UNCERTAINTY_MEASURE_WITH_UNIT(LENGTH_MEASURE(1.731981525537E-2),#155,
'distance_accuracy_value',
'Maximum model space distance between geometric entities at asserted con-
nectivities');
#162=(GEOMETRIC_REPRESENTATION_CONTEXT(3)GLOBAL_UNCERTAINTY_ASSIGNED_CONTEX
T((#161))GLOBAL_UNIT_ASSIGNED_CONTEXT((#155,#159,#160))REPRESENTATION_CONTE
XT ('ID1','3'));
#164=APPLICATION_CONTEXT('automotive_design');
#165=APPLICATION_PROTOCOL_DEFINITION('international standard',
'automotive_design',2001,#164);
#166=PRODUCT_DEFINITION_CONTEXT('part definition',#164,'design');
#167=PRODUCT_CONTEXT('',#164,'mechanical');
#168=PRODUCT('CUBE','CUBE','NOT SPECIFIED',(#167));
#169=PRODUCT_DEFINITION_FORMATION('1','LAST_VERSION',#168);
#176=DIMENSIONAL_EXPONENTS(1.E0,0.E0,0.E0,0.E0,0.E0,0.E0,0.E0);
#177=(LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.MILLI.,.METRE.));
#178=LENGTH_MEASURE_WITH_UNIT(LENGTH_MEASURE(2.54E1),#177);
#179=(CONVERSION_BASED_UNIT('INCH',#178)LENGTH_UNIT()NAMED_UNIT(#176));
#180=DERIVED_UNIT_ELEMENT(#179,2.E0);
#181=DERIVED_UNIT((#180));
#182=MEASURE_REPRESENTATION_ITEM('surface area measure',AREA_MEASURE(6.E4),
#181);
#186=DIMENSIONAL_EXPONENTS(1.E0,0.E0,0.E0,0.E0,0.E0,0.E0,0.E0);
#187=(LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.MILLI.,.METRE.));
#188=LENGTH_MEASURE_WITH_UNIT(LENGTH_MEASURE(2.54E1),#187);
#189=(CONVERSION_BASED_UNIT('INCH',#188)LENGTH_UNIT()NAMED_UNIT(#186));
#190=DERIVED_UNIT_ELEMENT(#189,3.E0);
#191=DERIVED_UNIT((#190));
#192=MEASURE_REPRESENTATION_ITEM('volume meas-
ure',VOLUME_MEASURE(1.E6),#191);
#196=CARTESIAN_POINT('centre point',(5.E1,5.E1,5.E1));
#201=PRODUCT_CATEGORY('part','');
#202=PRODUCT_RELATED_PRODUCT_CATEGORY('part','',(#168));
#203=PRODUCT_CATEGORY_RELATIONSHIP('','',#201,#202);
#71=EDGE_CURVE('',#52,#53,#5,.T.);
#73=EDGE_CURVE('',#53,#55,#9,.T.);
#75=EDGE_CURVE('',#55,#57,#13,.T.);
#77=EDGE_CURVE('',#57,#52,#17,.T.);
#88=EDGE_CURVE('',#52,#60,#21,.T.);
#90=EDGE_CURVE('',#60,#61,#37,.T.);
#92=EDGE_CURVE('',#53,#61,#33,.T.);
#103=EDGE_CURVE('',#57,#65,#25,.T.);
#105=EDGE_CURVE('',#65,#60,#41,.T.);
#117=EDGE_CURVE('',#55,#63,#29,.T.);
#119=EDGE_CURVE('',#63,#65,#45,.T.);
#132=EDGE_CURVE('',#61,#63,#49,.T.);
#163=ADVANCED_BREP_SHAPE_REPRESENTATION('',(#151),#162);
#170=PRODUCT_DEFINITION('part definition','',#169,#166);
#171=PRODUCT_DEFINITION_SHAPE('','SHAPE FOR CUBE.',#170);
#172=SHAPE_REPRESENTATION('',(#151),#162);
#173=SHAPE_ASPECT('','solid data associated with CUBE',#171,.F.);
#174=PROPERTY_DEFINITION('',
'shape for solid data with which properties are associated',#173);
#175=SHAPE_DEFINITION_REPRESENTATION(#174,#172);
#183=PROPERTY_DEFINITION('geometric_validation_property','area of
CUBE',#173);
#184=REPRESENTATION('surface area',(#182),#162);
#185=PROPERTY_DEFINITION_REPRESENTATION(#183,#184);
```

```
#193=PROPERTY_DEFINITION('geometric_validation_property','volume of
CUBE',#173);
#194=REPRESENTATION('volume',(#192),#162);
#195=PROPERTY_DEFINITION_REPRESENTATION(#193,#194);
#197=PROPERTY_DEFINITION('geometric_validation_property','centroid of
CUBE',
#173);
#198=REPRESENTATION('centroid',(#196),#162);
#199=PROPERTY_DEFINITION_REPRESENTATION(#197,#198);
#200=SHAPE_DEFINITION_REPRESENTATION(#171,#163);

/* Giving the material (Titanium) as a general part property */

#250=PROPERTY_DEFINITION('material property','material name',#170);
#251=DESCRIPTIVE_REPRESENTATION_ITEM('AMS4928','Titanium 6-4');
#252=REPRESENTATION('material name',(#251),#162);
#253=PROPERTY_DEFINITION_REPRESENTATION(#250,#252);

/* Assignment of density (2.0) to the material */

#300=PROPERTY_DEFINITION('material property','density of part',#170);
#301=MEASURE_REPRESENTATION_ITEM('density meas-
ure',POSITIVE_RATIO_MEASURE(2.0),#500);
#302=REPRESENTATION('density',(#301),#162);
#303=PROPERTY_DEFINITION_REPRESENTATION(#300,#302);

/* Mass and Density unit definitions for the unit context */

/* Mass unit [Pounds] Note: 1 kg = 2.206 lb */
#400=(MASS_UNIT() NAMED_UNIT(*) SI_UNIT(.KILO.,.GRAM.));
#401=DIMENSIONAL_EXPONENTS(0.E0,1.E0,0.E0,0.E0,0.E0,0.E0,0.E0);
#402=MASS_MEASURE_WITH_UNIT(MASS_MEASURE(4.536E-1),#400);
#403=(CONVERSION_BASED_UNIT('POUND',#402)MASS_UNIT()NAMED_UNIT(#401));

/* Density [lb/inch3] */
#500=DERIVED_UNIT((#501,#502));
#501=DERIVED_UNIT_ELEMENT(#403,1.);
#502=DERIVED_UNIT_ELEMENT(#155,-3.);
#503=NAME_ATTRIBUTE('POUND PER CUBIC INCH',#500);   /* optional */

ENDSEC;
END-ISO-10303-21;
```

## 6.2   Using "Material as Product", conforming to AP214 IS

Since the geometry given in the file is identical, only the part of the file defining the material and density is given here. To obtain a complete sample file for this approach, replace the highlighted entities in section 6.1 with the file excerpt given below.

This excerpt represents density as general property. For density as material property, take entities #300 to #503 from section 5.3.1.

```
/* Definition of the material (Titanium) as a product */

#250=PRODUCT('AMS4928','Titanium 6-4','',(#167));
#251=PRODUCT_RELATED_PRODUCT_CATEGORY('raw material','',(#250));
#252=PRODUCT_DEFINITION_FORMATION('1','LAST_VERSION',#250);
#253=PRODUCT_DEFINITION_CONTEXT('part definition',#164,'design');
#254=PRODUCT_DEFINITION('part definition','',#252,#253);
```

```
/* Establish the make_from_relationship */

#275=MAKE_FROM_USAGE_OPTION('Assign AMS4928 to CUBE','make
from','',#170,#254,1.0,'',#276);
#276=MEASURE_WITH_UNIT(COUNT_MEASURE(1),#277);
#277=NAMED_UNIT(#278);
#278=DIMENSIONAL_EXPONENTS(0.0,0.0,0.0,0.0,0.0,0.0,0.0);

/* assignment of density (2.0) to the material */

#300=PROPERTY_DEFINITION('material property','density',#254);
#301=MEASURE_REPRESENTATION_ITEM('density meas-
ure',POSITIVE_RATIO_MEASURE(2.0),#500);
#302=REPRESENTATION('density',(#301),#162);
#303=PROPERTY_DEFINITION_REPRESENTATION(#300,#302);

/* Mass and Density unit definitions for the unit context */

/* Mass unit [Pounds] Note: 1 kg = 2.206 lb */
#400=(MASS_UNIT() NAMED_UNIT(*) SI_UNIT(.KILO.,.GRAM.));
#401=DIMENSIONAL_EXPONENTS(0.E0,1.E0,0.E0,0.E0,0.E0,0.E0,0.E0);
#402=MASS_MEASURE_WITH_UNIT(MASS_MEASURE(4.536E-1),#400);
#403=(CONVERSION_BASED_UNIT('POUND',#402)MASS_UNIT()NAMED_UNIT(#401));

/* Density [lb/inch3] */
#500=DERIVED_UNIT((#501,#502));
#501=DERIVED_UNIT_ELEMENT(#403,1.);
#502=DERIVED_UNIT_ELEMENT(#155,-3.);
#503=NAME_ATTRIBUTE('POUND PER CUBIC INCH',#500); /* optional */
```

### 6.3  Conforming to AP203 with modular extensions

### 6.4  Conforming to AP203 Edition 2

# 7  Availability of implementation schemas

### 7.1  AP214

The AP214 IS schema supports the implementation of the capabilities as described. The schema can be retrieved from the 'Joint Testing Information' section of the CAx-IF web site:

http://www.cax-if.de/documents/ap214_is_schema.zip

### 7.2  AP203 with modular extensions

The extended schema for AP 203 including support for geometric validation properties, colors and layers, 3D text annotation, etc. and be used to support transfer of material identification and density. The schema can be accessed via WWW from:

http://www.cax-if.de/documents/ccd_cla_gvp_ast_asd.exp

### 7.3  AP203 edition 2

The schema for the second edition of AP203 supports the transfer of material identification and density as described in this document. The most current schema is available from

http://www.cax-if.de/joint_testing_info.html