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Industrial automation systems and integration — Industrial manufacturing management data —

Part 44: Information modelling for shop floor data acquisition

Systèmes d'automatisation industrielle et intégration — Données de gestion de fabrication industrielle —

Partie 44: Modélisation de l'information de gestion de fabrication pour l'acquisition des données d'atelier

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 4, *Industrial data*.

This second edition cancels and replaces the first edition (ISO 15531-44:2010), which has been technically revised.

A list of all parts in the ISO 15531 series can be found on the ISO website.

Introduction

ISO 15531 is an International Standard for the modelling of data used in manufacturing management (except for product and component data as well as catalogue or library data that are modelled using ISO 10303 and ISO 13584). ISO 15531-31 and ISO 15531-32 address the modelling of data used for the management of resources usage, whereas ISO 15531-43 addresses the modelling of manufacturing management data and ISO 15531-42 provides a time model.

The other data that are used for manufacturing management include some data that are captured at the control level of manufacturing, but that are stored at the management level and used at this level to manage manufacturing for quality, maintenance, rescheduling or any other management purpose.

These data are very often captured in various formats that are determined by device and process constraints. The time stamping and time measure related to this data capture, as well as the batch and resource to which this capture is associated, are also needed to manage manufacturing in an efficient way. Each occurrence of time measure and time stamping is also specific to the resource and its result is further related to a unique time model and reference.

After several translation operations and handling, the raw data collected from level 2 become level 3 data. They are stored in a database that gathers and organizes all the collected data in accordance with level 3 models that are predefined to be reusable. Their subsequent usage in various manufacturing management software implies that the corresponding models are well defined and unique for given information, even if that kind of information can appear several times from several resources.

NOTE The definitions of functional levels used here are those of IEC 62264-1 and are repeated for information in Clause 4 of this document. The monitoring and control of physical devices belong to level 2, while the management of manufacturing operations belongs to level 3. This document addresses the modelling of level 3 data that are the result of the collection at level 2 of raw data and the result of their translation and handling. The translation and handling are outside the scope of this document.

It is the aim of this document to provide, for those data, models that are shareable by any software used to manage and improve manufacturing.

Industrial automation systems and integration — Industrial manufacturing management data —

Part 44: Information modelling for shop floor data acquisition

1 Scope

This document addresses the modelling of the data collected from data acquisition systems at control level to be stored at the manufacturing management level and processed further at this level for any management purpose.

The following are within the scope of this document:

— quantitative or qualitative data collected from data acquisition systems at the control or management level to be stored at the management level and used later on to manage manufacturing;

— time stamping and time measurement provided from data acquisition systems for control and management data.

The following are outside the scope of this document:

— any data only related to remote and real time measurement and management;

— product definition data as modelled in the ISO 10303 series;

— catalogue and library data as modelled in ISO 13584 and ISO 15926;

— control data that are only used at the control level as well as those that are not used for manufacturing management.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
beginning date
instance of point in time that identifies an *event* (3.1.4) that is the starting point of something noticeable and durable

EXAMPLE Beginning date of a data capture occurrence, of a task, of a measure, or of a *state* (3.1.14) change.

Note 1 to entry: "Point in time" is defined in ISO 15531-42:2005, 3.1.13.

3.1.2
connection
junction of an identifier to another identifier related to an assembly operation

EXAMPLE Joining a part batch number to a subset.

Note 1 to entry: A connection does not have a property or attribute while the association is a semantic relationship.

3.1.3
ending date
instance of point in time that identifies an *event* (3.1.4) that is the ending point of something noticeable that has had duration

EXAMPLE Ending date of an activity, of a data capture.

Note 1 to entry: Point in time is defined in ISO 15531-42:2005, 3.1.13.

3.1.4
event
something noticeable that takes or can take place at a given place and point in time

EXAMPLE The start of a given activity, the anniversary of another event, the end of machine failure.

3.1.5
genealogy
connection (3.1.2) that relates unique identifiers

EXAMPLE Joining a serial number to another serial number.

Note 1 to entry: Genealogy is not a semantic relationship. For example, no property or attribute is associated with the junction between the serial numbers of the example given in this entry.

3.1.6
hazard event
noticeable failure during a *manufacturing process* (3.1.9)

Note 1 to entry: The failure is noticeable enough to be recorded in the database. It can be caused by the *resource* (3.1.13) on which the *event* (3.1.4) appears or by a previous event.

3.1.7
manufacturing
function or act of converting or transforming material from raw material or a semi-finished *state* (3.1.14) to a state of further completion

Note 1 to entry: Definition adapted from the APICS dictionary[22].

[SOURCE: ISO 15531-1:2004, 3.6.22]

3.1.8
manufacturing order
document, group of documents, or schedule conveying authority for the manufacture of specified parts or products in specified quantity

Note 1 to entry: A manufacturing order identifies a unit of scheduled work to be manufactured; it includes, for example, a reference, a quantity and a due date. The manufacturing order is also the *event* (3.1.4) that triggers a *manufacturing* (3.1.7) operation.

Note 2 to entry: Adapted from the APICS dictionary[22].

3.1.9
manufacturing process
structured set of activities or operations performed upon material to convert it from raw material or a semi-finished *state* (3.1.14) to a state of further completion

Note 1 to entry: Manufacturing processes can be arranged in process layout, product layout, cellular layout or fixed position layout. Manufacturing processes can be planned to support make-to-stock, make-to-order, assemble-to-order, etc., based on strategic use and placements of inventories.

[SOURCE: ISO 15531-1:2004, 3.6.25]

3.1.10
operation mode
one of the ways of operation expected from a *resource* (3.1.13) and set up in a given application

Note 1 to entry: Each machine can have one or more operation modes (e.g. automatic, step-by-step, manual) determined by the type of machine and its application.

Note 2 to entry: The operation mode is selected from those available by the operator.

Note 3 to entry: The operation mode is represented in the model by the entity mode (see 6.3.7.2).

3.1.11
process
structured set of activities involving various enterprise entities, that is designed and organized for a given purpose

Note 1 to entry: The definition provided here is very close to that given in ISO 10303-49. Nevertheless ISO 15531 needs the notion of structured set of activities, without any predefined reference to the time or steps. In addition, from the point of view of flow management, some empty processes can be needed for synchronization purposes although they are not actually doing anything (ghost tasks).

[SOURCE: ISO 15531-1:2004, 3.6.29]

3.1.12
product defect
anomaly identified, during a control, on a badly manufactured product

3.1.13
resource
device, tool and means at the disposal of the enterprise to produce goods or services

Note 1 to entry: Resources as defined in ISO 15531-1:2004, 3.6.43, exclude raw materials, products and components that are considered from a system theory point of view as parts of the environment of the system and do not belong to the system itself. Furthermore, this definition includes the definition found in ISO 10303-49 but is included in the definition that applies for ISO 18629-14 and ISO 18629-44 (which also includes raw materials and consumables), as well as ISO 18629-13.

Note 2 to entry: Resources, as they are defined here, include human resources considered as specific means with a given capability and a given capacity. Those means are considered to be capable of being involved in the *manufacturing process* (3.1.9) through assigned tasks, which does not include any modelling of an individual or common behaviour of human resources, except in their capability to perform a given task in the manufacturing process (e.g. transformation of a raw material or component, provision of logistic services). This means that human resources are only considered, as are the other resources, from the point of view of their functions, their capabilities and their status (e.g. idle, busy), excluding any modelling or representation of any aspect of individual or common "social" behaviour.

Note 3 to entry: Adapted from ISO 15531-1:2004, 3.6.43.

3.1.14
state
condition or situation during the life of an object during which it satisfies some condition, performs some activity, or waits for some *event* (3.1.4)

Note 1 to entry: The meaning of state here is similar to the meaning of state in "state automaton".

[SOURCE: ISO 15745-1:2003, 3.31, modified — the note to entry has been added]

3.1.15
work order
unit of scheduled work, that can be dispatched to a *resource* (3.1.13) and that addresses a specific phase of the *manufacturing process* (3.1.9)

Note 1 to entry: A work order can be dispatched to a physical device and/or a human (or group of humans), that are the two subclasses of the entity resource. This work order consists of lower level elements and is a component of a *manufacturing order* (3.1.8).

3.2 Abbreviated terms

KPI	Key Performance Indicator
LAN	Local Area Network
PLC	Programmable Logic Controller
PLIB	Parts Libraries (ISO 13584)
MANDATE	Manufacturing Data Exchange (ISO 15531)
RFID	Radio-Frequency IDentification
STEP	STandard for the Exchange of Product model data (ISO 10303)

4 General purpose and scope of ISO 15531

ISO 15531, also known as MANDATE, specifies the characteristics for a representation of manufacturing management information over the entire industrial process, with the necessary mechanisms and definitions to enable manufacturing management data to be shared and exchanged within the factory, with other plants or with companies.

Exchanges are made through different computer systems and environments associated with the complete industrial process. ISO 15531 (ISO 15531-1, ISO 15531-31, ISO 15531-32, ISO 15531-42 and ISO 15531-43) focuses on discrete manufacturing but is not limited to it. Nevertheless, any extension to industrial processes which does not belong to discrete manufacturing is always under consideration when it does not imply any contradiction or inconsistency with the initial objective of ISO 15531.

The following are within the scope of ISO 15531:

— the representation of production and resources information including capability capacity, monitoring, maintenance constraints and control;

NOTE 1 Maintenance constraints and relevant maintenance management data are taken into account from the point of view of their impact on the flow control.

— the exchange and sharing of production information and resources information, including storing, transferring, accessing and archiving.

The following are outside the scope of ISO 15531:

— enterprise modelling;

NOTE 2 This means that tools, architecture and methodologies for the modelling of an enterprise as a whole are not within the scope of ISO 15531.

— product data (representation and exchange of product information);

— component data (parts library: representation and exchange of computer-interpretable parts library information);

— cutting tools (electronic representation for exchange of cutting tool data);

— technical maintenance information (technical information such as that included in device repair, operation and maintenance manuals).

IEC 62264-1 identifies the following five levels for the functions related to manufacturing operation:

— Level 0, which addresses actual physical process;

— Level 1, which addresses functions involved in the sensing and manipulating of the physical process;

— Level 2, which addresses functions involved in the monitoring and controlling of the physical process;

— Level 3, which addresses functions involved in managing the work flows to produce the desired end products;

— Level 4, which addresses functions involved in the business-related activities needed to manage a manufacturing organization.

Figure 1 shows the hierarchy of functional levels.

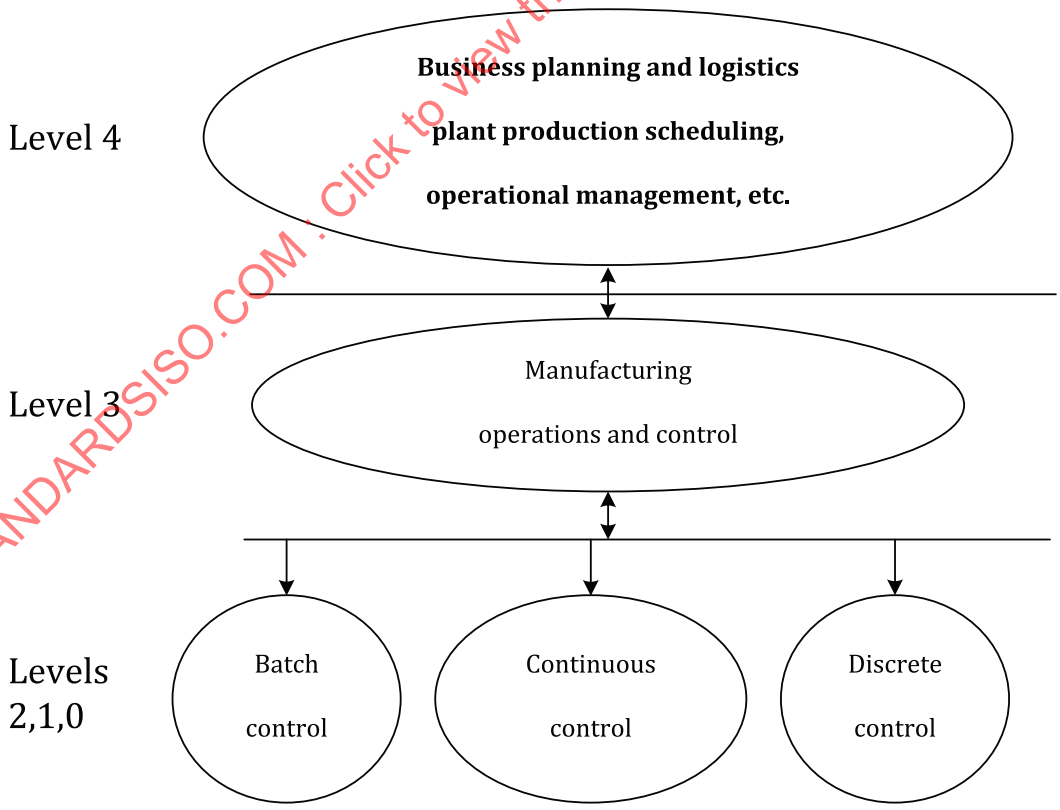

Figure 1 — Functional levels (from IEC 62264-1)

ISO 15531 addresses the modelling of any data (except product data) that are suitable to manage manufacturing operations (ISO 15531-31, ISO 15531-32, ISO 15531-43). Even if in this context ISO 15531

addresses level 3 or level 4 functions, it models any data suitable for the management of manufacturing operations including data that are collected at other levels.

5 Purpose, principles and structure of this document

5.1 Purpose of this document

The data acquisition process in a shop floor collects data at level 2 (shop floor level), it provides their identification and their content before their provision to level 3 (manufacturing management level). These manufacturing data can address the devices, the manufacturing batches, the products or the staff. They are requested for the KPI calculations, for the manufacturing and quality monitoring and for the improvement of manufacturing operations. They also enable the validation of shop floor models and scheduling scenario.

The compliance with a model eases the collection and organization as well as the handling of the data in the database built at level 3 (manufacturing management level) for historic and management purposes and the setup of shop floor monitoring systems, as well of their interoperability.

5.2 Basic principles of this document and overview of the main entities

Given that the model shall be as generic as possible and easy to specialize, the entities described in the model are themselves as generic as possible. Their specialization, if needed, shall be obtained through the use of the PLIB (ISO 13584-1, ISO 13584-24), where the specialization process is roughly described.

Although the model is mainly focused on the relationships between the manufacturing process events, activities, state changes, it nevertheless enables the modelling of any data collected at level 2 for a manufacturing management and or improvement purpose (level 3).

The main entities defined or used in the model are listed and outlined below:

NOTE 1 Some entities that are referenced from other schema and/or are service entities are described and specified in Clause 6, but are not listed or described below:

— **duration_reference**;

— **equipment**;

— **equipment_header**;

— **hazard_event**;

— **manufacturing_batch**;

— **manufacturing_order**;

— **manufacturing_order_header**;

— **manufactured_product**;

— **material_consumption**;

— **measurement_result**;

— **mode**;

— **product_defect**;

— **state**;

— **stock**;

— **time_reference**;

— **work_order**.

The **manufacturing_batch** entity addresses the lot of products or components scheduled to be produced or the lot of products or components that is produced in a range of operation.

NOTE 2 For discrete products or components the batch can be a standard set of products or components scheduled to be manufactured, while for non-discrete products the batch is the quantity that is planned to be produced in a given period based on a formula or recipe that is often developed to produce a given number of end items (see Reference [22]).

NOTE 3 This document only describes and uses the **manufacturing_batch** entity, which is a specialization of the batch entity given that it is mainly focused on discrete part manufacturing. In case of non-discrete products it is up to the user to modify this **manufacturing_batch** entity to take into account non-discrete products, or to add the parent entity (**batch**) or another specialization of the **batch** entity that addresses non-discrete products.

The **duration_reference** entity specifies a specific duration to which all the collected duration shall refer or be related in order to guarantee consistency between the durations collected.

The **equipment** entity describes a physical device that is used during a manufacturing process to transform raw materials and/or components into a more finished component or product. Equipment is a sub-class of resource. The other specialization of the entity resource is human, which is not used and not modelled in this standard.

The **equipment_header** entity includes all the needed information that is predefined and related to the equipment independently of its mode, status and of the work order it operates.

The entity **hazard_event** addresses unexpected noticeable incidents that occur during the manufacturing process.

EXAMPLE 1 A failure on a resource (equipment, human, etc.) is a **hazard_event**. The failure shall be important enough to be recorded.

The entity **manufacturing_batch**, which is a specialization of batch for manufacturing products, addresses a lot of products manufactured or to be manufactured in the same range of operation.

EXAMPLE 2 A set of products which will undergo the same work order.

The entity **manufacturing_order** represents the document or group of documents associated with a lot of components and/or products scheduled to be produced.

The **manufacturing_order_header** entity includes all the needed information that is predefined and not modified by the manufacturing process actually running.

The entity **manufactured_product** refers to the product along its manufacturing life cycle.

NOTE 4 **Manufactured_product** is a specialization of the ISO 10303 **product** entity (ISO 10303-1, ISO 10303-41).

The **material_consumption** entity describes, for traceability purposes, the volume, number and supplier batch number of raw materials and parts of all kinds used and consumed during the manufacturing process and corresponding to a given phase of the work order.

The entity **measurement_result** represents the result of a control. **Measurement_result** is a specialization of the **measure** entity of ISO 10303-41.

The entity **mode** reflects the operation mode that is one of the ways of operation expected of a resource and set up in a given application.

EXAMPLE 3 An operating mode of a machine can be: normal, degraded, closed.

The entity **product_defect** is a description of an anomaly detected on a product, semi-finished product or sub-assembly. This detection leads to a discard of the concerned product.

The entity **resource** can include two subclasses: the entities **equipment** and **human**. Special care has been taken to avoid that this model enables the monitoring and eventually the sanctioning of an individual staff member. No identification of a given employee shall be possible through the model. Thus the entity human has not been described or used in this standard. If developed, such an entity shall only model a group of persons and/or a generic type of human resource.

NOTE 5 A human resource can be, for example, "operator" or "technician", but it cannot be an individual, while an equipment resource can be identified as a specific instance of the resource.

The entity **state** addresses the condition or situation of equipment which satisfies some conditions, performs some activities, or waits for some events.

EXAMPLE 4 The state of an item of equipment can be automatic production, adjustment, maintenance.

NOTE 6 The entities **state** and **mode** are compliant with IEC 60204-1 and ISO 12100.

The entity **stock** represents products, components or raw materials which are not on the fabrication line.

The **time_reference** entity references a specific point in time that is used to establish the needed relationships between the various points in time related to the data collected locally by different systems.

The entity **work_order** represents the unit of scheduled work that can be dispatched to a resource and addresses a specific phase of the manufacturing process.

5.3 Structure of shop floor data acquisition system

The structure of the shop floor data acquisition system is shown in Figure 2.

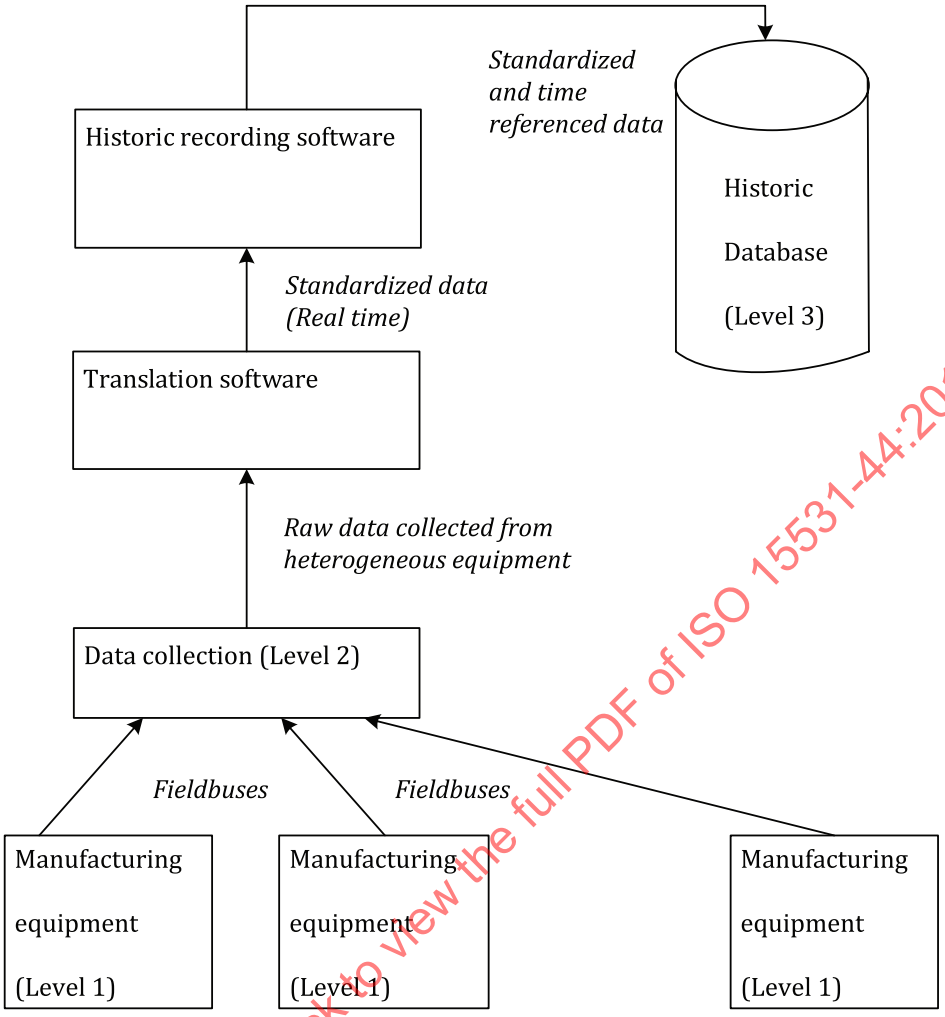

Figure 2 — Schema of the shop floor data acquisition and level 3 recording process

— The data gathering consists essentially of two components: a system dedicated to communication with manufacturing elements and a watcher that enables the cycle- or event-based gathering of the shop floor data. The picking up of the data can be performed automatically by the process itself or manually by ad hoc interfaces between humans and machines.

— The translation programme transforms in real time the picked up raw data (that represent several standardized data, and that can be superimposed, approximated or expressed in units that are specific to the equipment) into standardized data with well known format and meaning.

— The recording software set up makes and enriches the history and events log database. It also checks the consistency of events, aggregates the beginning and the end of events provided by the translation software, and releases the recording into the historic database. It is here that the biggest problems of size and size evaluation occur.

5.4 The captured data and their organization

5.4.1 General characteristics

The data that are picked up in the shop floor are classified according to their main use. For all activities, the first set of data addresses manufacturing orders. The other data are organized according to the diagram presented in Figure 3.

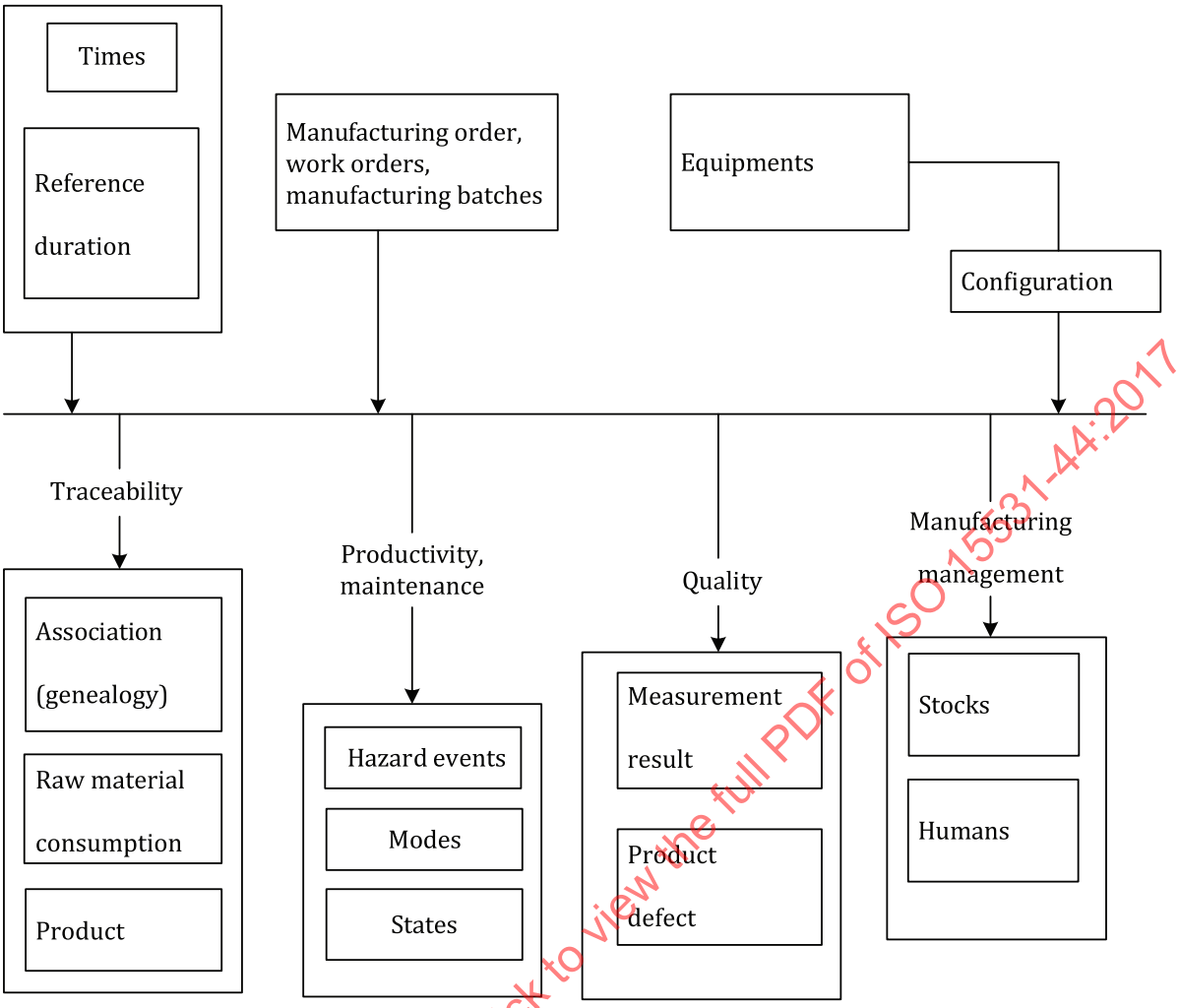

Figure 3 — Organization of the model: main data captured

The logic of the diagram presented in Figure 3 is the following.

The upper boxes identify common entities related to the time, to the work-orders, the equipment used and the configuration, while the boxes under the line identify specific entities related to the manufacturing process. These specific entities are organized into the following four groups:

— the first encompasses the entities related to traceability (association, raw material consumption, product);

— the second addresses the entities related to productivity and maintenance (hazard event, mode, state);

— the third addresses the entities related to quality (measurement result, product defect);

— the fourth encompasses the entities related to manufacturing management (stock, humans).

In the context of this document, there is no entity dedicated to the concept of genealogy. The genealogy is the capability to find components and/or compounds of a manufactured product (**manufactured_product**) from its serial number (**manufactured_product_id**). This function is only available for products that have a serial product. It does not exist for common placed production.

This function is mandatory. In this standard it is supported through the fact that the **manufactured_product** entity is recursive since one **manufactured_product** entity can be made up of one (or more) other **manufactured_product** entities (association relation).

EXAMPLE One usage of this genealogy is the identification and traceability of defective component batches; another is the retrieval of adjustment value for the thermic part ("son" element) of a magnetothermic circuit breaker ("father" element).

5.4.2 Manufacturing management data

— Stock monitoring.

— Staff management.

5.4.3 Quality management

— Measures made on sub-components or final products.

— Defects on sub-components or products checked as bad.

5.4.4 Productivity and maintenance

— Follow-up of equipment risks (defects).

— Follow-up of changes in MODE (EN 292-2, IEC 60204-1, ISO 12100).

— Follow-up of changes in STATUS (IEC 60204-1, ISO 12100).

5.4.5 Traceability

— Sub-component association (genealogy).

— Raw material consumption.

— Unitary product follow-up.

5.5 The question of time: time stamping and time measure

The installation of a time stamp on an event can occur at any step of the picking process with the following constraints:

— the time stamping is more accurate if it is made early. Even if the data capture system is a real-time system, it introduces some delay that is variable. In the data capture chain, all the buffers, retry process and examination cycles decrease the accuracy (they increase the entropy of the system). In such cases, it can be possible to avoid delays related to the checking, to the progress of information through the LAN and to the data processing. Time stamping can be done at the source with a resolution of 10 ms with a PLC. If performed by the translator it is sometimes unnecessary to go under 1s;

— the stamping is more homogenous between the various events and the various shop floor sections when it is done late in the process. That enables the establishment of relationships and correlations between data that are not bound by anything other than the time.

NOTE It is not realistic to keep the time stamping of several hundred PLCs exactly at the same time. A one hour shift in time stamping can hinder the identification of a relationship between events normally linked together.

The time stamping made by a crossed data processing system improves the requested consistency to the detriment of the accuracy.

Enabling the capture of both beginning date and duration as well as ending date in the time stamping can appear to be redundant. In fact, beginning date and ending date are related to events while duration is related to an activity, to a transformation (even empty), or to a phase of the manufacturing process. There can be redundancies between these data only if beginning date refers to the event "start of the activity" and ending date refers to the event "activity achievement". Even in that case, this "redundancy" can be used to improve the accuracy of the synchronization between different data sets collected at different dates from different data acquisition systems. It also enables the recovery of missing data in case of cumulated hazard events.

The collection of beginning date, ending date and duration of an activity or phase of manufacturing process through RFID tag in association with data collected through different LAN can also contribute to this better synchronization.

EXAMPLE 1 A hazard event starts. Then the system updates the recording every minute. In case of failure in the connection, the ending date becomes missing but can be approximately recovered through the beginning date and the connection duration.

Another important aspect of the recording of beginning date, ending date and duration is related to the techniques and the verbs used in nearly all request software.

EXAMPLE 2 A request based on "WHERE" will use beginning date and ending date while a request based on "SUM selection" will use duration.

The period of observation before the event time stamping has a significant impact on the precision of the time stamping as well as on the shortest event that will be possible to observe. When the event is time stamped, any kind of queue or intermediate storage can be envisioned for the concerned data. To spare bandwidth in the network it is even possible to customize periods of observation that can be different and can depend on the concerned equipment.

5.6 Size optimization

The storage in the historic database is the bottleneck of the whole data capture process in the shop floor. Thus it becomes vital to reduce as far as possible the volume of data to be recorded.

One solution is obviously to aggregate information that is similar (the same kind of information). That means keeping only the recording of just one event that can be used to summarize a whole period of observation. This naturally leads to the loss of the precise progress of events during this period.

EXAMPLE 1 Instead of the recording of all the measures made on the 1000 products manufactured during the day, it can be possible to store only the average, the standard deviation and the number of measures made.

EXAMPLE 2 Instead of memorizing any machine failure during the day, it is possible to summarize for each machine or group of machines the number of failures by kind of failure or by the duration only.

It is obvious that a high level of summarization means a reduction in the possibility of further analysis as well as a drastic reduction in the possibility of correlation with other events.

EXAMPLE 3 In the case of machine failures, it becomes impossible with an aggregate to determine if some manufactured references are involved in the failure, leading to the need to correlate with the equipment risk and manufacturing orders.

6 The EXPRESS schema definition of shop floor captured data

6.1 Shop floor captured data schema definition

The following EXPRESS declaration begins the **shopfloor_captured_data_schema** and identifies the necessary external references.

See ISO 10303-11 for EXPRESS specifications.


```
EXPRESS specification:
*)
```
SCHEMA shopfloor_captured_data_schema;

REFERENCE FROM support_resource_schema

```
(identifier,
label,
```
text); – ISO 10303-41

```
(*

*)
REFERENCE FROM product_definition_schema
(product);    -- ISO 10303-41
(*

*)
REFERENCE FROM measure_schema
(measure_with_unit,
context_dependent_unit,
unit);        -- ISO 10303-41
(*

*)
REFERENCE FROM resource_usage_management_schema
(resource);   -- ISO 15531-32
(*

*)
REFERENCE FROM time_domain_schema
(interval_of_time,  -- ISO 15531-42
point_in_time);
(*
```

6.2 Shopfloor_captured_data type definitions

6.2.1 type_of_movement

A **type_of_movement** is an alphanumeric string that identifies the different possibilities of movement the storage device is able to provide.

```
EXPRESS specification:
*)
TYPE type_of_movement = SELECT
(stock_in, stock_out, stock_taking);
END_TYPE;                    -- type_of_movement
(*
```

6.2.2 stock_in

One of the three types of movement applicable to stocks.

```
EXPRESS specification:
*)
ENTITY stock_in;
END_ENTITY;
(*
```
NOTE Used for products entering the storage device.

6.2.3 stock_out

One of the three types of movement applicable to stocks.

```
EXPRESS specification:
*)
ENTITY stock_out;
END_ENTITY;
(*
```

NOTE Used for products leaving the storage device.

6.2.4 stock_taking

One of the three types of movement applicable to stocks.

```
EXPRESS specification:
*)
ENTITY stock_taking;
END_ENTITY;
(*
```

NOTE Used to count the number of manufactured products in the inventory.

6.3 Shop floor captured data entity definitions

6.3.1 Stock

A stock is constituted of products, components or raw materials which are not on the fabrication line.

```
EXPRESS specification:
*)
ENTITY stock;
       contains: manufactured_product;
       refers_to: OPTIONAL manufacturing_batch;
       stored_on: equipment;
       quantity: OPTIONAL measure_with_unit;
       move: type_of_movement;
       date_of_movement: point_in_time;
END_ENTITY;
(*
```

Attribute definitions:

contains: specifies the **manufactured_product**s that are stored in this stock;

refers_to: specifies the **manufacturing_batch** to which this **stock** belongs;

stored_on: identifies the **equipment** on which the stock is stored;

quantity: OPTIONAL, is the actual size of the stock;

move: identifies one of the three possibilities defined in the entity **type_of_movement**;

date_of_movement: **point_in_time** that characterizes the date of the movement.

6.3.2 Manufactured_product

Manufactured_product is a specialization of the product entity (ISO 10303) that is a thing produced by the manufacturing process; it can be a finished or partly-finished product. **Manufactured_product** is not the instance of which the manufacturing process is in progress. **Manufactured_product** is actually the "product model" to which all the concerned instances belong.

EXAMPLE A **manufactured_product** can be a contactor model to which each contactor instance that is stored, or manufactured in the same manufacturing_batch belongs.

```
EXPRESS specification:
*)
ENTITY manufactured_product;
manufactured_product_id: identifier;
       relates_to: product;
       belongs_to: OPTIONAL manufacturing_batch;
UNIQUE
       UR1: manufactured_product_id;
END_ENTITY;
(*
```

Attribute definitions:

manufactured_product_id: identifies the **manufactured_product**;

related_to: specifies the **product**s to which the **manufactured_product** relates;

belongs_to: OPTIONAL, refers to the **manufacturing_batch** to which the **manufacturing_product** belongs.

6.3.3 Orders

6.3.3.1 Manufacturing_order

A manufacturing order is composed of all the work orders corresponding to the range of the manufactured product identified in the manufacturing order to be produced. The definition is provided in 3.1.8.

```
EXPRESS specification:
*)
ENTITY manufacturing_order;
is_composed_of: SET [0:?] OF work_order;
       header: manufacturing_order_header;
       duration: interval_of_time;
       ending_date: point_in_time;
       beginning_date: point_in_time;
END_ENTITY;
(*
```

Attribute definitions:

is_composed_of: list of **work_order**s that belong to the **manufacturing_order**;

header: identifies the **manufacturing_order_header** that includes all the attributes that are predefined for this **manufacturing_order**;

duration: **interval_of_time** during which the activities and/or phases to which the **manufacturing_order** refers, spread out;

ending_date: **point_in_time** of the event that marks the actual end of the activities to which the **manufacturing_order** refers (not the scheduled ending time);

beginning_date: **point_in_time** of the event that marks the actual starting point of the activities to which the **manufacturing_order** refers (not the scheduled starting time).

6.3.3.2 Manufacturing_order_header

The manufacturing_order_header is defined to include all the information that is predefined for the **manufacturing_order** and not subject to change during the manufacturing process.

```
EXPRESS specification:
*)
ENTITY manufacturing_order_header;
       manufacturing_order_id: identifier;
       customer_order: OPTIONAL label;
       manufacturing_order_label: OPTIONAL label;
reference: string;
       quantity: context_dependent_unit;
       measure: unit;
       due_date: point_in_time;
       beginning_scheduled_date: point_in_time;
UNIQUE
       UR1: manufacturing_order_id;
END_ENTITY;
(*
```

Attribute definitions:

manufacturing_order_id: identifies the **manufacturing_order** to which this **manufacturing_order_header** refers;

customer_order: OPTIONAL, identifies the customer order to which this **manufacturing_order** refers;

manufacturing_order_label: OPTIONAL, enables the recording of specific information;

reference: specifies a reference of the **product** to manufacture;

quantity: provides the quantity of **product** to be manufactured according to this manufacturing order;

This quantity can have a unit, but not necessarily;

measure: provides the **unit** used for the evaluation of the quantity;

due_date: identifies the date to which the manufacturing shall be achieved;

beginning_scheduled_date: identifies the scheduled beginning_date.

6.3.4 Manufacturing_batch

A **manufacturing batch** is a set of manufactured products. It is the gathering of manufactured products belonging to the same work order.

NOTE 1 A batch consists either of finished products, semi-finished products or sub-assemblies but never consists of raw material.

NOTE 2 The entity **manufacturing_batch** has been designed as a specialization of a possible entity batch (not described in this standard) focusing on discrete part manufacturing. Nevertheless it can be used as it is for non-discrete products. The designation **manufacturing_batch** enables user to add another specialization of the entity batch to take into account possible generic attributes specific to non-discrete products if needed.

```
EXPRESS specification:
*)
ENTITY manufacturing_batch;
       is_made_of : SET [0:?] OF manufactured_product;
       is_managed_by: manufacturing_order;
       batch_id: string;
       size: context_dependent_unit;
duration: interval_of_time;
       ending_date: point_in_time;
       beginning_date: point_in_time;
END_ENTITY;
(*
```

Attribute definitions:

is_made_of: specifies which **manufactured_product**sproduct belong to the batch;

is_managed_by: the evolution of the batch is given by the **manufacturing_order**;

batch_id: allows a batch to be identifie;

size: represents the number of **manufactured_product** in the batch;

duration: **interval_of_time** during which the activities and/or phases to which the **work_order** refers, spread out;

ending_date: **point_in_time** of the event that marks the actual end of the activities to which the **work_order** refers (not the scheduled ending time);

beginning_date: **point_in_time** of the event that marks the actual starting point of the activities to which the **work_order** refers (not the scheduled starting time).

6.3.5 Work_order

A work order represents the execution of a particular process phase of the work range.

Work_order is related to a given equipment and to a **manufacturing_order** that is related to a given **manufacturing_batch**.

EXAMPLE while a manufacturing order addresses the manufacturing of a lot of products (for example) along a manufacturing line, a work-order addresses a specific phase of this process and a specific manufacturing_batch that concerns a component (for example) processed on a given equipment of this line.

```
EXPRESS specification:
*)
ENTITY work_order;
       work_order_id: identifier;
       is_part_of: manufacturing_order;
       is_performed_on: equipment;
       duration: interval_of_time;
       ending_date: point_in_time;
       beginning_date: point_in_time;
       processed_quantity: context_dependent_unit;
       produced_quantity_OK: context_dependent_unit;
       produced_quantity_NOK: context_dependent_unit;
       previous_work_order: OPTIONAL work_order;
UNIQUE
       UR1:work_order_id;
END_ENTITY;
(*
```

Attribute definitions:

work_order_id: allows the **work_order** to be uniquely identified;

is_part_of: identifies the **manufacturing_order** to which this **work_order** belongs;

is_performed_on: identifies the **equipment** on which the **work_order** is processed;

duration: **interval_of_time** during which the activities and/or phases to which the **work_order** refers, spread out;

ending_date: **point_in_time** of the event that marks the actual end of the activities to which the **work_order** refers (not the scheduled ending time);

beginning_date: **point_in_time** of the event that marks the actual starting point of the activities to which the **work_order** refers (not the scheduled starting time);

processed_quantity: counts the quantity of **product**s that are manufactured on an **equipment**;

produced_quantity_OK: counts the quantity of good products that are manufactured on an **equipment**;

produced_quantity_NOK: counts the quantity of bad products that are manufactured on an **equipment**;

previous_work_order: is optional and when present identifies the **work_order** which has just been finished.

6.3.6 material_consumption

Volume, number and supplier batch number of raw material and parts of all kind used and consumed during the manufacturing process and corresponding to a given phase of the work order.

```
EXPRESS specification:
*)
ENTITY material_consumption;
supplier_batch_number: string;
quantity: OPTIONAL measure_with_unit;
internal_reference: string;
used_for: manufactured_product;
corresponds_to: work_order;
date_of_consumption: point_in_time;
used_equipment: OPTIONAL equipment;
END_ENTITY;
(*
```

Attribute definitions:

supplier_batch_number: batch number of the part used or consumed provided by the supplier of the part;

quantity: OPTIONAL, provides the quantity of material or part used or consumed during the assembly process;

internal_reference: name of the material or part used within the company;

used_for: product or sub-assembly within which the material or part is incorporated;

corresponds_to: **work_order** during which the material or part has been used or consumed;

date_of_consumption; **point_in_time** at which the material or part is consumed;

used_equipment; OPTIONAL, **equipment** on which the material or part is consumed.

6.3.7 Productivity_and_maintenance

6.3.7.1 Hazard_event

An hazard event is an unpredicted and harmful incident that occurs during a work process.

```
EXPRESS specification:
*)
ENTITY hazard_event;
hazard_event_id: identifier;
       hazard_event_type: string;
       hazard_event_gravity: string;
hazard_event_location: equipment;
relates_to: OPTIONAL work_order;
       beginning_date: point_in_time;
       ending_date: point_in_time;
       duration: interval_of_time;
UNIQUE
       UR1: hazard_event_id;
UR2: relates_to;
END_ENTITY;
(*
```

Attribute definitions:

hazard_event_id**:** allows a **hazard_event** to be uniquely identified;

hazard_event_type: allows a **hazard_event** to be classified;

hazard_event_gravity: allows a **hazard_event_gravity** to be fixed;

harzard_event_location: allows the **hazard_event** to be associated to a **work_order**;

relates-to: OPTIONAL, provides the manufacturing code number that identifies the **work_order** to which the **hazard_event** relates;

NOTE The **work_order** identified here is the **work_order** that is running when the **hazard-event** occurs.

beginning_date: **point_in_time** of the event that marks the actual starting point of the incident that is referred to by the **hazard_event**;

ending_date: **point_in_time** of the event that marks the actual end of the incident that is referred to by the **hazard_event**;

duration: **interval_of_time** during which the incident spread out.

6.3.7.2 Mode

The entity mode identifies the operation mode that characterizes the way of operating for the equipment and/or the work unit in the phase concerned by the **work_order**. It is selected into a list of values that is associated to the equipment or work unit in a PLIB library (ISO 13584-1, ISO 13584-24). It identifies the different working situations of an equipment.

```
EXPRESS specification:

*)

ENTITY mode;
mode_id: identifier;
name: label;
description: text;
beginning_date: point_in_time;
       ending_date: point_in_time;
       duration: interval_of_time;
occurred_on: equipment;
UNIQUE
UR1: mode_id;
END_ENTITY;

(*
```

Attribute definitions:

mode_id: enables the current mode of the **equipment** to be identified.

name: enables easy identification of the **mode**;

description: text that describes and specifies the **mode**;

beginning_date: **point_in_time** that characterizes the actual starting point of the current **mode**;

ending_date: **point_in_time** that characterizes the actual end of the current **mode**;

duration: **interval_of_time** during which the current **mode** is active;

occurred_on; **equipment** on which the current **mode** is active.

6.3.7.3 State

The entity state identifies a particular condition or situation of the equipment on which the **work_order** is performed.

```
EXPRESS specification:

*)

ENTITY state;
state_id: identifier;
name: label;
description: text;
beginning_date: point_in_time;
       ending_date: point_in_time;
       duration: interval_of_time;
occurred_on: equipment;

UNIQUE
UR1: state_id;
END_ENTITY;

(*
```

Attribute definitions:

state_id: enables the current state of the **equipment** to be identified;

name: enables easy identification of the **state**;

description: text that describes and specifies the **state**;

beginning_date: **point_in_time** that characterizes the actual starting point of the current **state**;

ending_date: **point_in_time** that characterizes the actual end of the current **state**;

duration: **interval_of_time** during which the current **state** is active;

occurred_on; **equipment** on which the current **state** is active.

6.3.8 Quality

6.3.8.1 Measurement result

Qualitative and/or quantitative control made on a manufactured product or on the manufacturing line for a verification purpose.

EXAMPLE This control can be made to verify, for example, whether the manufactured product is or risks being affected by a product defect.

NOTE The entity **measure** of ISO 10303-41 (STEP) represents the measure made on a **manufactured_product** to show if there is a product defect or not. In this standard a **measurement_result** does not mandatorily relate to a product defect; it can be, for example, related to a manufacturing efficiency, which is a difference from the ISO 10303 definition.

```
EXPRESS specification:
*)
ENTITY measurement_result;
       name: label;
       description: text;
       applies_to: OPTIONAL manufactured_product;
       occurred_on: equipment;
       shows: product_defect;
       corresponds_to: work_order;
       date_of_measurement: point_in_time;
       measure_unit: OPTIONAL unit;
       measure: OPTIONAL measure_with_unit;
END_ENTITY;
(*
```

Attribute definitions:

name: identifies the name of the **measure** that leads to this measurement result.

description: text that describes the **measure** made.

applies_to: OPTIONAL, the **measure** is made on a **manufactured_product**product.

occurred_on: **equipment** on which the **measure** is made.

shows: the **measure** reveals **product_defect**.

corresponds_to: the **work_order** during which the **measure** was made.

date_of_measurement: **point_in_time** at which the **measure** is made.

measure_unit: OPTIONAL, defines the **unit** to be used to interpret the **measurement_result.**

measure: OPTIONAL, identifies the fact that a **mesure_unit** is needed (or not) to interpret the **measurement_result**.

6.3.8.2 Product-defect

A product defect is the reporting of a measure which reveals that the quality of the product is out of the quality criteria defined. Each type of report has its own name, describing the issue.

```
EXPRESS specification:
*)
ENTITY product_defect;
       defect_id: identifier;
       relates_to: OPTIONAL product;
       is_shown_by: OPTIONAL measurement_result;
       defect_date: point_in_time;
       defect_type: label;
END_ENTITY;
(*
```

Attribute definitions:

defect_id: allows a **product_defect** to be identified;

relates_to: OPTIONAL, identifies the **product** to which the **product_defect** is in some cases associated;

is_shown_by: OPTIONAL, is revealed by the **measure** as described in ISO 10303-41 (STEP);

defect_date: **point_in_time** of the event that marks the actual moment where the **product_defect** is detected;

defect_type: describes the kind of the detected defect.

6.3.9 Resource

6.3.9.1 Equipment

Equipment is a physical device that is used during a manufacturing process to transform raw material and/or component into a more finished component or product. Equipment is a sub-class of resource and when used is referenced in a **work_order**.

```
EXPRESS specification:
*)
ENTITY equipment;
       allows_the_execution: work_order;
       is_made_of: SET [0:?] OF equipment;
       informs_person: resource;
       header: equipment_header;
equipment_mode: label;
       equipment_state: label;
END_ENTITY;
(*
```

Attribute definitions:

allows_the_execution: identifies the **work_order** that can be performed when the **equipment** is ready;

is_made_of: identifies the **equipment**s from which this **equipment** is made of;

informs_person: informs about the type of human resource that is **working** on this **equipment** for this **work_order**;

header: **equipment_header** that includes all the attributes that are predefined for this **equipment;**

equipment_mode: identifies the working **mode** of this **equipment** for this **work_order**;

equipment_state: identifies the **state** in which the **equipment** is.

Equipment_header

The equipment header includes all the information needed on the **equipment** that are predefined and not subject to changes during the manufacturing process. It can, for example, include configuration information. Some of this information is company and context specific.

```
EXPRESS specification:
*)
ENTITY equipment_header;
       equipment_id: identifier;
       equipment_label: OPTIONAL label;
UNIQUE
       UR1: equipment_id;
END_ENTITY;
(*
```

Attribute definitions:

equipment_id: identifies the **equipment** to which this **equipment_ header** refers;

equipment_label: OPTIONAL, enables the recording of needed information on the **equipment** (e.g. configuration information).

6.3.10 Time stamping and time reference

6.3.10.1 Time_reference

The entity **time_reference** is the specific **point_in_time** that is used to establish the needed relationships between the various **point_in_time**s collected locally by different systems.

```
EXPRESS specification:
*)
ENTITY time_reference;
       reference_date: point_in_time;
END_ENTITY;
(*
```

Attribute definitions:

reference_date: identifies the **point_in_time** to which the different **point_in_time**s collected should refer through specific relationships.

6.3.10.2 Duration_reference

The entity **duration_reference** is the specific duration to which all the collected durations shall refer.

```
EXPRESS specification:
*)
ENTITY duration_reference;
       reference_duration: interval_of_time;
END_ENTITY;
(*
```

Attribute definitions:

reference_duration: identifies the **interval_of_time** to which the collected durations refer through specific relationships.

```
END_SCHEMA;
```

Annex A
(normative)

Information object registration

To provide for unambiguous identification of an information object in an open system, the object identifier

```
iso standard 15531 part 44 version 1
```

is assigned to this part of ISO 15531. The meaning of this value is defined in ISO/IEC 8824-1.

Annex B
(informative)

EXPRESS listing

This annex provides a listing of the EXPRESS specified in this part of ISO 15531. No text or annotation is included. The computer interpretable form of this annex is provided in the file ISO TC184/SC4/JWG8 N583.

```
(*
       TC184/SC4/JWG 8 N583 2015-01-15
       EXPRESS DECLARATIONS FOR ISO 15531-44
*)


SCHEMA shopfloor_captured_data_schema;
REFERENCE FROM support_resource_schema
(identifier,
label,
text);                                          -- ISO 10303-41



REFERENCE FROM product_definition_schema
(product);                                              -- ISO 10303-41


REFERENCE FROM measure_schema
(measure_with_unit,
context_dependent_unit,
unit);                                                  -- ISO 10303-41


REFERENCE FROM resource_usage_management_schema
(resource);                                             -- ISO 15531-32

REFERENCE FROM time_domain_schema
(interval_of_time,                                      -- ISO 15531-42
point_in_time);

TYPE type_of_movement = SELECT
(stock_in, stock_out, stock_taking);
END_TYPE;                   -- type_of_movement

ENTITY stock_in;
END_ENTITY;

ENTITY stock_out;
END_ENTITY;

ENTITY stock_taking;
END_ENTITY;

ENTITY stock;
       contains: manufactured_product;
       refers_to: OPTIONAL manufacturing_batch;
       stored_on: equipment;
       quantity: OPTIONAL measure_with_unit;
       move: type_of_movement;
date_of_movement: point_in_time;
END_ENTITY;

ENTITY manufactured_product;
manufactured_product_id: identifier;
```