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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

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15531-44 was prepared by Technical Committee ISO/TC 184, *Automation systems and integration,* Subcommittee SC 4, *Industrial data.*

A complete list of parts of ISO 15531 is available from the Internet.

http://www.tc184-sc4.org/titles

Introduction

ISO 15531 is an International Standard for the modelling of data used in the manufacturing management (excepted 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 the 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 part of ISO 15531. The monitoring and control of physical devices belongs to level 2, while the management of manufacturing operations belongs to level 3. This part of ISO 15531 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 part of ISO 15531.

It is the aim of this part of ISO 15531 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 part of ISO 15531 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 is within the scope of this part of ISO 15531:

— 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 is outside the scope of this part of ISO 15531:

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

— product definition data as modelled in ISO 10303 (see ISO 10303-1);

— 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

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10303-11, *Industrial automation systems and integration – Product data representation and exchange – Part 11: Description methods: The EXPRESS language reference manual*

ISO 13584-1, *Industrial automation systems and integration – Parts library – Part 1: Overview and fundamental principles*

ISO 13584-24, *Industrial automation systems and integration – Parts library – Part 24: Logical resource: Logical model of supplier library*

ISO 15531-1, *Industrial automation systems and integration – Industrial manufacturing management data – Part 1: General overview*

ISO 15531-31, *Industrial automation systems and integration – Industrial manufacturing management data – Part 31: Resource information model*

ISO 15531-32, *Industrial automation systems and integration – Industrial manufacturing management data: Resources usage management – Part 32: Conceptual model for resources usage management data*

ISO 15531-42, *Industrial automation systems and integration – Industrial manufacturing management data – Part 42: Time Model*

ISO 15531-43, *Industrial automation systems and integration – Industrial manufacturing management data – Part 43: Manufacturing flow management data: Data model for flow monitoring and manufacturing data exchange*

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

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

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

NOTE Point in time is defined in ISO 15531-42.

EXAMPLE Beginning date of a data capture occurrence, of a task, of a measure, or of a state change.

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

EXAMPLE Joining of a part batch number to a subset.

NOTE A connection does not have property or attribute while association is a semantic relationship.

3.1.3
ending date
instance of point in time that identifies an event which is the ending point of something noticeable that has had duration

NOTE Point in time is defined in ISO 15531-42.

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

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 that relates unique identifiers

EXAMPLE Joining a serial number to another serial number.

NOTE Genealogy is not a semantic relationship. For example no property or attribute is associated to the junction between the serial numbers of the previous example.

3.1.6
hazard event
noticeable failure during a manufacturing process

NOTE The failure is noticeable enough to be recorded in the database. It can be caused by the resource on which the event appears or by a previous event.

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

NOTE Definition adapted from APICS dictionary.

[ISO 15531-1:2004, definition 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 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 that triggers a manufacturing operation.

NOTE 2 Adapted from APICS dictionary.

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

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

[ISO 15531-1:2004, definition 3.6.25]

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

NOTE 1 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 The operation mode is selected from the available ones by the operator.

NOTE 3 The operation mode is represented in the model by the entity **mode** (see 6.7.2).

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

NOTE 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 may be needed for a synchronisation purpose although they are not actually doing anything (ghost task).

[ISO 15531-1:2004, definition 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 Resources as defined in ISO 15531-1 except raw material, 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 from ISO 10303-49 but is included in the definition that applies for ISO 18629-14 and ISO 18629-44 that also includes raw materials and consumables as well as ISO 18629-13.

NOTE 2 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 as being able to be involved in the manufacturing process through assigned tasks. That does not include any modelling of an individual or common behaviour of human resource excepted in their capability to perform a given task in the manufacturing process (e.g. transformation of raw material or component, provision of logistic services). That means that human resources are only considered, as the other ones, from the point of view of their functions, their capabilities and their status (e.g. idle, busy). That excludes any modelling or representation of any aspect of individual or common "social" behaviour.

NOTE 3 Adapted from ISO 15531-1:2004, definition 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

[ISO 15745-1:2003, definition 3.31]

NOTE The meaning of state here is similar to the meaning of state in "state automaton".

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

NOTE 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.

3.2 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)
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 (see 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 That 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 those included in devices repair, operation and maintenance manuals).

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

— Level 0 that addresses actual physical process;

— Level 1 that addresses functions involved in the sensing and manipulating the physical process;

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

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

— Level 4 that addresses functions involved in the business-related activities needed to manage a manufacturing organization;

Figure 1 shows the hierarchy of functional levels

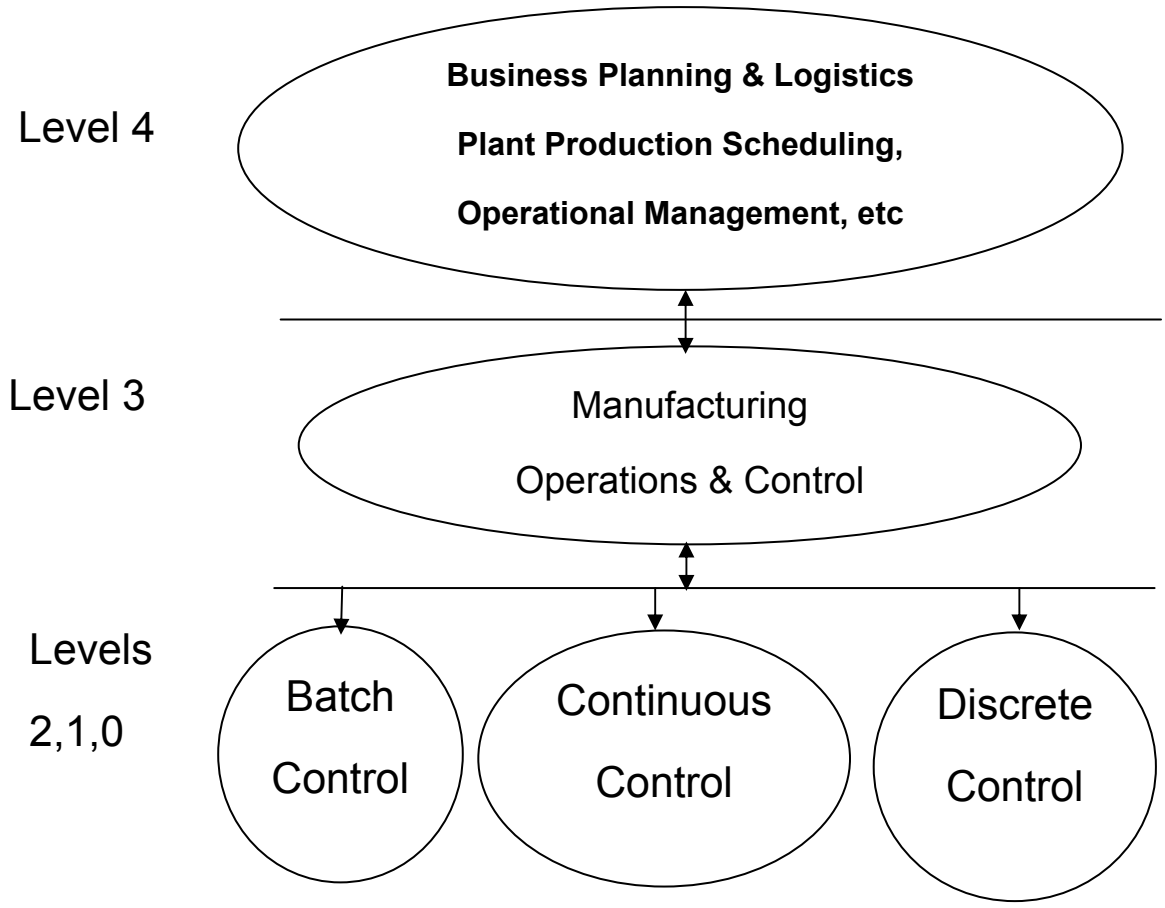


Figure 1: Functional Levels (From IEC 62264-1)

ISO 15531 addresses the modelling of any data (excepted product data) that are suitable to manage manufacturing operations (See ISO 15531-31, ISO 15531-32 and 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 part of ISO 15531

5.1 Purpose of this part of ISO 15531

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 the level 3 (Manufacturing management level). These manufacturing data may 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 enable also the validation of shop floor models and scheduling scenario.

The compliance to 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 purpose and the set up, of shop floor monitoring systems as well of their interoperability,

5.2 Basic principles of this part of ISO 15531 and overview of the main entities

According to the fact 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 specialisation, if needed, shall be obtained through the use of PLIB libraries (See ISO 13584-1 and ISO 13584-24). In that case the specialisation process is roughly described in the standard.

The model is mainly focused on the relationships between the manufacturing process events, activities, state changes, it enables nevertheless 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 just described and specified in clause 6, but they are not listed nor 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 **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 may 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 (APICS dictionary).

NOTE 3 This standard only describes and use the **manufacturing_batch** entity which is a specialisation of the batch entity according the the fact that it is mainly focused on discrete part manufacturing. In case of non-discrete product it is up to the user to modify this **manufacturing_batch** entity to take in account non-discrete products, or to add the parent entity (**batch**) or to add another specialisation of the **batch** entity that addresses non-discrete products.

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

The **equipment** entity describes 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. The other specialisation 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,…) is an **hazard_event**. The failure shall be important enough to be recorded.

The entity **manufacturing_batch**, which is a specialisation 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 to 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 all along its manufacturing life cycle.

NOTE 4 **Manufactured_product** is a specialisation of the ISO 10303 **product** entity (see ISO 10303-1 and ISO 10303-41 ed3).

The **material_consumption** entity describe for traceability purpose the 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.

The entity **measurement_result** represents the result of a control. M**easurement_result** is a specialisation of the **measure** entity of ISO 10303-41.

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

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

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

The entity **resource** may includes two subclasses: the entities **equipment** and **human**. A special care has been taken to avoid that this model enables the monitoring and eventually the sanction of a individual in the staff. No identification of a given employee shall be possible through the model. Then the entity human has not

been decribed nor used in this standard. If developed such an entity shall only model a group of person and/or a generic type of human resource.

NOTE 5 A human resource may be “operator”, “technician”, it cannot be an individual while an equipment resource may 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 equipment may be automatic production, adjustments, maintenance.

NOTE 6 The entities state and mode are compliant to IEC 60204 and ISO 12100 (see ISO 12100-1 and ISO 12100-2)

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

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

The entity **work_order** represents the unit of scheduled work that may 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.

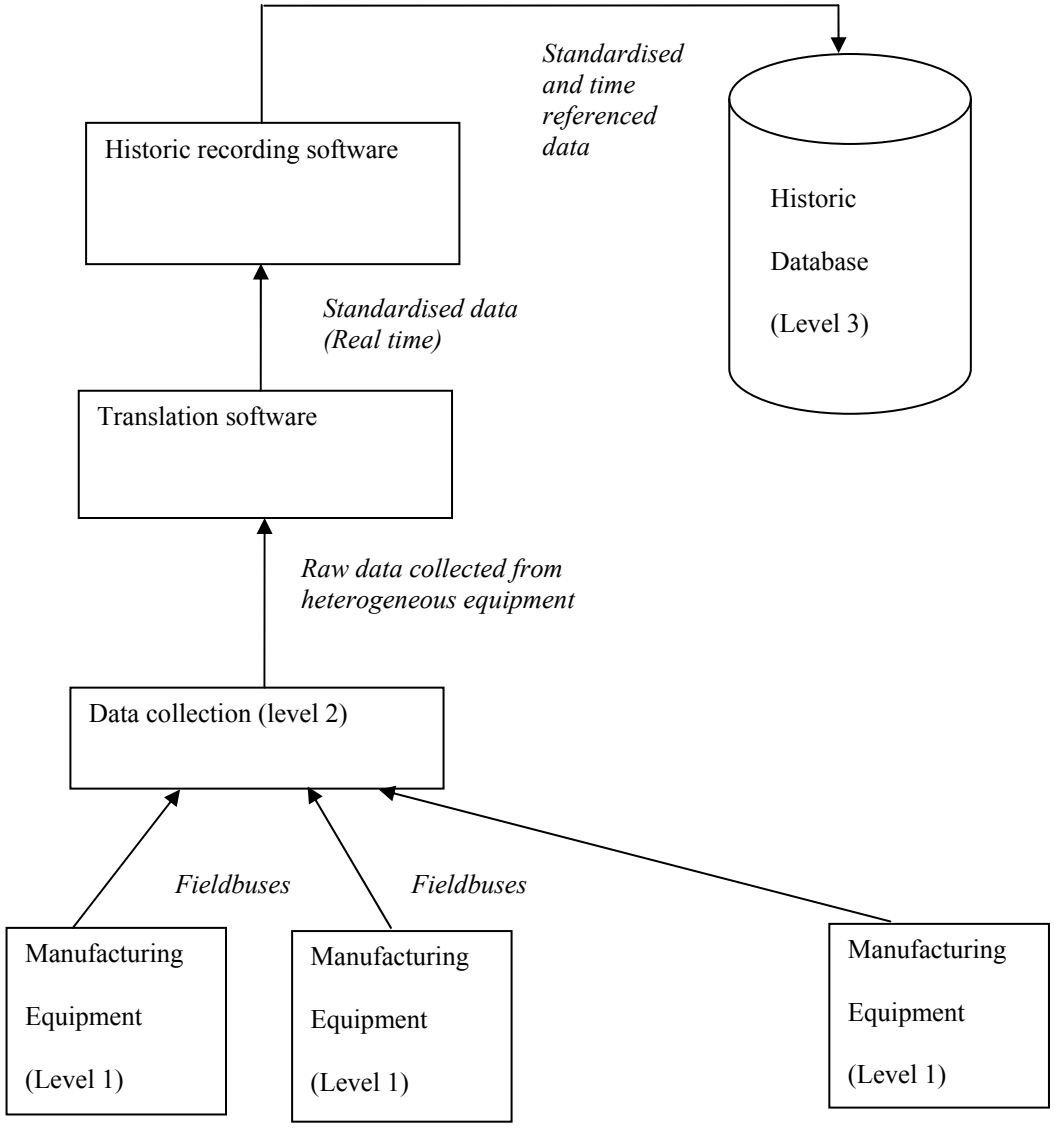


Figure 2 : Schema of the shop floor data acquisition and level 3 recording process

— The data gathering is made essentially of two components: a system dedicated to the 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 may be performed automatically by the process itself or manually by ad hoc interfaces between humans and machines;

— The translation program transforms in real time the picked up raw data (that represent several standardized data, that may be super-imposed, 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 database of history and events log. It also checks the consistency of events, it aggregates the beginning and the end or events provided by the translation software, it releases the recording in the historic database. It is here that the biggest problem of size and size evaluation occurs.

5.4 The captured data and their organization

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.

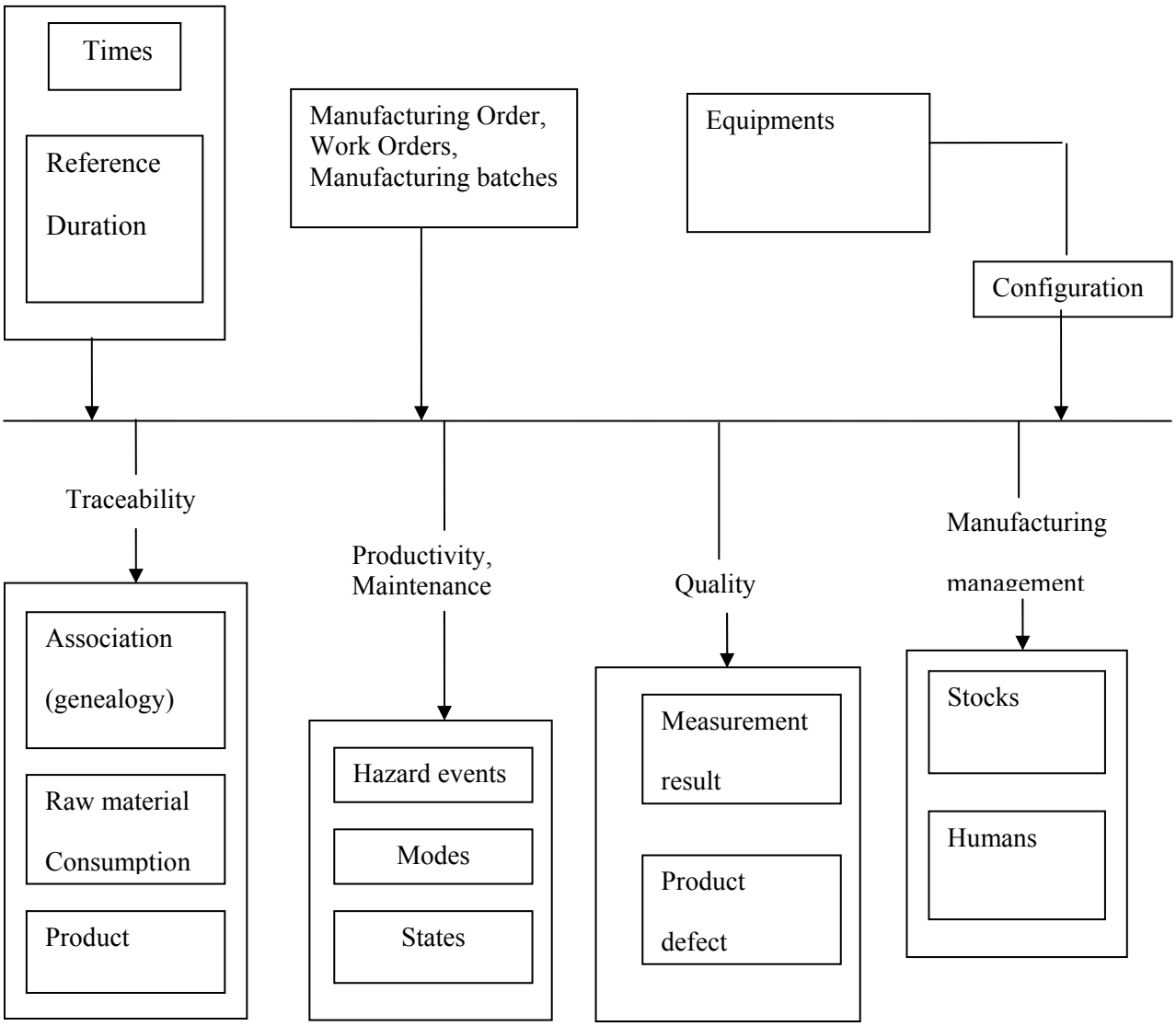


Figure 3: Organization of the model: main data captured

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 equipments used and the configuration while the boxes under the line identify specific entities related to the manufacturing process. These specific entities are organized in the following four groups:

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

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

— The third one addresses the entities related to quality (Measurement result, product defect);

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

In the context of this standard, there is no entity dedicated to the concept of genealogy. The genealogy is the capability to find component and/or compound 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 doesn't exist for common placed production.

This function is mandatory. In this standard it is supported through the fact the the **manufactured_product** entity is recursive since one **manufactured_product** entity may be made 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 ; one other is the retrieval of adjustment value for the thermic part ("son" element) of a magnetothermic circuit breaker ("father" element).

5.4.1 Manufacturing management data

— Stock monitoring;

— Staff management.

5.4.2 Quality management

— Measures made on sub-components or final products;

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

5.4.3 Productivity and maintenance

— Follow-up of equipments risks (defects);

— Follow-up of changes in MODE (see EN 292-2, IEC 60204 and ISO 12100);

— Follow-up of changes in STATUS (see IEC 60204 and ISO 12100).

5.4.4 Traceability

— Sub-component association (genealogy);

— Raw material consumption;

— Unitary product follow-up.

5.5 The question of time

5.5.1 Time stamping and time measure

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

— the time stamping is all more accurate that it is made early. Even if the data capture system is actually a real-time one, it introduces some delay that is variable. In the data capture chain, all the buffers, retry process, examination cycles are decreasing accuracy (they increase the entropy of the system). In that case, it may be

possible to avoid delays related to the checking, to the information progress through the LAN and to the data processing. Time stamping can be done at the source with a resolution of 10ms with a PLC. If performed by the translator it may be unnecessary to go under 1s;

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

NOTE It is delusive to keep the time stamping of several hundred of PLC exactly at the same time. A one hour shift in time stamping may 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 may appear as a redundancy. 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 may 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" may be used to improve the accuracy of the synchronisation between different data sets collected at different date 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 may also contribute to this better synchronisation.

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

Another big interest of this 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 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 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 may be envisioned for the concerned data. To spare bandwidth in the network it is even possible to customize periods of observation that may be different and may depend on the concerned equipment.

5.6 Size optimization

The storage in the historic database is the bottle neck of the whole data capture process in the shop, floor. According to that it becomes mandatory 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 to only keep the recording of just one event that is able to summarize a whole period of observation. Of course the precise progress of events during this period is lost in this case.

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

EXAMPLE 2 Instead of memorizing any machine failure along 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 implies that the possibility of further analyse is reduced with the same rate. Besides, in that case, the possibility of correlation with other events is drastically reduced.

EXAMPLE 3 In the case of machine failures, it becomes impossible with an aggregate to determine if some manufactured references are involved in this failure. That may need correlation 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 the specifications of EXPRESS.

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 Manufacturing management

6.3.1.1 Stock

A stock is constituted of products, component 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 : 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**.**

6.4 Manufactured_product

Manufactured_product is a specialisation of the product entity (from ISO 10303) that is a thing produced by the manufacturing process; it may 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" of which all the concerned instances belong.

EXAMPLE **a manufacturted_product** may be contactor model to which each contactor instances that are stored, or manufactured in the same manufacturing_batch belong.

EXPRESS specification:

```
*)
ENTITY manufactured_product;
   manufactured_product_id: identifier;
   is_made_of: SET [0:?] OF manufactured_product;
   relates_to: product;
   belongs_to: OPTIONAL manufacturing_batch;
UNIQUE
   UR1: manufactured_product_id;
END_ENTITY;
(*
```

Attribute definitions:

manufactured_product_id; identifies the **manufactured_product**.

is_made_of : specifies which **manufactured_product** is used in the assembly.

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.

6.5 Orders

6.5.1 Manufacturing_order

See the definition in clause 3.1.8. 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.

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).

6.5.2 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;

   symbol : 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.

symbol: specify a reference of the **product** to manufacture.

quantity: provides the quantity of **product** to be manufactured according to this manufacturing order. This quantity may or may not have a unit.

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.

6.5.3 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 specialisation of a possible entity batch (not described in this standard) focusing on discrete part manufacturing. Nevertheless it may be used has it is for non-discrete products. The appellation **manufacturing_batch** enables user to add another specialisation of the entity batch to take in 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**s 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 identified

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).

6.5.4 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 unikely 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.

6.6 Traceability

6.6.1 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: OPTIONAL work_order;
   date_of_consumption: point_in_time;
   used_equipment: equipment;
END_ENTITY;
(*
```

Attribute definitions:

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

quantity: 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; **equipment** on which the material or part is consumed.

NOTE The information about the phase of the work order is not mandatory

6.7 Productivity_and_maintenance

6.7.1 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** may relate.

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.

6.7.2 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 value that is associated to the equipment or work unit in a PLIB library (See ISO 13584-1 and 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.

6.7.3 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.

6.8 Quality

6.8.1 Measurement result

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

EXAMPLE This control may be made to verify, for example, if the manufactured product is or risks to be 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 product_defect or not. In this standard a **measurement_result** does not mandatory relate to a product defect, it may be for example related to a manufacturing efficiency, that is a difference with STEP definition.

EXPRESS specification:

```
*)

ENTITY measurement_result;

   name: label;

   description: text;

   applies_to: OPTIONAL manufactured_product;
```

```
   occurred_on: equipment;
   shows: product_defect;
   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 : the **measure** is made ona **manufactured_product.**

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

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

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 a **mesure_unit** is needed (or not) to interpret the **measurement_result**.

6.8.2 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** may be associated.

is_shown_by: is revealed by the **measure** as it is described in ISO10303-41 (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.

6.9 Resource

6.9.1 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 **state** in which the **equipment** is.

6.9.2 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 may, 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).

6.10 Time stamping and time reference

6.10.1 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.

6.10.2 Duration_reference

The entity **duration_reference** is the specific duration to which all the collected duration has to 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 N570.

```
(*
   TC184/SC4/JWG 8  N570  2010-05-05
   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;
   is_made_of: SET [0:?] OF manufactured_product;
   relates_to: product;
   belongs_to: OPTIONAL manufacturing_batch;
UNIQUE
   UR1: manufactured_product_id;
END_ENTITY;

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;

ENTITY manufacturing_order_header;
   manufacturing_order_id: identifier;
   customer_order: OPTIONAL label;
   manufacturing_order_label: OPTIONAL label;
   symbol : 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;
```

```
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;

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;

ENTITY material_consumption;
   supplier_batch_number: string;
   quantity: OPTIONAL measure_with_unit;
   internal_reference: string;
```

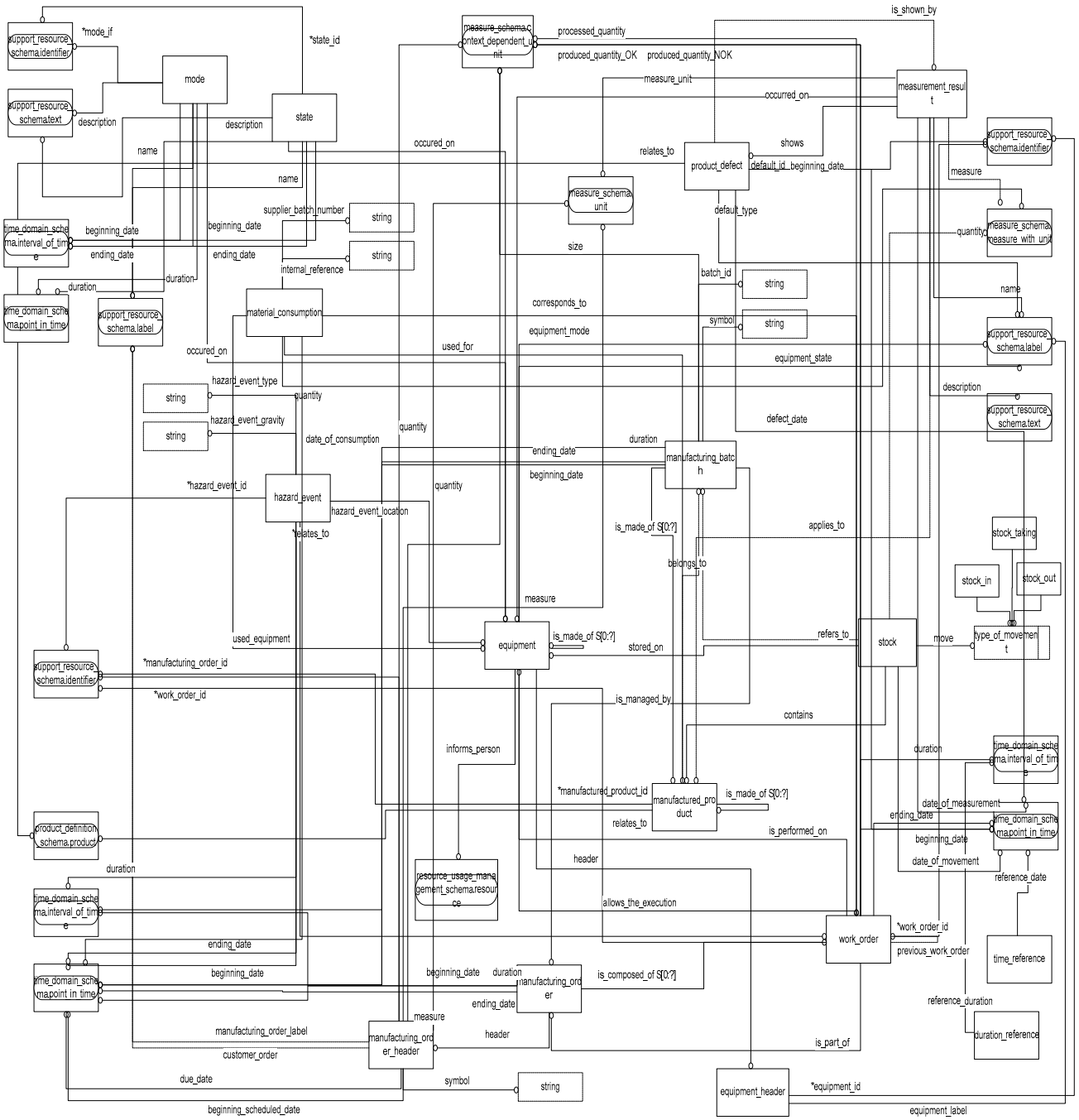
```
   used_for: manufactured_product;
   corresponds_to: OPTIONAL work_order;
   date_of_consumption: point_in_time;
   used_equipment: equipment;

END_ENTITY;

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;

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;

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;

ENTITY measurement_result;
   name: label;
   description: text;
   applies_to: OPTIONAL manufactured_product;
   occurred_on: equipment;
   shows: product_defect;
   date_of_measurement: point_in_time;
   measure_unit: OPTIONAL unit;
   measure: OPTIONAL measure_with_unit;
END_ENTITY;

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;

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;

ENTITY equipment_header;
   equipment_id: identifier;
   equipment_label: OPTIONAL label;
UNIQUE
   UR1: equipment_id;
END_ENTITY;

ENTITY time_reference;
   reference_date: point_in_time;
END_ENTITY;

ENTITY duration_reference;
   reference_duration: interval_of_time;
END_ENTITY;
```

```
END_SCHEMA;
```

Annex C
(informative)
EXPRESS-G Diagrams



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