Z - B R E 4 K

Grant agreement nº: 768869

Call identifier: H2020-FOF-2017

Strategies and Predictive Maintenance models wrapped around physical systems for Zero-unexpected-Breakdowns and increased operating life of Factories

Z-BRE4K

Deliverable D3.5

Z-BRE4K semantic modelling

Work Package 3

Enhanced semantic modelling based on the feedback from validation

Document type	:	Report
Version	:	V1.0
Date of issue	:	29th May 2020
Dissemination level	:	Public
Lead beneficiary	:	13 – EPFL

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 768869.

Executive Summary

Abstract	This document reports on the results and deliverables of Task 3.5, i.e. 'Enhanced semantic modelling based on the feedback from validation'. Accordingly, it acts as an amendment of Deliverable D 3.1 as it provides a revised version of Z-BRE4K ontology including updates to the classes and their relations. Further on, it explains principles, methodology, and all the entities of the project and models relevant structures covering the maintenance domain.
Keywords	Semantic modelling, Ontology, Predictive maintenance, production assets, products and processes, Strategy implementation, Maintenance policies, Zero-breakdown, Manufacturing

Revision history

Version	Author(s)	Changes	Date
V0.1	Sangje Cho (EPFL)	Deliverable outline	12/12/2019
V0.2	Sangje Cho (EPFL)	Update of outline	31/1/2020
V0.5	Sangje Cho (EPFL)	Initiation of content	15/2/2020
V0.7	Marlène Hildebrand-Ehrhardt (EPFL)	Ontology population chapter	19/2/2020
V1.0	Sangje Cho (EPFL) Marlène Hildebrand-Ehrhardt (EPFL)	First draft	28/2/2020
V1.1	Marlène Hildebrand-Ehrhardt (EPFL)	Formatting	16/03/2020

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1 INTRODUCTION

This document describes the results of Task 3.5 the update of all the entities and relations in the context of Z-BRE4K.

WP 3 deals with the design and implementation of knowledge and predictive modelling. To summarize, the main objectives of WP3 are:

- **Semantic modelling** to empower KBS for cognitive manufacturing.
- **Incorporation of risk analysis**, KRIs and FMECA.
- **Incorporation of predictive/prescriptive analytics** to support decision making and associated Z-Strategies.

1.1 Objectives of Task 3.5

This task considers the second iteration of Task 3.1 for the enhancement of semantic modelling. The initial version of the ontology, for the modelling of the production assets, the products and the manufacturing operations will be enhanced and improved based on the feedback from the end-users, the technical partners during the development of WP3 and WP4, and the validation procedures in WP5. The iterative approach will ensure that the ontology of Z-Bre4k will be updated with validated data resulting to meet requirements in a higher degree for access to different aspects of machinery and process-related data and knowledge.

1.2 Contents of the deliverable

The main purpose of this document is to present enhanced semantic modelling based on the feedback from validation. The Z-BRE4K ontology is a generalization of the business scenarios serving as an upper template for all Z-BRE4K business cases as well as future business cases, and specific ontologies describe the domain interests in each business scenario. Z-BRE4K ontology has been specialized for each-business cases after ontology population. The deliverable includes all the information in Z-BRE4K ontology.

As the main result of T 3.5, the Z-BRE4K ontology includes the instances in the domain of interest. It encapsulates explicit knowledge in the domain of interest. Meanwhile, this ontology constitutes the formal representation of the Z-BRE4K semantic model and the knowledge that this model encapsulates as the Z-BRE4K semantic component. Therefore, to populate ontology as a codification of the knowledge will allow exchanging business-oriented information, in order to increase the added value of Z-BRE4K platform. In addition, Z-BRE4K ontology enables integration of heterogeneous data from various sensors. The data integration enables the Z-BRE4K platform to have semantic interoperability. The Z-BRE4K ontology plays the role of defining the structure and contact of the Triple Store, to be used to define semantic search parameters, and to be used to query triples.

The document is structured as follows. In Chapter 2, we provide an explanation of the ontology population and its importance for the Z-BRE4K. Respectively, in Chapter 3, 4 and 5, the SACMI, PHILIPS and GESTAMP ontologies are presented in compliance with the Z-BRE4K ontology presented in deliverable 3.1. Subsequently, Chapter 6 highlights relevant information

concerning the actual implementation. Finally, Chapter 7 concludes the document by highlighting the main results achieved and the connections with future activities.

2 ONTOLOGY POPULATION

Ontology population is the process of creating instances of an ontology that will stand for the various data sources it intends to describe and collect data from. This process is intended to receive and ontology and a list of data sources as inputs, and link those data sources to the elements of the ontology. This is done by extracting, for each data source, which class in the ontology it corresponds to, and create an instance of that class that will represent this particular data source, that will consist of the class name and a unique identifier.

This process is an important preparatory work in order to be able to use the ontology to express data that will be collected from these data sources, and more specifically stored in a database. Combined with graph data, ontologies help express data in terms of entities and their relationships. It is possible to express the relationships between different entities as well as the relationship between an entity and a piece of information. Data will be expressed in the form of triples subject – predicate – object, and stored in a specific type of database called a triplestore. The subject is the instance of a class, the predicate a relationship, and the object is either another instance of a class, or a literal value. Triples are expressed with the Resource Description Framework (RDF), a language that helps express data models with metadata. The instances and relationships are expressed with URIs (Unique Resource Identifier), which are the concatenation of the ontology's URI, the name of the class or the relationship, and in the case of instances, a unique id.

In the present case, identifying the data sources means identifying the machines equipped with sensors as well as the processes that produce data. Once we have listed them, we will be ready to populate the ontology. This means we can match them to a corresponding class in the ontology, representing either a process or a machine, and then for each data source, we will create an instance of the corresponding class that will represent that data source in particular. For example, if a shop floor has several cold-forming machines with sensors that measure temperature, and we have a class in the ontology that stands for cold-forming machines, we will create an instance of that class for each cold-forming machine in the shop floor, and each instance will stand for one machine.

Thanks to this preliminary work, when data will be coming from a machine, we will already know the URI of the instance representing that machine, and we will be able to use it to create new triples, with that URI as a subject. In the example aforementioned, data coming from a cold forming machine is temperature data, and therefore it will produce triples consisting of the URI of that machine, the URI of the "hasTemperature" relationship, and the value of the temperature. The work of populating the ontology is therefore really important in order to be able to identify the main elements of a manufacturing process, and facilitate the automatic collection of data coming from various sources.

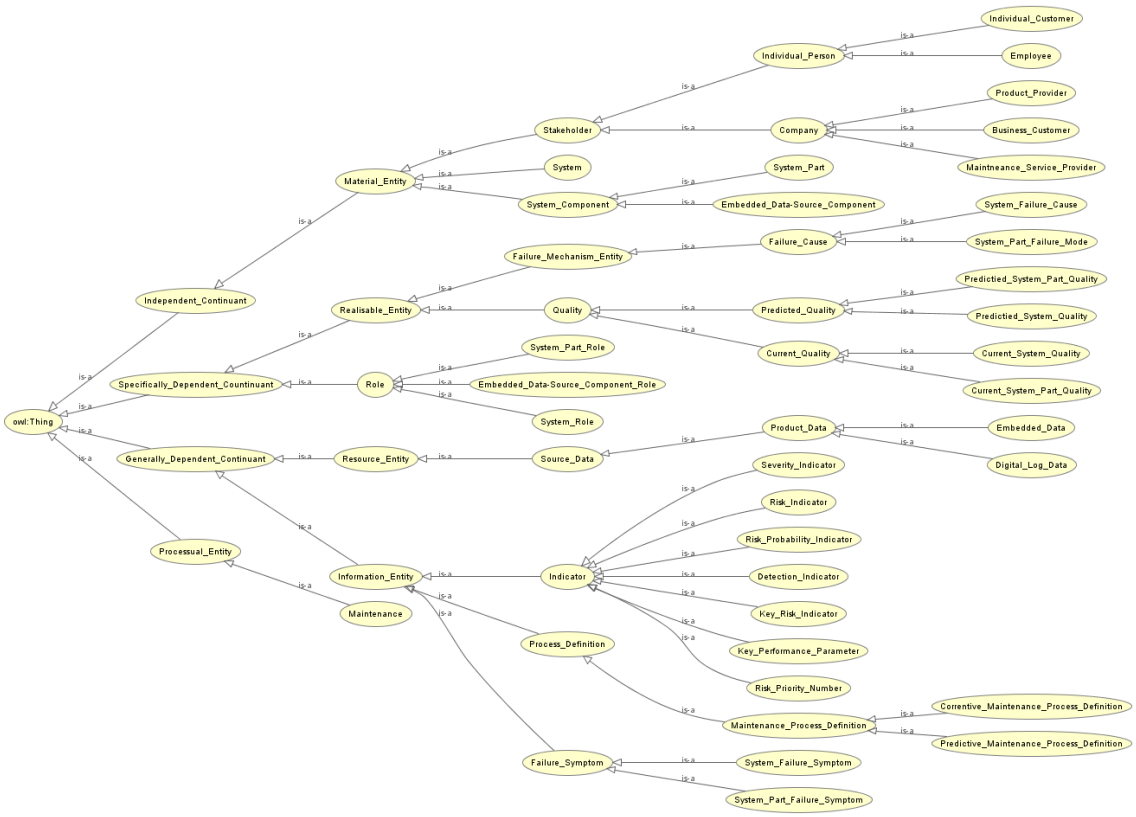

Figure 1: Z-BRE4K ontology

Deliverable 3.1 provides a list of all the classes, object properties, and datatype properties (See Figure 1). Accordingly, Z-BRE4K ontology has been populated (See **¡Error! No se encuentra el origen de la referencia.**), including all the type of systems, system parts, Embedded Data source components, failure modes/symptoms, corrective/predictive maintenance actions, severity indicators of failure modes. This information provided instances to ontology with certain relations following the rules of Z-BRE4K ontology and this ontology has been implemented as a part of the Knowledge Base System under Task 3.2. Knowledge Base system provides a SPARQL based search engine and it facilitates finding relevant data.

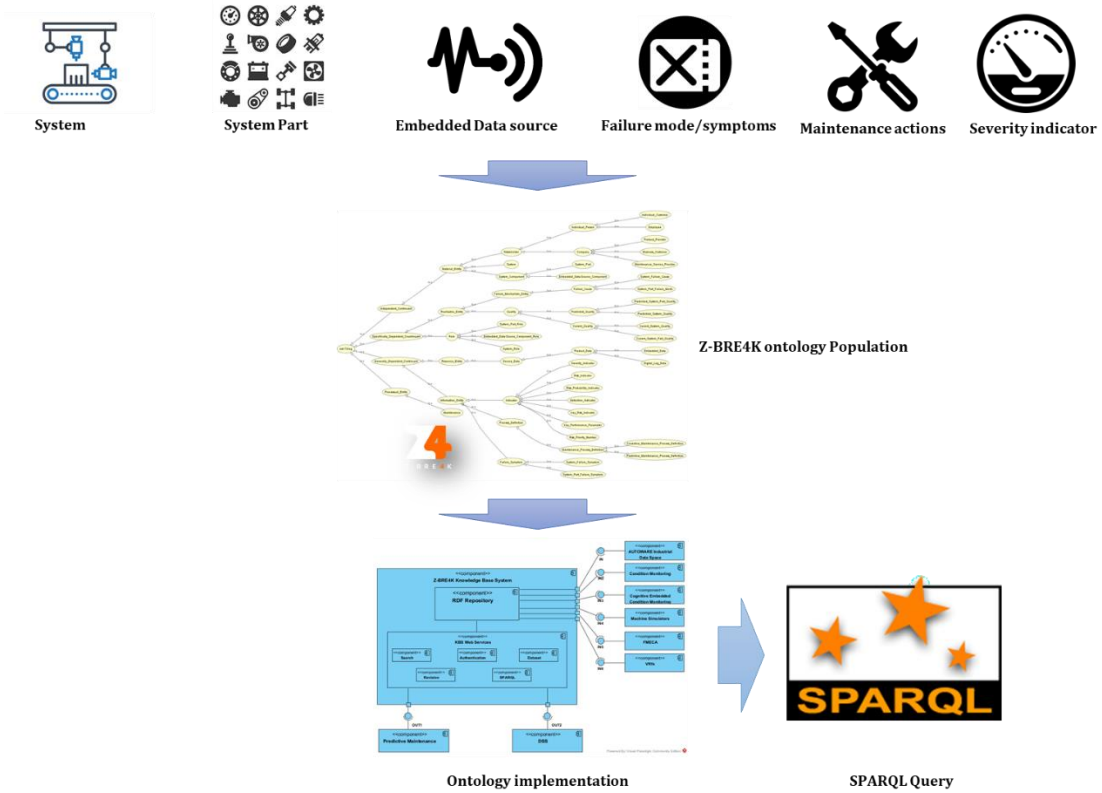

Figure 2: Z-BRE4K ontology population

3 SACMI ONTOLOGY

This section presents the SACMI ontology with all the instances. The SACMI ontology is a branch of Z-BRE4K ontology, including specific knowledge of SACMI use case. The target systems are comprised of various parts. The following tables show all the instances of target systems and their parts.

Table 1: Ex and its parts

Instance	Class	Funtion_of_System_Part_Role	Redundancy_provided_of_System_Part_Role	Technical_Information_CDS_Machine_of_System_Part_Role
Ex	System_Role			
Motor_of_plastic_extruder_screw_motor_of_Ex	*System_Part_Role*	Enables_the_rotation_of_the_extruder_screw	0	55KW - 4 POLE - 50Hz
Motor_of_plastic_extruder_screw_motor_of_Ex	*System_Part_Role*	Enables_the_rotation_of_the_extruder_screw	0	0
Motor_for_pump_of_Ex	*System_Part_Role*	Enables_the_rotation_of_the_polymer_dosing_pump	0	4KW - 4 POLE - 50 Hz
Motor_for_pump_of_Ex	*System_Part_Role*	Enables_the_rotation_of_the_polymer_dosing_pump	0	0
Screw_gearbox_of_Ex	*System_Part_Role*	Changes_(reduces)_the_speed_ratio_of_electrical_motor_with_respect_to_the_extruder_screw	0	I=13,6
Screw_gearbox_of_Ex	*System_Part_Role*	Changes_(reduces)_the_speed_ratio_of_electrical_motor_with_respect_to_the_extruder_screw	0	0
Pump_gearbox_of_Ex	*System_Part_Role*	Changes_(reduces)_the_speed_ratio_of_electrical_motor_with_respect_to_the_polymer_dosing_pump	0	I=23,4
Pump_gearbox_of_Ex	*System_Part_Role*	Changes_(reduces)_the_speed_ratio_of_electrical_motor_with_respect_to_the_polymer_dosing_pump	0	0
Pump_of_Ex	*System_Part_Role*	Makes_the_polymer_flow_constant_(stationary)	0	58,2 CC/REV - MAX 100 RPM IN pressure MIN 10 bar IN pressure MAX.350 bar Pressure Differential MAX.275 bar Work temperature max 345°C
Pump_of_Ex	*System_Part_Role*	Makes_the_polymer_flow_constant_(stationary)	0	0
Polymer_of_Ex	*System_Part_Role*	Plastic_material_which_is_firstly_molten,_then_moulded_to_obtain_the_finished_closure_product	0	Annex 1
Polymer_of_Ex	*System_Part_Role*	Plastic_material_which_is_firstly_molten,_then_moulded_to_obtain_the_finished_closure_product	0	0
Bypass_valve_of_Ex	*System_Part_Role*	Directs_the_molten_polymer_flow_alternatively_towords_the_stamps_or_towards_the_scrap	0	Supply air pressure 0,5 Mpa Control cylinder Force IN 982 N

				Control cylinder Force OUT 825 N Resulting Torque 55Nm Resulting Torque 46Nm
Bypass_valve_of_Ex	*System_Part_Role*	Directs_the_molten_polymer_flow_alternatively_towords_the_stamps_or_towards_the_scrap	0	0
Cooling_fans_of_Ex	*System_Part_Role*	Provides_the_cylinder_with_cooling_power	0	KW0.25 - 2 POLE - 50/60Hz rotor dim. 120X60X11
Cooling_fans_of_Ex	*System_Part_Role*	Provides_the_cylinder_with_cooling_power	0	55KW 4POLI V40069050
Mixer_of_Ex	*System_Part_Role*	Homogenizes_molten_polymer_(temperature_and_colour)	0	Max. allowable pressure drop 180 bar Max. allowable temperature 350°C Max. allowable cleaning temperature 450°C
Heaters_of_Ex	*System_Part_Role*	Provides_cylinder_with_heating_power	In several zones, more than one heating resistance is present. If failure of one of the resistances occurs, it can be partially covered by the thermal power of the others	Zone 1-2: n°8 1650W r=5,83 W/cm2 Zone 3-4-5: n°12 1250W r=4,42 W/cm2 Zone 6: n°2 2000W r=4,63 W/cm2 Zona 7:n°4 400W 230V Zone 8: n°3 W280 r=2,2 W/cm2 Zone 9: n°2 600W r=1,44 W/cm2 Zone 10: n°4 300W 220V Zone 11: n°2 300W 200V
Screw_of_Ex	*System_Part_Role*	Plastifyies_the_polymer_and_pushes_it_towards_the_pump_together_with_the_cylinder	0	D=75X30D barrier
Cylinder_of_Ex	*System_Part_Role*	Plastifyies_the_polymer_and_pushes_it_towards_the_pump_together_with_the_screw	0	Cylinder D=75

Table 2: HU and its parts

Instance	Class	Funtion_of_System_Part_Role	Redundancy_provided_of_System_Part_Role	Technical_Information_CDS_Machine_of_System_Part_Role
HU	System_Role			
Motor_of_plastic_extruder_screw_motor_of_HU	*System_Part_Role*	Enables_the_rotation_of_the_extruder_screw	0	55KW - 4 POLE - 50Hz
Motor_of_plastic_extruder_screw_motor_of_HU	*System_Part_Role*	Enables_the_rotation_of_the_extruder_screw	0	0
Motor_for_pump_of_HU	*System_Part_Role*	Enables_the_rotation_of_the_polymer_dosing_pump	0	4KW - 4 POLE - 50 Hz
Motor_for_pump_of_HU	*System_Part_Role*	Enables_the_rotation_of_the_polymer_dosing_pump	0	0
Screw_gearbox_of_HU	*System_Part_Role*	Changes_(reduces)_the_speed_ratio_of_electrical_motor_with_respect_to_the_extruder_screw	0	I=13,6

Screw_gearbox_of_HU	*System_Part_Role*	Changes_(reduces)_the_speed_ratio_of_electrical_motor_with_respect_to_the_extruder_screw		0	0
Pump_gearbox_of_HU	*System_Part_Role*	Changes_(reduces)_the_speed_ratio_of_electrical_motor_with_respect_to_the_polymer_dosing_pump		0	I=23,4
Pump_gearbox_of_HU	*System_Part_Role*	Changes_(reduces)_the_speed_ratio_of_electrical_motor_with_respect_to_the_polymer_dosing_pump		0	0
Pump_of_HU	*System_Part_Role*	Makes_the_polymer_flow_constant_(stationary)		0	58,2 CC/REV - MAX 100 RPM IN pressure MIN 10 bar IN pressure MAX.350 bar Pressure Differential MAX.275 bar Work temperature max 345°C
Pump_of_HU	*System_Part_Role*	Makes_the_polymer_flow_constant_(stationary)		0	0
Polymer_of_HU	*System_Part_Role*	Plastic_material_which_is_firstly_molten,_then_moulded_to_obtain_the_finished_closure_product		0	Annex 1
Polymer_of_HU	*System_Part_Role*	Plastic_material_which_is_firstly_molten,_then_moulded_to_obtain_the_finished_closure_product		0	0
Bypass_valve_of_HU	*System_Part_Role*	Directs_the_molten_polymer_flow_alternatively_towords_the_stamps_or_towards_the_scrap		0	Supply air pressure 0,5 Mpa Control cylinder Force IN 982 N Control cylinder Force OUT 825 N Resulting Torque 55Nm Resulting Torque 46Nm
Bypass_valve_of_HU	*System_Part_Role*	Directs_the_molten_polymer_flow_alternatively_towords_the_stamps_or_towards_the_scrap		0	0
Cooling_fans_of_HU	*System_Part_Role*	Provides_the_cylinder_with_cooling_power		0	KW0.25 - 2 POLE - 50/60Hz rotor dim. 120X60X11
Cooling_fans_of_HU	*System_Part_Role*	Provides_the_cylinder_with_cooling_power		0	55KW 4POLI V40069050
Mixer_of_HU	*System_Part_Role*	Homogenizes_molten_polymer_(temperature_and_colour)		0	Max. allowable pressure drop 180 bar Max. allowable temperature 350°C Max. allowable cleaning temperature 450°C
Heaters_of_HU	*System_Part_Role*	Provides_cylinder_with_heating_power	In several zones, more than one heating resistance is present. If failure of one of the resistances occurs, it can be partially covered by the thermal power of the others		Zone 1-2: n°8 1650W r=5,83 W/cm2 Zone 3-4-5: n°12 1250W r=4,42 W/cm2 Zone 6: n°2 2000W r=4,63 W/cm2 Zona 7:n°4 400W 230V Zone 8: n°3 W280 r=2,2 W/cm2 Zone 9: n°2 600W r=1,44 W/cm2 Zone 10: n°4 300W 220V Zone 11: n°2 300W 200V
Screw_of_HU	*System_Part_Role*	Plastifyies_the_polymer_and_pushes_it_towards_the_pump_together_with_the_cylinder		0	D=75X30D barrier
Cylinder_of_HU	*System_Part_Role*	Plastifyies_the_polymer_and_pushes_it_towards_the_pump_together_with_the_screw		0	Cylinder D=75

Table 3: TH and its parts

Instance	Class	Funtion_of_System_Part_Role	Redundancy_provided_of_System_Part_Role	Technical_Information_CDS_Machine_of_System_Part_Role
TH	System_Role			
Pumps_of_Th	*System_Part_Role*	Provide_the_cooling_fluid_circuits_with_the_required_head_(pressure)_and_flow	0	15 m3/h - 4KW - 50Hz - 2 POLE
Pumps_of_Th	*System_Part_Role*	Provide_the_cooling_fluid_circuits_with_the_required_head_(pressure)_and_flow	0	0
Cooling_fluid_of_Th	*System_Part_Role*	Exchange_thermal_energy_between_the_hot_reservoirs_(e.g.:_stamps)_and_the_cold_reservoir_(cooling_circuit_output)_by_means_of_conduction	0	Annex 1
Solenoid_valves_of_Th	*System_Part_Role*	Open/close_the_hydraulic_circuits_by_means_of_electrical_signal	0	Q max 9,6 m3/h Kv 9,6 m3/h max temperature 90°C Max pressure 20 bar
Pneumatic_valves_of_Th	*System_Part_Role*	Open/close_the_hydraulic_circuits'_branches_by_means_of_pneumatic_impulses	0	Kv 48,8 m3/h max temperature 80°C Max pressure 10 bar
Filter_of_Th	*System_Part_Role*	Retains_debris_and_metal_particles,_preventing_the_pump_impeller_from_damaging_or_cooling_circuits_from_clogging_	0	Filter 100 micron max temperature 80°C Max pressure 16 bar
Heat_exchangers_of_Th	*System_Part_Role*	Exchange_thermal_energy_between_the_cooling_circuit_(hot_reservoir)_and_the_refrigerator_unit_(cold_reservoir)	0	Q max 8,8 m3/h max temperature 225°C Max pressure 33 bar
Heat_exchangers_of_Th	*System_Part_Role*	Exchange_thermal_energy_between_the_cooling_circuit_(hot_reservoir)_and_the_refrigerator_unit_(cold_reservoir)	0	0

Each system part has its own failure modes and relevant symptoms. All the instances of failure modes/symptoms are as follows:

Table 4: Failure Modes of Ex parts

Instances	Class	Description_of_System_Part_Failure_Mode	Measurability_of_System_Part_Failure_Mode	Alarm_code_of_System_Part_Failure_Mode

System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	*System_Part_Failure_Mode*	motor is worn	Mechanical torque motor screw Angular speed of motor and screw Polymer flow measurement	3072
System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	*System_Part_Failure_Mode*	motor bearing is damaged	Local temperature increase in mechanical bearing Motor power consumption increases Vibration in bearing	0
System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	*System_Part_Failure_Mode*	motor is worn	Mechanical torque motor Angular speed of motor Polymer flow measurement	3072
System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	*System_Part_Failure_Mode*	motor bearing is damaged	Local temperature increase in mechanical bearing Motor consumes more power than nominal (setpoint) Vibration in bearing	0
System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	*System_Part_Failure_Mode*	wear	Vibration/noise in gearbox Angular speed of motor rotor becomes more irregular	0
System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	*System_Part_Failure_Mode*	broken	Mechanical torque motor screw Angular speed of motor and screw Polymer flow measurement	3072
System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	*System_Part_Failure_Mode*	wear	Vibration/noise in gearbox Motor rotation speed becomes more irregular	0
System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	*System_Part_Failure_Mode*	broken	Mechanical torque motor Angular speed of motor Polymer flow measurement	3072
System_Part_Failure_Mode1_of_Pump_of_Ex	*System_Part_Failure_Mode*	wear (teeth and bearing)	Vibration in pump Fused polymer flow becomes more irregular Angular speed of motor rotor becomes more irregular Motor power consumption increases	3072
System_Part_Failure_Mode2_of_Pump_of_Ex	*System_Part_Failure_Mode*	broken	Mechanical torque motor Angular speed of motor Polymer flow measurement	3072
System_Part_Failure_Mode1_of_Polymer_of_Ex	*System_Part_Failure_Mode*	wrong composition	Fused polymer mechanical properties change (i.e.: viscosity @ given Temp) Fused polymer flow rate change Fused polymer temperature change Pressure in cylinder change	3072 3081
System_Part_Failure_Mode2_of_Polymer_of_Ex	*System_Part_Failure_Mode*	presence of humidity within the polymer	Fused polymer mechanical properties change (i.e.: viscosity @ given Temp) Fused polymer flow rate change Fused polymer temperature change Pressure in cylinder change	3072
System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	*System_Part_Failure_Mode*	block	Bypass valve does not carry out commuting action	0
System_Part_Failure_Mode2_of_Bypass_valve_of_Ex	*System_Part_Failure_Mode*	starts sticking	Pressure drop in bypass increasing trend Measurement of pump outbound pressure	0

System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	*System_Part_Failure_Mode*	motor is worn	Cooling fan(s) power changes	3081
System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	*System_Part_Failure_Mode*	motor bearing is damaged	Cooling fan(s) power changes	0
System_Part_Failure_Mode1_of_Mixer_of_Ex	*System_Part_Failure_Mode*	broken	Pressure drop inmixer increasing trend Measurement of pump outbound pressure irregular colour mixing	3081
System_Part_Failure_Mode1_of_Heaters_of_Ex	*System_Part_Failure_Mode*	burns itself	Electrical current of heating resistance drops to open circuit (zero level)	3081
System_Part_Failure_Mode1_of_Screw_of_Ex	*System_Part_Failure_Mode*	wear	Screw (motor) speed gradually increases Change of Internal pressure within cylinder	3072 3081
System_Part_Failure_Mode1_of_Cylinder_of_Ex	*System_Part_Failure_Mode*	wear	Screw (motor) speed gradually increases Change of Internal pressure within cylinder	3072 3081

Table 5: Failure Modes of HU parts

Instances	Class	Description_of_System_Part_Failure_Mode	Measurability_of_System_Part_Failure_Mode	Alarm_code_of_System_Part_Failure_Mode
System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	*System_Part_Failure_Mode*	motor is worn	Mechanical torque motor screw Angular speed of motor and screw Polymer flow measurement	3072
System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	*System_Part_Failure_Mode*	motor bearing is damaged	Local temperature increase in mechanical bearing Motor power consumption increases Vibration in bearing	0
System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	*System_Part_Failure_Mode*	motor is worn	Mechanical torque motor Angular speed of motor Polymer flow measurement	3072
System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	*System_Part_Failure_Mode*	motor bearing is damaged	Local temperature increase in mechanical bearing Motor consumes more power than nominal (setpoint) Vibration in bearing	0
System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	*System_Part_Failure_Mode*	wear	Vibration/noise in gearbox Angular speed of motor rotor becomes more irregular	0
System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	*System_Part_Failure_Mode*	broken	Mechanical torque motor screw Angular speed of motor and screw Polymer flow measurement	3072
System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	*System_Part_Failure_Mode*	wear	Vibration/noise in gearbox Motor rotation speed becomes more irregular	0

System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	*System_Part_Failure_Mode*	broken	Mechanical torque motor Angular speed of motor Polymer flow measurement	3072
System_Part_Failure_Mode1_of_Pump_of_HU	*System_Part_Failure_Mode*	wear (teeth and bearing)	Vibration in pump Fused polymer flow becomes more irregular Angular speed of motor rotor becomes more irregular Motor power consumption increases	3072
System_Part_Failure_Mode2_of_Pump_of_HU	*System_Part_Failure_Mode*	broken	Mechanical torque motor Angular speed of motor Polymer flow measurement	3072
System_Part_Failure_Mode1_of_Polymer_of_HU	*System_Part_Failure_Mode*	wrong composition	Fused polymer mechanical properties change (i.e.: viscosity @ given Temp) Fused polymer flow rate change Fused polymer temperature change Pressure in cylinder change	3072 3081
System_Part_Failure_Mode2_of_Polymer_of_HU	*System_Part_Failure_Mode*	presence of humidity within the polymer	Fused polymer mechanical properties change (i.e.: viscosity @ given Temp) Fused polymer flow rate change Fused polymer temperature change Pressure in cylinder change	3072
System_Part_Failure_Mode1_of_Bypass_valve_of_HU	*System_Part_Failure_Mode*	block	Bypass valve does not carry out commuting action	0
System_Part_Failure_Mode2_of_Bypass_valve_of_HU	*System_Part_Failure_Mode*	starts sticking	Pressure drop in bypass increasing trend Measurement of pump outbound pressure	0
System_Part_Failure_Mode1_of_Cooling_fans_of_HU	*System_Part_Failure_Mode*	motor is worn	Cooling fan(s) power changes	3081
System_Part_Failure_Mode2_of_Cooling_fans_of_HU	*System_Part_Failure_Mode*	motor bearing is damaged	Cooling fan(s) power changes	0
System_Part_Failure_Mode1_of_Mixer_of_HU	*System_Part_Failure_Mode*	broken	Pressure drop inmixer increasing trend Measurement of pump outbound pressure irregular colour mixing	3081
System_Part_Failure_Mode1_of_Heaters_of_HU	*System_Part_Failure_Mode*	burns itself	Electrical current of heating resistance drops to open circuit (zero level)	3081
System_Part_Failure_Mode1_of_Screw_of_HU	*System_Part_Failure_Mode*	wear	Screw (motor) speed gradually increases Change of Internal pressure within cylinder	3072 3081
System_Part_Failure_Mode1_of_Cylinder_of_HU	*System_Part_Failure_Mode*	wear	Screw (motor) speed gradually increases Change of Internal pressure within cylinder	3072 3081

Table 6: Failure Modes of Th parts

Instances	Class	Description_of_System_Part_Failure_Mode	Measurability_of_System_Part_Failure_Mode	Alarm_code_of_System_Part_Failure_Mode
System_Part_Failure_Mode1_of_Pumps_of_Th	*System_Part_Failure_Mode*	wear/ internal leakage	Provided Pressure (source) and flow changes from setpoit value	3042 3043
System_Part_Failure_Mode2_of_Pumps_of_Th	*System_Part_Failure_Mode*	broken	Pump(s) fail(s) to provide cooling fluid flow	3042 3043
System_Part_Failure_Mode1_of_Cooling_fluid_of_Th	*System_Part_Failure_Mode*	Quality of fluid drop	Cooling fluid circuits' pressure drop changes (clogging increases pressure drop)	3042 3043
System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	*System_Part_Failure_Mode*	Block	Temperature changes in the cooling circuit	3094 3095 3096 3097 3099
System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	*System_Part_Failure_Mode*	Block	Measurement of flow in the cooling circuit branches	0
System_Part_Failure_Mode1_of_Filter_of_Th	*System_Part_Failure_Mode*	Clogged	Measurement of pressure drop and flow (inversely related to temperature)	3042 3043
System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	*System_Part_Failure_Mode*	Clogged	Flow and temperature drift monitoring	3094 3095 3096 3097 3099
System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	*System_Part_Failure_Mode*	Internal leakage	Thermal balance among heat exchanger circuits is unbalanced (Qin≠Qout)	3113

Table 7: Failure symptoms of EX parts

Instances	Classes	Description_of_System_Part_Failure_Symptom
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	*System_Part_Failure_Symptom*	local abnormal heating local abnormal noise/vibrations
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	*System_Part_Failure_Symptom*	local abnormal heating local abnormal noise/vibrations
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	*System_Part_Failure_Symptom*	local abnormal noise/ vibration

System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	*System_Part_Failure_Symptom*	local abnormal noise/ vibration
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_of_Ex	*System_Part_Failure_Symptom*	abnormal flow rate and pressure local abnormal noise/ vibration
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_of_Ex	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Polymer_of_Ex	*System_Part_Failure_Symptom*	abnormal process conditions (flow rate, temperatures, pressures)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Polymer_of_Ex	*System_Part_Failure_Symptom*	abnormal process conditions (flow rate, temperatures, pressures)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Bypass_valve_of_Ex	*System_Part_Failure_Symptom*	increase of the switching time incomplete switching of the valve increase of the pump outbound pressure
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	*System_Part_Failure_Symptom*	abnormal temperature regulations (no air flow provided)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	*System_Part_Failure_Symptom*	abnormal temperature regulations (different amount of air flow provided)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Mixer_of_Ex	*System_Part_Failure_Symptom*	thermal drift of the melted polymer irregular colour mixing
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heaters_of_Ex	*System_Part_Failure_Symptom*	abnormal temperature regulations (different heating provided)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_of_Ex	*System_Part_Failure_Symptom*	increase of the screw speed abnormal melt pressure fluctuation ; abnormal flow rate fluctuation abnormal melt temperature abnormal temperature regulations
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cylinder_of_Ex	*System_Part_Failure_Symptom*	increase of the screw speed abnormal melt pressure fluctuation ; abnormal flow rate fluctuation abnormal melt temperature abnormal temperature regulations

Table 8: Failure symptoms of HU parts

Instances	Classes	Description_of_System_Part_Failure_Symptom
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)

System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	*System_Part_Failure_Symptom*	local abnormal heating local abnormal noise/vibrations
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	*System_Part_Failure_Symptom*	local abnormal heating local abnormal noise/vibrations
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	*System_Part_Failure_Symptom*	local abnormal noise/ vibration
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	*System_Part_Failure_Symptom*	local abnormal noise/ vibration
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_of_HU	*System_Part_Failure_Symptom*	abnormal flow rate and pressure local abnormal noise/ vibration
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_of_HU	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Polymer_of_HU	*System_Part_Failure_Symptom*	abnormal process conditions (flow rate, temperatures, pressures)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Polymer_of_HU	*System_Part_Failure_Symptom*	abnormal process conditions (flow rate, temperatures, pressures)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Bypass_valve_of_HU	*System_Part_Failure_Symptom*	Stop the machines (no polymer provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Bypass_valve_of_HU	*System_Part_Failure_Symptom*	increase of the switching time incomplete switching of the valve increase of the pump outbound pressure
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cooling_fans_of_HU	*System_Part_Failure_Symptom*	abnormal temperature regulations (no air flow provided)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Cooling_fans_of_HU	*System_Part_Failure_Symptom*	abnormal temperature regulations (different amount of air flow provided)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Mixer_of_HU	*System_Part_Failure_Symptom*	thermal drift of the melted polymer irregular colour mixing
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heaters_of_HU	*System_Part_Failure_Symptom*	abnormal temperature regulations (different heating provided)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_of_HU	*System_Part_Failure_Symptom*	increase of the screw speed abnormal melt pressure fluctuation ; abnormal flow rate fluctuation abnormal melt temperature abnormal temperature regulations
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cylinder_of_HU	*System_Part_Failure_Symptom*	increase of the screw speed abnormal melt pressure fluctuation ; abnormal flow rate fluctuation abnormal melt temperature abnormal temperature regulations

Table 9: Failure symptoms of Th parts

Instances	Classes	Description_of_System_Part_Failure_Symptom
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pumps_of_Th	*System_Part_Failure_Symptom*	volumetric efficency reduction / abnormal flow rate and pressure reduction local abnormal noise/ vibration
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pumps_of_Th	*System_Part_Failure_Symptom*	machine stops (no water provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cooling_fluid_of_Th	*System_Part_Failure_Symptom*	Metallic particles and debris contained in the cooling fluid may cause wear and clogging of elements (valves, etc.)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	*System_Part_Failure_Symptom*	machine stops (Temperature drift)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	*System_Part_Failure_Symptom*	Machine stops (no water provided in machine)
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Filter_of_Th	*System_Part_Failure_Symptom*	Abnormal pressure Abnormal flow rate reduction Temperature drift Abnormal water quality
System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	*System_Part_Failure_Symptom*	abnormal pressure abnormal flow rate reduction Temperature drift
System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	*System_Part_Failure_Symptom*	abnormal pressure abnormal flow rate reduction Temperature drift abnormal water quality

Each failure mode has Severity indicators which are indicators of how serious and destructive failure modes are. All the instances of Severity indicators are as follows:

Table 10: Severity indicator of Ex

Instances	Classes	Severity_level_of_Severity_Indicator
Severity_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	*Severity_Indicator*	Minor

Severity_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Pump_of_Ex	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode2_of_Pump_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Polymer_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode2_of_Polymer_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode2_of_Bypass_valve_of_Ex	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode1_of_Mixer_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Heaters_of_Ex	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Screw_of_Ex	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode1_of_Cylinder_of_Ex	*Severity_Indicator*	Minor

Table 11: Severity indicator of HU

Instances	Classes	Severity_level_of_Severity_Indicator
Severity_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Pump_of_HU	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode2_of_Pump_of_HU	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Polymer_of_HU	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode2_of_Polymer_of_HU	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Bypass_valve_of_HU	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode2_of_Bypass_valve_of_HU	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode1_of_Cooling_fans_of_HU	*Severity_Indicator*	Major

Severity_of_System_Part_Failure_Mode2_of_Cooling_fans_of_HU	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode1_of_Mixer_of_HU	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Heaters_of_HU	*Severity_Indicator*	Major
Severity_of_System_Part_Failure_Mode1_of_Screw_of_HU	*Severity_Indicator*	Minor
Severity_of_System_Part_Failure_Mode1_of_Cylinder_of_HU	*Severity_Indicator*	Minor

Table 12: Severity indicator of HU

Instances	Classes	Severity_level_of_Severity_Indicator
Severity_of_System_Part_Failure_Mode1_of_Pumps_of_Th	*Severity_Indicator*	medium
Severity_of_System_Part_Failure_Mode2_of_Pumps_of_Th	*Severity_Indicator*	medium
Severity_of_System_Part_Failure_Mode1_of_Cooling_fluid_of_Th	*Severity_Indicator*	medium
Severity_of_System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	*Severity_Indicator*	medium
Severity_of_System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	*Severity_Indicator*	medium
Severity_of_System_Part_Failure_Mode1_of_Filter_of_Th	*Severity_Indicator*	medium
Severity_of_System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	*Severity_Indicator*	medium
Severity_of_System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	*Severity_Indicator*	medium

Instances of Predictive/corrective maintenance actions are as follows:

Table 13: Predictive maintenance actions of ACP 5331H

Instances	Classes	predictive_actions_of_Predictive_Maintenance_Process_Definition
predictive_actions_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life

		Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Pump_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Pump_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Polymer_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Prevent non-compliant productions (the Stop the machines before the failure) Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Polymer_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Prevent non-compliant productions (the Stop the machines before the

		failure) Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Bypass_valve_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Mixer_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Heaters_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Screw_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Cylinder_of_Ex	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES

Table 14: Predictive maintenance actions of HU

Instances	Classes	predictive_actions_of_Predictive_Maintenance_Process_Definition

predictive_actions_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Pump_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Pump_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Polymer_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Prevent non-compliant productions (the Stop the machines before the

		failure) Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Polymer_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Prevent non-compliant productions (the Stop the machines before the failure) Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Bypass_valve_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Bypass_valve_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Cooling_fans_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Cooling_fans_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Mixer_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Heaters_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Screw_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Cylinder_of_HU	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES

Table 15: Predictive maintenance actions of Th

Instances	Classes	predictive_actions_of_Predictive_Maintenance_Process_Definition
predictive_actions_of_System_Part_Failure_Mode1_of_Pumps_of_Th	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Pumps_of_Th	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Cooling_fluid_of_Th	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	*Predictive_Maintenance_Process_Definition*	Remaining useful life
predictive_actions_of_System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	*Predictive_Maintenance_Process_Definition*	Remaining useful life
predictive_actions_of_System_Part_Failure_Mode1_of_Filter_of_Th	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES
predictive_actions_of_System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	*Predictive_Maintenance_Process_Definition*	Issue health status Remaining useful life Determine the reason for the malfunction Adapt the operating parameters jointly with the MES

Table 16: Corrective maintenance actions of ACP 5331H

Instances	Classes	Corrective_actions_of_Predictive_Maintenance_Process_Definition
corrective_actions_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Pump_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Pump_of_Ex	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Polymer_of_Ex	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Polymer_of_Ex	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Bypass_valve_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database

corrective_actions_of_System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Mixer_of_Ex	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Heaters_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Screw_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Cylinder_of_Ex	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database

Table 17: Corrective maintenance actions of HU

Instances	Classes	Corrective_actions_of_Predictive_Maintenance_Process_Definition
corrective_actions_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Pump_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Pump_of_HU	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Polymer_of_HU	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Polymer_of_HU	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Bypass_valve_of_HU	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Bypass_valve_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database

corrective_actions_of_System_Part_Failure_Mode1_of_Cooling_fans_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Cooling_fans_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Mixer_of_HU	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Heaters_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Screw_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Cylinder_of_HU	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database

Table 18: Corrective maintenance actions of AGR 14

Instances	Classes	Corrective_actions_of_Predictive_Maintenance_Process_Definition
corrective_actions_of_System_Part_Failure_Mode1_of_Pumps_of_Th	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Pumps_of_Th	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Cooling_fluid_of_Th	*Correntive_Maintenance_Process_Definition*	Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database

corrective_actions_of_System_Part_Failure_Mode1_of_Filter_of_Th	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database
corrective_actions_of_System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	*Correntive_Maintenance_Process_Definition*	Stop the machines Signal the malfunction (to the maintenance technician and to SACMI) Add the malfunction to the failures database

All instances of embedded data source components and their descriptive information are as follows:

Table 19: Embedded data source component of ACP 5331H

Instances	***Classes***	***Signals_involved_of_Embedded_Data-Source_Component_Role***	**q_ty_of_Embedded_Data-Source_Component_Role**	**Type_of_signal_of_Embedded_Data-**	**sampling_frequency_before_signal_elaboration_of_Embedded_Data-**	**sampling_frequency_before_signal_elaboration_of_Embedded_Data-**	**machine_part_linked_to_sensor_of_Embedded_Data-Source_Component_Role**	**is_it_used_for_automation_machine_of_Embedded_Data-**	**we_want_to_share_sansor_with_customer_of_Embedded_Data-Source_Component_Role**	**do_we_need_filter_or_elaborate_signal_of_Embedded_Data-Source_Component_Role**	**storage_frequency_after_elaboration_of_Embedded_Data-Source_Component_Role**	**Allarm_code_of_Embedded_Data-Source_Component_Role**	**Priority_of_Embedded_Data-Source_Component_Role**
EX1_of_Ex	Embedded_Data-Source_Component_Role	Motor_power_signal_from_inverter	2	analog	10 Hz	1 Hz	Ø polymer pellet feeder Ø screw Ø cylinder Ø pump Ø mixer Ø motors Ø gearboxes	no	yes	yes	once per hour with machine in running conditions	3072 3081	3 3

							Ø polymer Ø bypass valve heaters cooling fans						
EX2_of_Ex	Embedded_Data-Source_Component_Role	Speed_motor_signal_from_inverter	2	analog	10 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø polymer pellet feeder Ø screw Ø cylinder Ø pump Ø mixer Ø motors Ø gearboxes Ø polymer Ø bypass valve heaters cooling fans	si	yes	yes	once per hour with machine in running conditions	3072 3081	2 3
EX3_of_Ex	Embedded_Data-Source_Component_Role	Pressure_gauge_(inlet_pump)	1	analog (4-20 mA)	10 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø polymer pellet feeder Ø screw Ø cylinder Ø pump Ø motors Ø gearboxes Ø polymer heaters cooling fans	si	yes	yes	once per hour with machine in running conditions	3072	1
EX4_of_Ex	Embedded_Data-Source_Component_Role	Pressure_gauge_(outlet_pump)	1	analog (4-20 mA)	10 Hz	1 Hz (turret standing) 1 per cycle	Ø polymer pellet feeder Ø screw Ø cylinder Ø pump Ø mixer Ø motors	si	yes	yes	once per hour with machine in running conditions		

						(turret running)	Ø gearboxes Ø polymer Ø bypass valve heaters cooling fans						
EX7_of_Ex	Embedded_Data-Source_Component_Role	heaters_status	12 (11)	digital on/off	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø polymer pellet feeder Ø screw Ø cylinder Ø pump Ø mixer Ø motors Ø gearboxes Ø polymer Ø bypass valve	yes	yes	yes	once per hour with machine in running conditions	3072 3081	3 2
EX8_of_Ex	Embedded_Data-Source_Component_Role	cooling_fans_status_status	5	digital on/off	1 kHz /	1 dato al secondo 1 dato a giro	Ø polymer pellet feeder Ø screw Ø cylinder Ø pump Ø mixer Ø motors Ø gearboxes Ø polymer Ø bypass valve heaters cooling fans	yes	yes	yes	once per hour with machine in running conditions		
EX12_of_Ex	Embedded_Data-Source_Component_Role	Thermocouple_in_contact_wi	1	thermocouple J	1 Hz	1 Hz (turret standing) 1 per	Ø polymer pellet feeder Ø screw Ø cylinder Ø pump	no	yes	yes	once per hour with machine in running conditions	3072 3081	3 3

		th_polymer_melt				cycle (turret running)	Ø mixer Ø motors Ø gearboxes Ø polymer Ø bypass valve heaters cooling fans						
EX13_of_Ex	Embedded_Data-Source_Component_Role	Thermocouples_(extruders_zones_control)	12 (11)	thermocouple J	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø polymer pellet feeder Ø screw Ø cylinder Ø pump Ø mixer Ø motors Ø gearboxes Ø polymer Ø bypass valve heaters cooling fans	yes	yes	yes	once per hour with machine in running conditions	3072 3081	3 1
EX16_of_Ex	Embedded_Data-Source_Component_Role	inductive_sensor__(_bypass)	2	analog	1 kHz /	/	Ø screw Ø cylinder Ø pump Ø mixer Ø motors Ø gearboxes Ø polymer Ø bypass valve heaters cooling fans	yes	yes	yes	once per hour with machine in running conditions		

EX17_of_Ex	Embedded_Data-Source_Component_Role	resistance_thermometer_in_contact_with_water_(line_4-_chiller)	11	PT100 resistance thermometer	1 kHz /	/	Ø polymer pellet feeder Ø screw Ø cylinder Ø pump Ø mixer Ø motors Ø gearboxes Ø polymer Ø bypass valve heaters cooling fans	yes	yes	yes	once per hour with machine in running conditions		
EX18_of_Ex	Embedded_Data-Source_Component_Role	Thermocouples_(extruders_zones_control)_set	11	const	every change	every change		yes	yes	yes	once per hour with machine in running conditions	3081	1
EX19_of_Ex	Embedded_Data-Source_Component_Role	Pressure_gauge_(inlet_pump)_set	1	const	every change	every change		yes	yes	yes	once per hour with machine in running conditions	3072	1

Table 20: Embedded data source component of HU

Instances	*Classes*	*Signals_involved_of_Embedded_Data-Source_Component_Role*	q_ty_of_Embedded_Data-Source_Component_Role	Type_of_signal_of_Embedded_Data-Source_Component_Role	sampling_frequency_before_signal_elaboration_of_Embedded_Data-Source_Component_Role	sampling_frequency_before_signal_elaboration_of_Embedded_Data-Source_Component_Role	machine_part_linked_to_sensor_of_Embedded_Data-Source_Component_Role	is_it_used_for_automation_machine_of_Embedded_Data-	we_want_to_share_sansor_with_customer_of_Embedded_Data-	do_we_need_filter_or_elaborate_signal_of_Embedded_Data-Source_Component_Role	storage_frequency_after_elaboration_of_Embedded_Data-Source_Component_Role	Allarm_code_of_Embedded_Data-Source_Component_Role	Priority_of_Embedded_Data-Source_Component_Role
HU1_of_HU	Embedded_Data-Source_Component_Role	Motor power signal from inverter	2	analog	10 Hz	1 Hz	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves Ø filter Ø accumulators	no	yes	yes	once per hour with machine in running conditions	3099 1052 1053	3 1 1
HU2_of_HU	Embedded_Data-Source_Component_Role	Speed motor signal from inverter	2	analog	10 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure	no	yes	yes	once per hour with machine in running conditions	1052 1053	1 1

							regulators Ø flow regulators Ø non-return valves Ø accumulators						
HU5_of_HU	Embedded_Data - Source_Component_Role	Pressure gauge (line 1 - output)	1	analog (4-20 mA)	10 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves Ø accumulators	yes	yes	yes	once per hour with machine in running conditions	3099 1052	3 3
HU7_of_HU	Embedded_Data - Source_Component_Role	Pressure gauge (line 2 - accumulator)	1	analog (4-20 mA)	10 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves	no	yes	yes	once per hour with machine in running conditions	3099 1053	3 3

							Ø accumulators						
HU9_of_HU	Embedded_Data - Source_Component_Role	MOTOR REFERENCE YV36A	1	analog	/	1 Hz (turret standing) 1 per cycle (turret running)	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves Ø accumulators	yes	yes	yes	once per hour with machine in running conditions	1053	3
HU10_of_HU	Embedded_Data - Source_Component_Role	Pressure gauge (line 3 - output)	1	analog (4-20 mA)	10 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves Ø accumulators	yes	yes	yes	once per hour with machine in running conditions	3099	3

HU11_of_HU	Embedded_Data - Source_Component_Role	PRESSURE SET (line 1)	1	const	every change	every change		yes	yes	no	once per hour with machine in running conditions	1052	3
HU12_of_HU	Embedded_Data - Source_Component_Role	MOTOR REFERENCE SET YV36	1	const	/	every change		yes	yes	no	once per hour with machine in running conditions	1053	3
HU13_of_HU	Embedded_Data - Source_Component_Role	flowmeter (line 1)	1	analogico (4-20 mA)	/	/	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves Ø accumulators	no	yes	yes	once per hour with machine in running conditions		
HU14_of_HU	Embedded_Data - Source_Component_Role	flowmeter (line 2)	1	analog (4-20 mA)	/	/	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return	no	yes	yes	once per hour with machine in running conditions		

							valves Ø accumulators						
HU16_of_HU	Embedded_Data - Source_Component_Role	Differential pressure gauge (line 4 - filter)	1	analog (4-20 mA)	/	/	Ø motor Ø pumps Ø oil Ø filter	yes	yes	yes	once per hour with machine in running conditions		
HU18_of_HU	Embedded_Data - Source_Component_Role	Thermocouple in contact with oil	1	thermocouple J	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves Ø filter Ø accumulators	yes	yes	yes	once per hour with machine in running conditions	3099	1
HU19_of_HU	Embedded_Data - Source_Component_Role	oil temperature set	1	const	every change	every change		yes	yes	yes	once per hour with machine in running conditions	3099	1
HU23_of_HU	Embedded_Data - Source_Component_Role	Pressure gauge (line 5	1	analog (4-20 mA)	/	/	Ø motor Ø pumps Ø oil Ø solenoids valves	yes	yes	yes	once per hour with machine in running conditions		

		tank return)					Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves Ø accumulators						
HU25_of_HU	Embedded_Data - Source_Component_Role	solenoid valves status	1	digital on/off	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)		yes	yes	no	once per hour with machine in running conditions	3099	2
HU29_of_HU	Embedded_Data - Source_Component_Role	Pistons position transducer (average)	1	analog (4-20 mA)	10 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves Ø filter Ø accumulators	yes	yes	yes	once per hour with machine in running conditions	1053	3
HU30_of_HU	Embedded_Data - Source_Component_Role	Pistons position transducer set	1	const	every change	every change		yes	yes	no	once per hour with machine in running conditions	1053	

HU31_of_HU	Embedded_Data - Source_Component_Role	Encoder on machine motor gear box	1	analog	10 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves Ø filter Ø accumulators	yes	yes	yes	once per hour with machine in running conditions		
HU32_of_HU	Embedded_Data - Source_Component_Role	Encoder on machine motor gear box set	1	const	every change	every change		yes	yes	no	once per hour with machine in running conditions		
HU33_of_HU	Embedded_Data - Source_Component_Role	Cooling status oil	1	digital on/off	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Ø motor Ø pumps Ø oil Ø solenoids valves Ø logical elements Ø pressure regulators Ø flow regulators Ø non-return valves Ø filter	yes	yes	yes	once per hour with machine in running conditions	3099	2

Ø
accumulators

Table 21: Embedded data source component of Th

Instances	***Classes***	***Signals_involved_of_Embedded_Data-Source_Component_Role***	**q_ty_of_Embedded_Data-**	**Type_of_signal_of_Embedded_Data-Source_Component_Role**	**sampling_frequency_before_signal_elaboration_of_Embedded_Data-**	**sampling_frequency_before_signal_elaboration_of_Embedded_Data-Source_Component_Role**	**machine_part_linked_to_sensor_of_Embedded_Data-Source_Component_Role**	**is_it_used_for_automation_machine_of_Embedded_Data-Source_Component_Role**	**we_want_to_share_sansor_with_customer_of_Embedded_Data-Source_Component_Role**	**do_we_need_filter_or_elaborate_signal_of_Embedded_Data-Source_Component_Role**	**storage_frequency_after_elaboration_of_Embedded_Data-Source_Component_Role**	**Allarm_code_of_Embedded_Data-Source_Component_Role**	**Priority_of_Embedded_Data-Source_Component_Role**
TH3_of_Th	Embedded_Data-Source_Component_Role	Pressure gauge (line 1 - before filter)	1	analog (4-20 mA)	1 kHz /	/	Pumps Heat exchangers Cooling fluid Filters Pneumatic valves Solenoid	no	yes	yes	once per hour with machine in running conditions		

							Valves Motors						
TH5_of_TH	Embedded_Data-Source_Component_Role	Pressure gauge (line 2 - source)	1	analog (4-20 mA)	1 Hz	1 Hz	Pumps Heat exchangers Cooling fluid Filters Pneumatic valves Solenoid Valves Motors	no	yes	yes	once per hour with machine in running conditions	3042 3097 3113	3 3 3
TH6_of_TH	Embedded_Data-Source_Component_Role	Pressure gauge (line 2 - before filter)	1	analog (4-20 mA)	1 kHz /	/	Pumps Heat exchangers Cooling fluid Filters Pneumatic valves Solenoid Valves Motors	no	yes	yes	once per hour with machine in running conditions		
TH11_of_TH	Embedded_Data-Source_Component_Role	flowmeter (line 1)	1	analogic o (4-20 mA)	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Pumps Heat exchangers Cooling fluid Filters Pneumatic valves Solenoid Valves Motors	yes	yes	yes	once per hour with machine in running conditions	3043 3113	1 3

TH12_of_TH	Embedded_Data-Source_Component_Role	flowmeter (line 2)	1	analog (4-20 mA)	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Pumps Heat exchangers Cooling fluid Filters Pneumatic valves Solenoid Valves Motors	yes	yes	yes	once per hour with machine in running conditions	3042 3097 3113	1 3 3
TH15_of_TH	Embedded_Data-Source_Component_Role	resistance thermometer in contact with cooling fluid (line 1)	1	PT100 resistance thermometer	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Pumps Heat exchangers Cooling fluid Filters	yes	yes	yes	once per hour with machine in running conditions		
TH16_of_TH	Embedded_Data-Source_Component_Role	resistance thermometer in contact with cooling fluid (line 2)	1	PT100 resistance thermometer	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Pumps Heat exchangers Cooling fluid Filters	yes	yes	yes	once per hour with machine in running conditions	3097	1
TH17_of_TH	Embedded_Data-Source_Component_Role	resistance thermometer in contact with cooling fluid (line 3)	1	PT100 resistance thermometer	/	1 Hz (turret standing) 1 per cycle (turret running)	Pumps Heat exchangers Cooling fluid Filters	yes	yes	yes	once per hour with machine in running conditions		

TH18_of_TH	Embedded_Data-Source_Component_Role	Cooling fluid temperature set (line 1)	1	const	every change	every change	Pumps Heat exchangers Cooling fluid Filters	yes	yes	no	once per hour with machine in running conditions		
TH19_of_TH	Embedded_Data-Source_Component_Role	Cooling fluid temperature set (line 2)	1	const	every change	every change	Pumps Heat exchangers Cooling fluid Filters	yes	yes	no	once per hour with machine in running conditions	3097	1
TH20_of_TH	Embedded_Data-Source_Component_Role	Cooling fluid temperature set (line 3)	1	const	/	every change	Pumps Heat exchangers Cooling fluid Filters	yes	yes	no	once per hour with machine in running conditions	3099	2
TH22_of_TH	Embedded_Data-Source_Component_Role	solenoid valves status	2 (3)	digital on/off	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Pumps Heat exchangers Cooling fluid Filters Pneumatic valves Solenoid Valves Motors	yes	yes	yes	once per hour with machine in running conditions	3099 3097	2 2
TH23_of_TH	Embedded_Data-Source_Component_Role	Pressure gauge (line 4 - chiller)	1	digital on/off	1 kHz /	/	Pumps Heat exchangers Cooling fluid Filters Pneumatic valves Solenoid	yes	yes	yes	once per hour with machine in running conditions		

							Valves Motors						
TH24_of_TH	Embedded_Data-Source_Component_Role	resistance thermometer in contact with water (line 4-chiller)	1	digital on/off	/	/	Pumps Heat exchangers Cooling fluid Filters	yes	yes	yes	once per hour with machine in running conditions		
TH25_of_TH	Embedded_Data-Source_Component_Role	Cooling status (line 1)	1	digital on/off	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Pumps Heat exchangers Cooling fluid Filters	yes	yes	yes	once per hour with machine in running conditions		
TH26_of_TH	Embedded_Data-Source_Component_Role	Cooling status (line 2)	1	digital on/off	1 Hz	1 Hz (turret standing) 1 per cycle (turret running)	Pumps Heat exchangers Cooling fluid Filters	yes	yes	yes	once per hour with machine in running conditions	3097	2
TH27_of_TH	Embedded_Data-Source_Component_Role	Cooling status (line 3)	1	digital on/off	/	1 Hz (turret standing) 1 per cycle (turret running)	Pumps Heat exchangers Cooling fluid Filters	yes	yes	yes	once per hour with machine in running conditions	3099	2

All the relations between instances of SACMI use cases are listed as follows:

Table 22: Relations between instances of ACP 5331H

Relations	*consists_of_System_Part_Role_of_System_Role*		*has_System_Part_Failure_Mode*		*has_System_Part_Failure_Symptom*		*has_Severity_Indicator_of_System_Part_Failure_Mode*		*requires_Predictive_Maintenance_Process_Definition_of_System_Part_Failure_Mode*		*requires_Correntive_Maintenance_Process_Definition_of_System_Part_Failure_Mode*
Ex	Motor_of_plastic_extruder_screw_motor_of_Ex	Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_Ex
Ex	Motor_of_plastic_extruder_screw_motor_of_Ex	Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	Severity_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	predictive_actions_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex	corrective_actions_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_Ex
Ex	Motor_for_pump_of_Ex	Motor_for_pump_of_Ex	System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_Ex
Ex	Motor_for_pump_of_Ex	Motor_for_pump_of_Ex	System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	Severity_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	predictive_actions_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex	corrective_actions_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_Ex
Ex	Screw_gearbox_of_Ex	Screw_gearbox_of_Ex	System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_Ex

Ex	Screw_gearbox_of_Ex	Screw_gearbox_of_Ex	System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	Severity_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	predictive_actions_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex	corrective_actions_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_Ex
Ex	Pump_gearbox_of_Ex	Pump_gearbox_of_Ex	System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_Ex
Ex	Pump_gearbox_of_Ex	Pump_gearbox_of_Ex	System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	Severity_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	predictive_actions_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex	corrective_actions_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_Ex
Ex	Pump_of_Ex	Pump_of_Ex	System_Part_Failure_Mode1_of_Pump_of_Ex	System_Part_Failure_Mode1_of_Pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_of_Ex	System_Part_Failure_Mode1_of_Pump_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Pump_of_Ex
Ex	Pump_of_Ex	Pump_of_Ex	System_Part_Failure_Mode2_of_Pump_of_Ex	System_Part_Failure_Mode2_of_Pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_of_Ex	System_Part_Failure_Mode2_of_Pump_of_Ex	Severity_of_System_Part_Failure_Mode2_of_Pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_of_Ex	predictive_actions_of_System_Part_Failure_Mode2_of_Pump_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_of_Ex	corrective_actions_of_System_Part_Failure_Mode2_of_Pump_of_Ex
Ex	Polymer_of_Ex	Polymer_of_Ex	System_Part_Failure_Mode1_of_Polymer_of_Ex	System_Part_Failure_Mode1_of_Polymer_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Polymer_of_Ex	System_Part_Failure_Mode1_of_Polymer_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Polymer_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Polymer_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Polymer_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Polymer_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Polymer_of_Ex
Ex	Polymer_of_Ex	Polymer_of_Ex	System_Part_Failure_Mode2_of_Polymer_of_Ex	System_Part_Failure_Mode2_of_Polymer_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Polymer_of_Ex	System_Part_Failure_Mode2_of_Polymer_of_Ex	Severity_of_System_Part_Failure_Mode2_of_Polymer_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Polymer_of_Ex	predictive_actions_of_System_Part_Failure_Mode2_of_Polymer_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Polymer_of_Ex	corrective_actions_of_System_Part_Failure_Mode2_of_Polymer_of_Ex
Ex	Bypass_valve_of_Ex	Bypass_valve_of_Ex	System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Bypass_valve_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Bypass_valve_of_Ex
Ex	Bypass_valve_of_Ex	Bypass_valve_of_Ex	System_Part_Failure_Mode	System_Part_Failure_Mode	System_Part_Failure_Symptom_of_System_Part_Failure_	System_Part_Failure_Mode	Severity_of_System_Part_Failure_Mode2_of_B	System_Part_Failure_Symptom_of_System_Part_Failure_	predictive_actions_of_System_Part_Failure_Mode2	System_Part_Failure_Symptom_of_System_Part_Failure_	corrective_actions_of_System_Part_Failure_Mode2

			2_of_Bypass_valve_of_Ex	2_of_Bypass_valve_of_Ex	Mode2_of_Bypass_valve_of_Ex	2_of_Bypass_valve_of_Ex	ypass_valve_of_Ex	Mode2_of_Bypass_valve_of_Ex	_of_Bypass_valve_of_Ex	Mode2_of_Bypass_valve_of_Ex	_of_Bypass_valve_of_Ex
Ex	Cooling_fans_of_Ex	Cooling_fans_of_Ex	System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cooling_fans_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Cooling_fans_of_Ex
Ex	Cooling_fans_of_Ex	Cooling_fans_of_Ex	System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	Severity_of_System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	predictive_actions_of_System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Cooling_fans_of_Ex	corrective_actions_of_System_Part_Failure_Mode2_of_Cooling_fans_of_Ex
Ex	Mixer_of_Ex	Mixer_of_Ex	System_Part_Failure_Mode1_of_Mixer_of_Ex	System_Part_Failure_Mode1_of_Mixer_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Mixer_of_Ex	System_Part_Failure_Mode1_of_Mixer_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Mixer_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Mixer_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Mixer_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Mixer_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Mixer_of_Ex
Ex	Heaters_of_Ex	Heaters_of_Ex	System_Part_Failure_Mode1_of_Heaters_of_Ex	System_Part_Failure_Mode1_of_Heaters_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heaters_of_Ex	System_Part_Failure_Mode1_of_Heaters_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Heaters_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heaters_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Heaters_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heaters_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Heaters_of_Ex
Ex	Screw_of_Ex	Screw_of_Ex	System_Part_Failure_Mode1_of_Screw_of_Ex	System_Part_Failure_Mode1_of_Screw_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_of_Ex	System_Part_Failure_Mode1_of_Screw_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Screw_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Screw_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Screw_of_Ex
Ex	Cylinder_of_Ex	Cylinder_of_Ex	System_Part_Failure_Mode1_of_Cylinder_of_Ex	System_Part_Failure_Mode1_of_Cylinder_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cylinder_of_Ex	System_Part_Failure_Mode1_of_Cylinder_of_Ex	Severity_of_System_Part_Failure_Mode1_of_Cylinder_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cylinder_of_Ex	predictive_actions_of_System_Part_Failure_Mode1_of_Cylinder_of_Ex	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cylinder_of_Ex	corrective_actions_of_System_Part_Failure_Mode1_of_Cylinder_of_Ex

Table 23: Relations between instances of HU

	consists_of_System_Part_Role_of_Sys	***has_System_Part_Failure_Mode***	***has_System_Part_Failure_Symptom***	***has_Severity_Indicator_of_System_Part_Failure_Mode***	***requires_Predictive_Maintenance_Process_Definition_of_System_P***	***requires_Correntive_Maintenance_Process_Definition_of_System_P***

	tem_Role								***art_Failure_Mode***		***art_Failure_Mode***
HU	Motor_of_plastic_extruder_screw_motor_of_HU	Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	Severity_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Motor_of_plastic_extruder_screw_motor_of_HU
HU	Motor_of_plastic_extruder_screw_motor_of_HU	Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	Severity_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	predictive_actions_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU	corrective_actions_of_System_Part_Failure_Mode2_of_Motor_of_plastic_extruder_screw_motor_of_HU
HU	Motor_for_pump_of_HU	Motor_for_pump_of_HU	System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	Severity_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Motor_for_pump_of_HU
HU	Motor_for_pump_of_HU	Motor_for_pump_of_HU	System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	Severity_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	predictive_actions_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_HU	corrective_actions_of_System_Part_Failure_Mode2_of_Motor_for_pump_of_HU
HU	Screw_gearbox_of_HU	Screw_gearbox_of_HU	System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	Severity_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Screw_gearbox_of_HU
HU	Screw_gearbox_of_HU	Screw_gearbox_of_HU	System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	Severity_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	predictive_actions_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_HU	corrective_actions_of_System_Part_Failure_Mode2_of_Screw_gearbox_of_HU
HU	Pump_gearbox_of_HU	Pump_gearbox_of_HU	System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	Severity_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Pump_gearbox_of_HU

HU	Pump_gearbox_of_HU	Pump_gearbox_of_HU	System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	Severity_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	predictive_actions_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_HU	corrective_actions_of_System_Part_Failure_Mode2_of_Pump_gearbox_of_HU
HU	Pump_of_HU	Pump_of_HU	System_Part_Failure_Mode1_of_Pump_of_HU	System_Part_Failure_Mode1_of_Pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_of_HU	System_Part_Failure_Mode1_of_Pump_of_HU	Severity_of_System_Part_Failure_Mode1_of_Pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pump_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Pump_of_HU
HU	Pump_of_HU	Pump_of_HU	System_Part_Failure_Mode2_of_Pump_of_HU	System_Part_Failure_Mode2_of_Pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_of_HU	System_Part_Failure_Mode2_of_Pump_of_HU	Severity_of_System_Part_Failure_Mode2_of_Pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_of_HU	predictive_actions_of_System_Part_Failure_Mode2_of_Pump_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pump_of_HU	corrective_actions_of_System_Part_Failure_Mode2_of_Pump_of_HU
HU	Polymer_of_HU	Polymer_of_HU	System_Part_Failure_Mode1_of_Polymer_of_HU	System_Part_Failure_Mode1_of_Polymer_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Polymer_of_HU	System_Part_Failure_Mode1_of_Polymer_of_HU	Severity_of_System_Part_Failure_Mode1_of_Polymer_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Polymer_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Polymer_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Polymer_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Polymer_of_HU
HU	Polymer_of_HU	Polymer_of_HU	System_Part_Failure_Mode2_of_Polymer_of_HU	System_Part_Failure_Mode2_of_Polymer_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Polymer_of_HU	System_Part_Failure_Mode2_of_Polymer_of_HU	Severity_of_System_Part_Failure_Mode2_of_Polymer_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Polymer_of_HU	predictive_actions_of_System_Part_Failure_Mode2_of_Polymer_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Polymer_of_HU	corrective_actions_of_System_Part_Failure_Mode2_of_Polymer_of_HU
HU	Bypass_valve_of_HU	Bypass_valve_of_HU	System_Part_Failure_Mode1_of_Bypass_valve_of_HU	System_Part_Failure_Mode1_of_Bypass_valve_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Bypass_valve_of_HU	System_Part_Failure_Mode1_of_Bypass_valve_of_HU	Severity_of_System_Part_Failure_Mode1_of_Bypass_valve_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Bypass_valve_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Bypass_valve_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Bypass_valve_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Bypass_valve_of_HU
HU	Bypass_valve_of_HU	Bypass_valve_of_HU	System_Part_Failure_Mode2_of_Bypass_valve_of_HU	System_Part_Failure_Mode2_of_Bypass_valve_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Bypass_valve_of_HU	System_Part_Failure_Mode2_of_Bypass_valve_of_HU	Severity_of_System_Part_Failure_Mode2_of_Bypass_valve_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Bypass_valve_of_HU	predictive_actions_of_System_Part_Failure_Mode2_of_Bypass_valve_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Bypass_valve_of_HU	corrective_actions_of_System_Part_Failure_Mode2_of_Bypass_valve_of_HU
HU	Cooling_fans_of_HU	Cooling_fans_of_HU	System_Part_Failure_Mode1_of_Cooling_fans_of_HU	System_Part_Failure_Mode1_of_Cooling_fans_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cooling_fans_of_HU	System_Part_Failure_Mode1_of_Cooling_fans_of_HU	Severity_of_System_Part_Failure_Mode1_of_Cooling_fans_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cooling_fans_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Cooling_fans_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cooling_fans_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Cooling_fans_of_HU
HU	Cooling_fans_of_HU	Cooling_fans_of_HU	System_Part_Failure_Mode	System_Part_Failure_Mode	System_Part_Failure_Symptom_of_System_Part_Failure_	System_Part_Failure_Mode	Severity_of_System_Part_Failure_Mode2_of_C	System_Part_Failure_Symptom_of_System_Part_Failure_	predictive_actions_of_System_Part_Failure_Mode2_	System_Part_Failure_Symptom_of_System_Part_Failure_	corrective_actions_of_System_Part_Failure_Mode2_

			2_of_Cooling_fans_of_HU	2_of_Cooling_fans_of_HU	Mode2_of_Cooling_fans_of_HU	2_of_Cooling_fans_of_HU	ooling_fans_of_HU	Mode2_of_Cooling_fans_of_HU	of_Cooling_fans_of_HU	Mode2_of_Cooling_fans_of_HU	of_Cooling_fans_of_HU
HU	Mixer_of_HU	Mixer_of_HU	System_Part_Failure_Mode1_of_Mixer_of_HU	System_Part_Failure_Mode1_of_Mixer_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Mixer_of_HU	System_Part_Failure_Mode1_of_Mixer_of_HU	Severity_of_System_Part_Failure_Mode1_of_Mixer_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Mixer_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Mixer_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Mixer_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Mixer_of_HU
HU	Heaters_of_HU	Heaters_of_HU	System_Part_Failure_Mode1_of_Heaters_of_HU	System_Part_Failure_Mode1_of_Heaters_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heaters_of_HU	System_Part_Failure_Mode1_of_Heaters_of_HU	Severity_of_System_Part_Failure_Mode1_of_Heaters_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heaters_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Heaters_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heaters_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Heaters_of_HU
HU	Screw_of_HU	Screw_of_HU	System_Part_Failure_Mode1_of_Screw_of_HU	System_Part_Failure_Mode1_of_Screw_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_of_HU	System_Part_Failure_Mode1_of_Screw_of_HU	Severity_of_System_Part_Failure_Mode1_of_Screw_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Screw_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Screw_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Screw_of_HU
HU	Cylinder_of_HU	Cylinder_of_HU	System_Part_Failure_Mode1_of_Cylinder_of_HU	System_Part_Failure_Mode1_of_Cylinder_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cylinder_of_HU	System_Part_Failure_Mode1_of_Cylinder_of_HU	Severity_of_System_Part_Failure_Mode1_of_Cylinder_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cylinder_of_HU	predictive_actions_of_System_Part_Failure_Mode1_of_Cylinder_of_HU	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Cylinder_of_HU	corrective_actions_of_System_Part_Failure_Mode1_of_Cylinder_of_HU

Table 24: Relations between instances of Th

	consists_of_System_Part_Role_of_System_Role		***has_System_Part_Failure_Mode***		***has_System_Part_Failure_Symptom***		***has_Severity_Indicator_of_System_Part_Failure_Mode***		***requires_Predictive_Maintenance_Process_Definition_of_System_Part_Failure_Mode***		***requires_Correntive_Maintenance_Process_Definition_of_System_Part_Failure_Mode***
TH	Pumps_of_Th	Pumps_of_Th	System_Part_Failure_Mode1_of_Pumps_of_Th	System_Part_Failure_Mode1_of_Pumps_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pumps_of_Th	System_Part_Failure_Mode1_of_Pumps_of_Th	Severity_of_System_Part_Failure_Mode1_of_Pumps_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pumps_of_Th	predictive_actions_of_System_Part_Failure_Mode1_of_Pumps_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pumps_of_Th	corrective_actions_of_System_Part_Failure_Mode1_of_Pumps_of_Th
TH	Pumps_of_Th	Pumps_of_Th	System_Part_Failure_Mode2_of_Pumps_of_Th	System_Part_Failure_Mode2_of_Pumps_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pumps_of_Th	System_Part_Failure_Mode2_of_Pumps_of_Th	Severity_of_System_Part_Failure_Mode2_of_Pumps_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pumps_of_Th	predictive_actions_of_System_Part_Failure_Mode2_of_Pumps_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Pumps_of_Th	corrective_actions_of_System_Part_Failure_Mode2_of_Pumps_of_Th
TH	Cooling_fluid_of_Th	Cooling_fl	System_Part_Failure_Mo	System_Part_Failure_Mo	System_Part_Failure_Symptom_of_Syste	System_Part_Failure_Mo	Severity_of_System_Part_Fail	System_Part_Failure_Symptom_of_Syste	predictive_actions_of_System_Part_	System_Part_Failure_Symptom_of_Syste	corrective_actions_of_System_Part_

		uid_of_Th	de1_of_Cooling_fluid_of_Th	de1_of_Cooling_fluid_of_Th	m_Part_Failure_Mode1_of_Cooling_fluid_of_Th	de1_of_Cooling_fluid_of_Th	ure_Mode1_of_Cooling_fluid_of_Th	m_Part_Failure_Mode1_of_Cooling_fluid_of_Th	Failure_Mode1_of_Cooling_fluid_of_Th	m_Part_Failure_Mode1_of_Cooling_fluid_of_Th	Failure_Mode1_of_Cooling_fluid_of_Th
TH	Solenoid_valves_of_Th	Solenoid_valves_of_Th	System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	Severity_of_System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	predictive_actions_of_System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Solenoid_valves_of_Th	corrective_actions_of_System_Part_Failure_Mode1_of_Solenoid_valves_of_Th
TH	Pneumatic_valves_of_Th	Pneumatic_valves_of_Th	System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	Severity_of_System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	predictive_actions_of_System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th	corrective_actions_of_System_Part_Failure_Mode1_of_Pneumatic_valves_of_Th
TH	Filter_of_Th	Filter_of_Th	System_Part_Failure_Mode1_of_Filter_of_Th	System_Part_Failure_Mode1_of_Filter_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Filter_of_Th	System_Part_Failure_Mode1_of_Filter_of_Th	Severity_of_System_Part_Failure_Mode1_of_Filter_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Filter_of_Th	predictive_actions_of_System_Part_Failure_Mode1_of_Filter_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Filter_of_Th	corrective_actions_of_System_Part_Failure_Mode1_of_Filter_of_Th
TH	Heat_exchangers_of_Th	Heat_exchangers_of_Th	System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	Severity_of_System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	predictive_actions_of_System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode1_of_Heat_exchangers_of_Th	corrective_actions_of_System_Part_Failure_Mode1_of_Heat_exchangers_of_Th
TH	Heat_exchangers_of_Th	Heat_exchangers_of_Th	System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	Severity_of_System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	predictive_actions_of_System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	System_Part_Failure_Symptom_of_System_Part_Failure_Mode2_of_Heat_exchangers_of_Th	corrective_actions_of_System_Part_Failure_Mode2_of_Heat_exchangers_of_Th

4 PHILIPS ONTOLOGY

This section presents the PHILIPS ontology with all the instances. The PHILIPS ontology is a branch of Z-BRE4K ontology, including specific knowledge of PHILIPS use case. The target systems are comprised of various parts. The following tables show all the instances of target systems and their parts.

Table 25 : Cold_Forming_Manufacturing_System and its parts

Instance	**Cold_Forming_Manufacturing_System**
Class	System_Role
consists_of_Embedded_Data-Source_Component_Role_of_System_Role	Acoustic_Emission_Sensor
consists_of_System_Part_Role_of_System_Role	Die_Module_1
consists_of_System_Part_Role_of_System_Role	Die_Module_2
consists_of_System_Part_Role_of_System_Role	Die_Module_3
consists_of_System_Part_Role_of_System_Role	Die_Module_4
consists_of_System_Part_Role_of_System_Role	Die_Module_5
consists_of_System_Part_Role_of_System_Role	Die_Module_6
consists_of_System_Part_Role_of_System_Role	RAM
consists_of_System_Part_Role_of_System_Role	Housing

Table 26 : Acoustic_Emission_Sensor

Instance	**Class**
Acoustic_Emission_Sensor	Embedded_Data-Source_Component_Role

Table 27 : Parts of Cold_Forming_Manufacturing_System and their Failure Modes

Instance	***Class***	**has_System_Part_Failure_Mode**	**has_System_Part_Failure_Mode**	**has_System_Part_Failure_Mode**	**Redundancy_provided_of_System_Part_Role**
Die_Module_1	*System_Part_Role*	Failure_Mode_1	Failure_Mode_2	Failure_Mode_3	No
Die_Module_2	*System_Part_Role*	Failure_Mode_4	Failure_Mode_5		No
Die_Module_3	*System_Part_Role*	Failure_Mode_1	Failure_Mode_2	Failure_Mode_3	No
Die_Module_4	*System_Part_Role*				No
Die_Module_5	*System_Part_Role*				No
Die_Module_6	*System_Part_Role*	Failure_Mode_1	Failure_Mode_2	Failure_Mode_3	No
RAM	*System_Part_Role*				No
Housing	*System_Part_Role*				No

Table 28 : Severity Indicators of Failure Modes

Instance	*Class*	Description_of_Severity	Severity_level_of_Severity_Indicator
Severity_Indicator_1	*Severity_Indicator*		1
Severity_Indicator_2	*Severity_Indicator*		2
Severity_Indicator_3	*Severity_Indicator*		3
Severity_Indicator_4	*Severity_Indicator*	planned adjustment	4
Severity_Indicator_5	*Severity_Indicator*	immediate line stop	5

Table 29 : Key Performance Parameters

Instance	*Class*	Description_of_Key_Performance_Parameter
Mean_Time_Between_Failures	*Key_Performance_Parameter*	Average time the machine will run without failing
Mean_Time_To_Repair	*Key_Performance_Parameter*	Average time it takes to repair a machine failure
Cycle_Time	*Key_Performance_Parameter*	Time it takes to perform a process step
Critical_To_Quality_Parameters	*Key_Performance_Parameter*	Product feature which is critical to quality for the end user
Fall_off	*Key_Performance_Parameter*	Percentage of faulty products which will be scrapped
Reference_Measurement	*Key_Performance_Parameter*	A measurement which is performed every x hours to make sure the measurement system is stable
Corrective_Vs_Predictive_Maintenance	*Key_Performance_Parameter*	Distribution of maintenance between preventing breakdowns and correcting after breakdowns
Maintenance_Costs	*Key_Performance_Parameter*	Total cost of maintenance. Cost of spare parts, machine and workers hours

Table 30 : Failure Modes of Cold Forming Manufacturing System parts

Instance	*Class*	Description_of_System_Failure_Cause	has_System_Part_Failure_Symptom	Failure_Cause	realized_in_Embedded_Data-Source_Component_Role_of_System_Part_Failure_Mode
Failure_Mode_1	*System_Part_Failure_Mode*	Scrap from cutting returns into Die	System_Failure_Symptom_1	Blunt punch or worn die plate	Acoustic_Emission_Sensor
Failure_Mode_2	*System_Part_Failure_Mode*	Punch Breakage	System_Failure_Symptom_1	Wrong strip feed or blunt punch	Acoustic_Emission_Sensor
Failure_Mode_3	*System_Part_Failure_Mode*	Blunt punch	System_Failure_Symptom_2	Wear or lack of oil	Acoustic_Emission_Sensor
Failure_Mode_4	*System_Part_Failure_Mode*	die parts break	System_Failure_Symptom_2	Fatigue	Acoustic_Emission_Sensor
Failure_Mode_5	*System_Part_Failure_Mode*	wrong thickness	System_Failure_Symptom_2	Unknown	Acoustic_Emission_Sensor

Table 31 : Maintenance Actions of Cold_Forming_Manufacturing_System parts

Instance	*Class*	predictive_actions_of_Predictive_Maintenance_Process_Definition
Maintenance_Action_1	*Predictive_Maintenance_Process_Definition*	cleaning or maintenance by die workshop

Maintenance_Action_2	*Predictive_Maintenance_Process_Definition*	Maintenance by die workshop
Maintenance_Action_3	*Predictive_Maintenance_Process_Definition*	replace part by die workshop
Maintenance_Action_4	*Predictive_Maintenance_Process_Definition*	height adjustment by die workshop

Table 32 : Failure Symptoms of Cold_Forming_Manufacturing_System parts

Instance	*Class*	Description_of_System_Part_Failure_Mode	requires_Predictive_Maintenance_Process_Definition_of_System_Part_Failure_Symptom
System_Failure_Symptom_1	*System_Part_Failure_Symptom*	press stops immediately	Maintenance_Action_1
System_Failure_Symptom_2	*System_Part_Failure_Symptom*	press stops immediately	Maintenance_Action_2
System_Failure_Symptom_3	*System_Part_Failure_Symptom*	Product deviation	Maintenance_Action_2
System_Failure_Symptom_4	*System_Part_Failure_Symptom*	Product deviation	Maintenance_Action_3
System_Failure_Symptom_5	*System_Part_Failure_Symptom*	Product deviation	Maintenance_Action_4

5 GESTAMP ONTOLOGY

This section presents the GESTAMP ontology with all the instances. The GESTAMP ontology is a branch of Z-BRE4K ontology, including specific knowledge of GESTAMP use case. The target systems are comprised of various parts. The following tables show all the instances of target systems and their parts.

Table 33: Welding_Manufacturing_System and its parts

Instance	**Welding_Manufacturing_System**
Class	System_Role
consists_of_Embedded_Data-Source_Component_Role_of_System_Role	Infra-red camera
consists_of_System_Part_Role_of_System_Role	Contact Tip

Table 34: Infra-red_camera

Instance	***Class***
Infra-red_camera	*Embedded_Data-Source_Component_Role*

Table 35: The part of Welding_Manufacturing_System and its failure modes

Instance	***Class***	**has_System_Part_Failure_Mode**	**has_System_Part_Failure_Mode**	**has_System_Part_Failure_Mode**	**has_System_Part_Failure_Mode**
Contact Tip	*System_Part_Role*	Failure_Mode_1	Failure_Mode_2	Failure_Mode_3	Failure_Mode_4

Table 36: Key Performance Parameters

Instance	*Class*	Description_of_Key_Performance_Parameter
Mean_Time_Between_Failures	*Key_Performance_Parameter*	Average time the machine will run without failing
Mean_Time_Between_Defects	*Key_Performance_Parameter*	Average time the cell will run without defective parts

Table 37: The Failure Modes of the Welding_Manufacturing_System parts

Instance	*Class*	Description_of_System_Failure_Cause	has_System_Part_Failure_Symptom	Failure_Cause	realized_in_Embedded_Data-Source_Component_Role_of_System_Part_Failure_Mode
Failure_Mode_1	*System_Part_Failure_Mode*	Unstable	System_Failure_Symptom_1	Worn out contact tip	Infra-red camera
Failure_Mode_2	*System_Part_Failure_Mode*	Off seam	System_Failure_Symptom_1	Worn out contact tip	Infra-red camera
Failure_Mode_3	*System_Part_Failure_Mode*	Pores	System_Failure_Symptom_1	Worn out contact tip	Infra-red camera
Failure_Mode_4	*System_Part_Failure_Mode*	Stuck Wire	System_Failure_Symptom_2	Worn out contact tip	Infra-red camera

Table 38: Failure Symptoms of Welding_Manufacturing_System

Instance	*Class*	Description_of_System_Part_Failure_Mode	requires_Predictive_Maintenance_Process_Definition_of_System_Part_Failure_Symptom
System_Failure_Symptom_1	*System_Part_Failure_Symptom*	Reduction in dynamic strength of the weld, loss of structural integrity	Maintenance_Action_1
System_Failure_Symptom_2	*System_Part_Failure_Symptom*	Welding cell stopped	Maintenance_Action_2

Table 39: Maintenance Processes of Welding_Manufacturing_System

Instance	*Class*	predictive_actions_of_Predictive_Maintenance_Process_Definition
Maintenance_Action_1	*Predictive_Maintenance_Process_Definition*	Establish a tip change frequency and change it
Maintenance_Action_2	*Predictive_Maintenance_Process_Definition*	Unblock wire, guide it again and change contact tip

6 UPDATED ONTOLOGY IMPLEMENTATION

6.1 Knowledge Extraction

The Z-BRE4K ontology has been designed to apply the competency questions method which facilitates the satisfaction of requirements of stakeholders in the domain field. From this methodology, the domain of interest was extracted and provided for the Z-BRE4K ontology, referring to various data sources. The ontology serves as a common reference model for the annotation and description in the context of Z-BRE4K project. Moreover, the ontology describes the basic entities of the Z-BRE4K project and model relevant maintenance structures. This explicit knowledge adds value for people who try to understand domain knowledge of Z-BRE4K project. Furthermore, the ontology constitutes the formal representation of the semantic

model and the knowledge that this model encapsulates as part of the Z-BRE4K platform. Therefore, a codification of the knowledge will allow to exchange information regarding the Product-Service context and to be desirable to use it, in order to increase the added value of the Z-BRE4K platform.

Currently, the Z-BRE4K platform is demonstrated by three business scenarios that are representatives of predictive maintenance domain and each one has unique challenges and requirements. The Z-BRE4K ontology provides the generalization of maintenance domain knowledge and the SACMI, PHILIPS and GESTAMP ontologies each describe the domain knowledge of a specific business scenario to meet its requirements. Further on, domain knowledge of the maintenance in the Z-BRE4K context can be visualized as a graph from the ontology. The nodes of the graph can show entire entities and edges can demonstrate the various relations between entities, to make it easily understandable.

6.2 Data integration and Semantic Interoperability

The Z-BRE4K ontology plays a role which is to integrate various data sources for intelligent filtering. By the relations between the data sources representing the product states, all the data instances will have the labels following rules of the ontology. Therefore, one of the key benefits of Semantic technologies is the creation of data for identifying data sources which will have semantic meaning into the ontology.

On the other hand, data integration enables Z-BRE4K to have semantic interoperability. The semantic interoperability provides abilities to exchange data and information with unambiguous, shared meaning to the platform. This is a requirement of machine computable logic, inferencing, knowledge discovery, and data federation between various modules in the platform.

7 Rules inference

The Z-BRE4K ontology has the ability to assume the existence of rules expressing logics. To clarify rules inference, a simple example can be used. Z-BRE4K ontology might have simple rules such as “a sensor should belong to at least one system part” and “a system should have at least one system part”. In that case, rule inference will provide a new knowledge saying “a sensor should belong to at least one system”. Rule inference engines provide such results automatically and facilitate the combination of more than two rules which provide complex conclusions.

It is important to highlight that rule inference is a self-initiated process. It is a background process every time that an ontology is updated or extended. In the ontology, it provides trace availability, when the platform gets abnormal signals or critical user feedback.

In general, Knowledge extraction, Data integration and Rule Inference represent the three main exploitation features leveraged by any semantic technologies based models.

8 Conclusion

This document presented all the instances of the SACMI, PHILIPS and GESTAMP ontologies and the implementation details of the Z-BRE4K semantic model as an ontology. The Z-BRE4K

ontology has been developed including the domain of interest for all the three business scenarios of the Z-BRE4K project. In order to meet the requirements of stakeholders in the domain field, the competency question method has been applied.

As a result of Task 3.5, the SACMI, PHILIPS and GESTAMP ontologies have been created including all the type of systems, system parts, Embedded Data source components, failure modes/symptoms, corrective/predictive maintenance actions, severity indicators of failure modes to Z-BRE4K ontology. This information provided instances to these ontologies with certain relations following the rules of Z-BRE4K ontology and this ontology has been implemented as a part of the Knowledge Base System under Task 3.2. Knowledge Base system provides a SPARQL based search engine and it facilitates finding relevant data.

Z-BRE4K ontology has been created, inspired by Z-BRE4K business cases. Therefore, development was data and business case-oriented and the bottom-up approach and the ontology has been improved by a technical implementation. It might bring additional benefit if the ontology can be synchronized with another ontology developed by a fundament oriented method such as IOF maintenance ontology. In addition, since IOF maintenance ontology has been improved through an intersection between philosophy-engineering, it will bring a strong philosophical background to Z-BRE4K ontology.