ISO 14224 – with semantics

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Situation

Positive

- The ISO14224 standard is a conceptualisation of how equipment can be structured for reliability and maintenance data collection.
- ISO 14224 is widely used in industry.
- SAP is ubiquitous in many organisation. The way maintenance data is capture in the SAP APM software maps to many fields identified in ISO 14224.

Challenges

- ISO 14224 does not define functions.
- There is no agreed set of engineering functions. Though concepts have been defined in 1) DOLCE ontological functions and listed in 2) the IEC 81346 standard
- There are levels in an equipment hierarchy (equipment, subunit, maintainable item, component) – each with functions.
- Each function will have potential functional failures.
- Is it possible to give semantic meaning to common equipment functions and related loss of function to semantic concepts for failure descriptors?

What is the ISO 14224:2016 standard?

- ISO 14224 provides a structured approach to collecting and exchanging reliability and maintenance data.
- The standard covers a wide range of equipment used in the process industries during their operational life cycle.
- Users of the standard aims to improve the reliability, availability, and maintainability of equipment by standardising data representation and exchange between different organisations (e.g. operators, contractors, manufacturers).
- The main categories of data described in the standard are:
  - equipment data, e.g. equipment taxonomy, equipment attributes;
  - failure data, e.g. failure cause, failure consequence;
  - maintenance data, e.g. maintenance action, resources used, maintenance consequence, down time.

Ref: https://www.iso.org/standard/64076.html

Who uses the ISO 14224 standard?

- The original developers of the ISO 14224 standard were organisations involved in the oil and gas and petrochemical industries.
- Today ISO 14224 is also used as a reference by other process plant organisations such as in the mining and mineral processing industries.
- The equipment hierarchy breakdown structure and list of concepts (such as failure modes) form the basis of the OREDA database for industry failure rate data for use in offshore oil and gas equipment design. This includes functional safety data.
- The OREDA data collection project has been going for more than 43 years.
- SAP, a multinational software company providing enterprise software to most of the Western World's process plants uses many ISO 14224 definitions in its SAP-APM (asset performance management) software. Many relevant classes of data in SAP APM are directly mappable to ISO 14224 concepts.

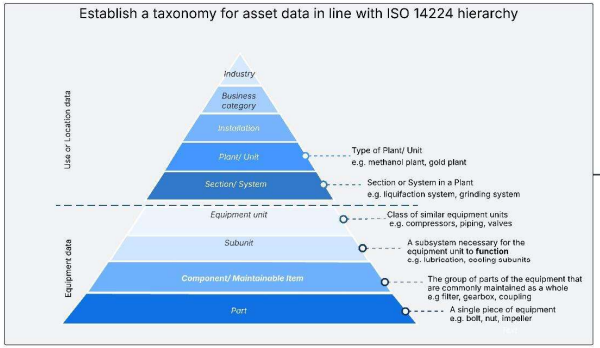
Ref: https://www.iso.org/standard/64076.html

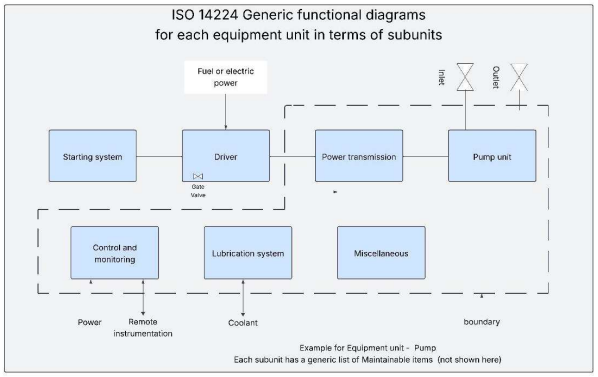
Comparing SAP, ISO 14224 & IEC 60812 definitions

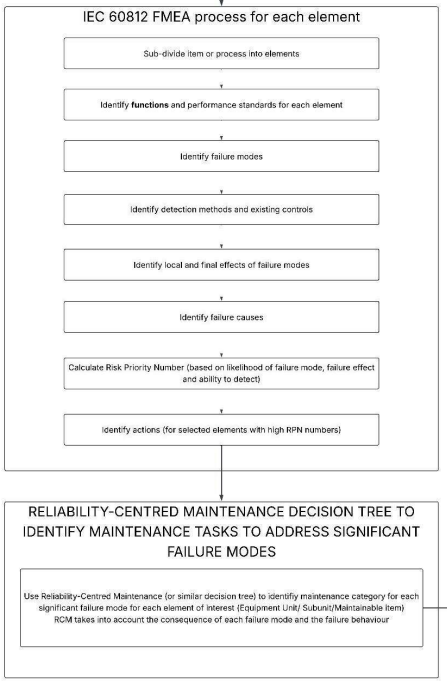
Term	SAP definition*	ISO 14224:2016 definition (Collection and exchange of reliability and maintenance data for equipment)	IEC 60812:2020 definition (Failure modes and effects analysis)
Function	statement of what the user wants an item (equipment, etc.) to do and to what standard of performance.	n/a	n/a
Failure	n/a	<of an item> loss of ability to perform as required *Note 1: A failure of an item is an event that results in a fault of that item*	n/a
Functional Failure	the termination of the ability of an item (equipment, etc.) to perform a required function.	n/a	n/a
Failure mode	the way in which the inability of an item (such as equipment) to perform a required function occurs.	manner in which failure occurs	Same as for ISO 14224:2016 *Note 1: a FM may be determined by function lost or other state transition*
Failure mechanism	description of the physical, chemical, or other processes which have led to the failure (mode).	process that leads to failure, the process can be physical, chemical, logical or combination	Same as for ISO 14224:2016 but the 2nd clause is in a Note.
Causes	circumstances during design, manufacture, or use which have triggered the failure mechanism and led to the failure (mode).	set of circumstances that leads to failure	Same as for ISO 14224:2016
Failure effect	describes what happens to the item (such as equipment) when a Failure Mode occurs.	n/a	consequence of a failure, within or beyond the boundary of the failed item
Item	n/a	subject being considered. *Notes: Item can be an individual part, component, device, functional unit, equipment, subsystem or system. Also, hardware, software and/or people.*	Same as for ISO 14224:2016
Maintainable item	Same as ISO 14224:2016	item that constitutes a part or an assembly of parts that is normally the lowest level in the equipment hierarchy during maintenance.	n/a

* From SAP Asset Reliability Engineering page

ISO 14224:2016 and other processes and tables

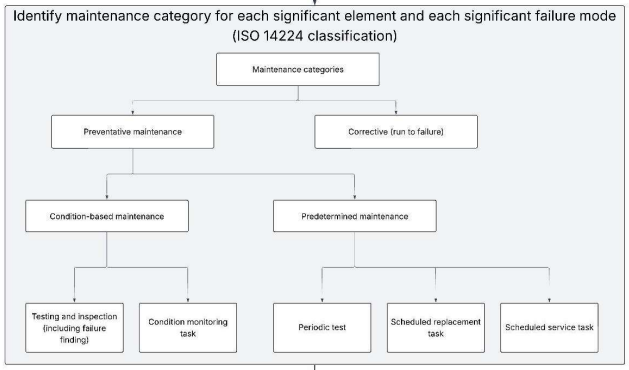






RELIABILITY-CENTRED MAINTENANCE DECISION TREE TO IDENTIFY MAINTENANCE TASKS TO ADDRESS SIGNIFICANT FAILURE MODES

Use Reliability-Centred Maintenance (or similar decision tree) to identify maintenance category for each significant failure mode for each element of interest (Equipment Unit/ Subunit/Maintainable Item)
RCM takes into account the consequence of each failure mode and the failure behaviour



DEVELOP MAINTENANCE PLAN FROM IDENTIFIED TASKS

EXECUTE MAINTENANCE PLAN

COLLECT FAILURE AND MAINTENANCE DATA

ISO 14224 FAILURE MODES (*table shows a few examples only*)
Failure modes should normally relate to the equipment-class level in the asset hierarchy

Failure modes are categorised as three types:
a) function not obtained
b) function lost or outside of acceptable limits
c) failure indication observed but no immediate impact e.g. degradation or wear

Failure mode code	Description	Examples
AIR	Abnormal instrument reading	False alarm, faulty instrument indication
BRD	Breakdown	Serious damage (seizure, breakdown)
NOI	Noise	Abnormal noise
PDE	Parameter deviation	Monitored parameter exceeds limit
UST	Spurious stop	Unexpected shutdown
VIB	Vibration	Abnormal vibration

ISO 14224 failure data requirements per failure event

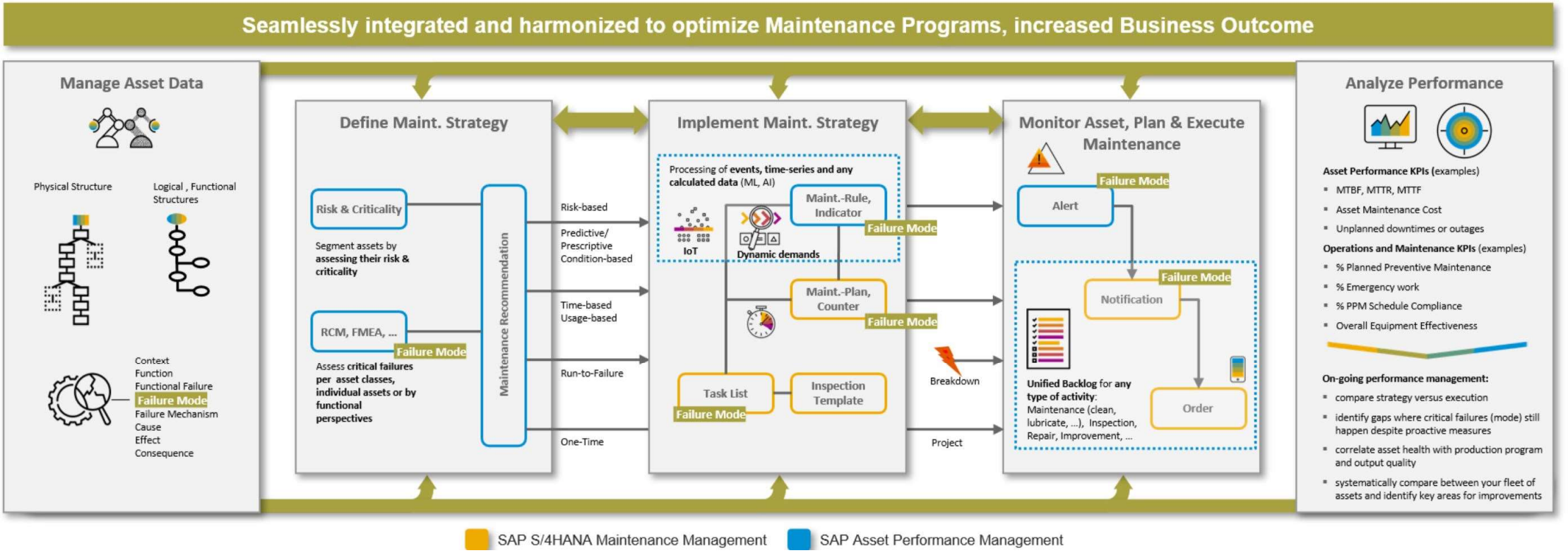
Data category	Data to be recorded	Description
Identification	Failure record*	Unique failure record identifier
Failure data	Equipment identifier/ Location*	e.g. tag number
	Failure date*	Date of failure identification
	Failure mode*	Usually at equipment-unit level
	Failure impact on plant safety (personnel, environment, assets)	Use corporate's risk matrix
	Failure impact on plant operations	Use corporate's risk matrix
	Failure impact on equipment function	Effect on equipment-unit function: critical, degraded or incipient failure
	Failure mechanism	Physical, chemical or other processes that have led to failure
	Failure cause	Circumstances during design, manufacture or use which has led to failure
	Subunit failed	Name of the subunit that failed
	Component/ Maintainable item(s) failed	Name of the failed component/ maintainable item(s)
	Detection method	How the failure was detected
	Operating condition at failure *	Run-down, start-up, running, hot standby, idle, cold standby, testing
	SIS failure mode classification	For Safety Instrumented Systems (DO, DU, SU, SD)

ISO 14224 FAILURE MECHANISMS
Failure mechanisms shoud be at subunit or maintainable item levels

Failure mechanism	FM subdivision
Mechanical failure	General
	Leakage
	Vibration
	Clearance/ alignment
	Deformation
	Looseness
	Sticking
Material failure	General
	Cavitation
	Corrosion
	Erosion
	Wear
	Breakage
	Fatigue
	Overheating
	Burst
Miscellaneous	General
	No cause found
	Combined causes
	Other
	Unknown

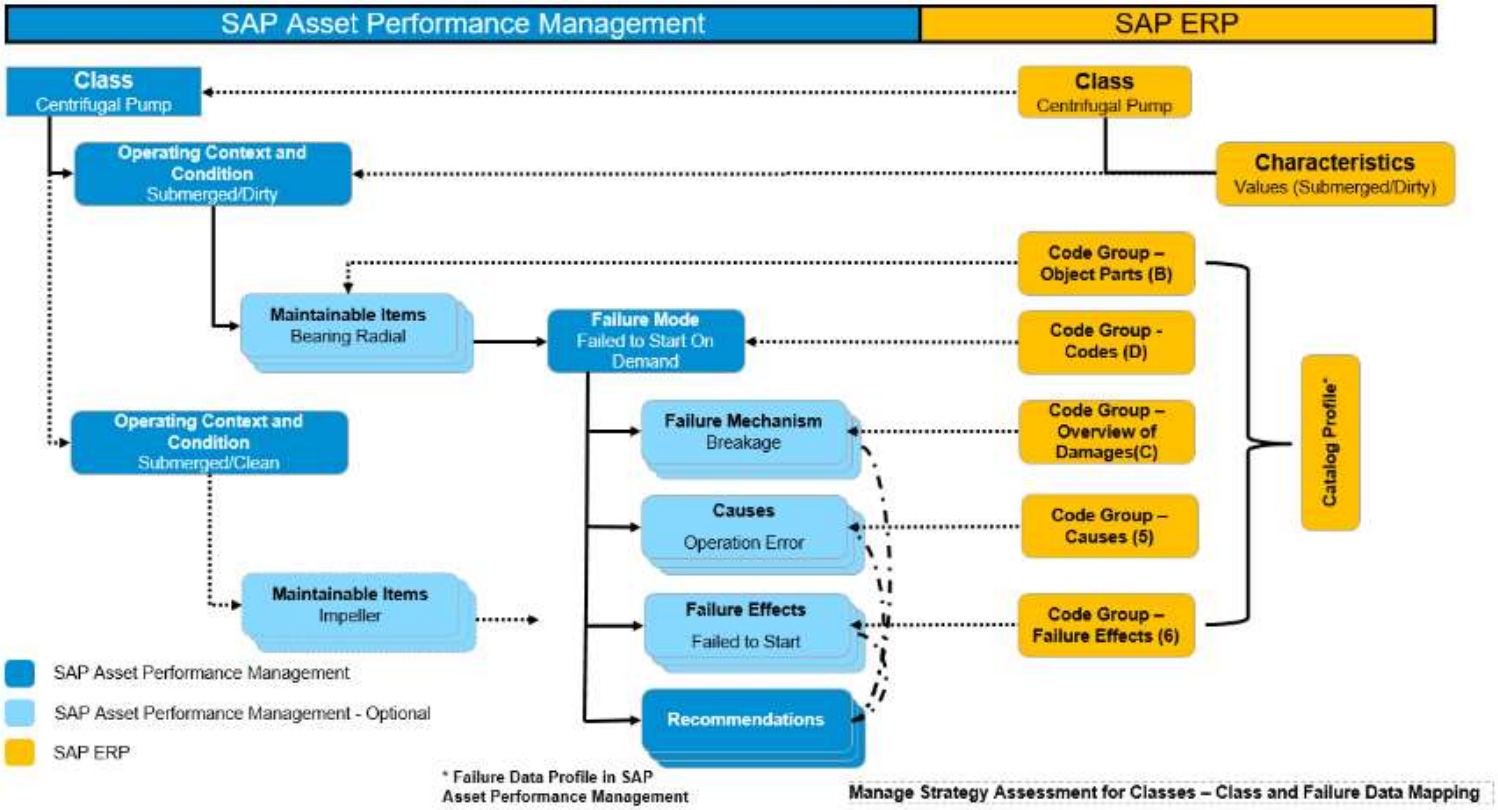
Failure mechanism	FM subdivision
Instrument failure	General
	Control failure
	No signal/ indication/ alarm
	Faulty signal/ indication/ alarm
	Out of adjustment
	Software error
	Common cause/ common mode
Electrical failure	General
	Short circuit
	Open circuit
	No power/voltage
	Faulty power/ voltage
	Earth/ isolation fault
External influence	General
	Blockage/ plugged
	Contamination
	Misc. external influence

SAP APM



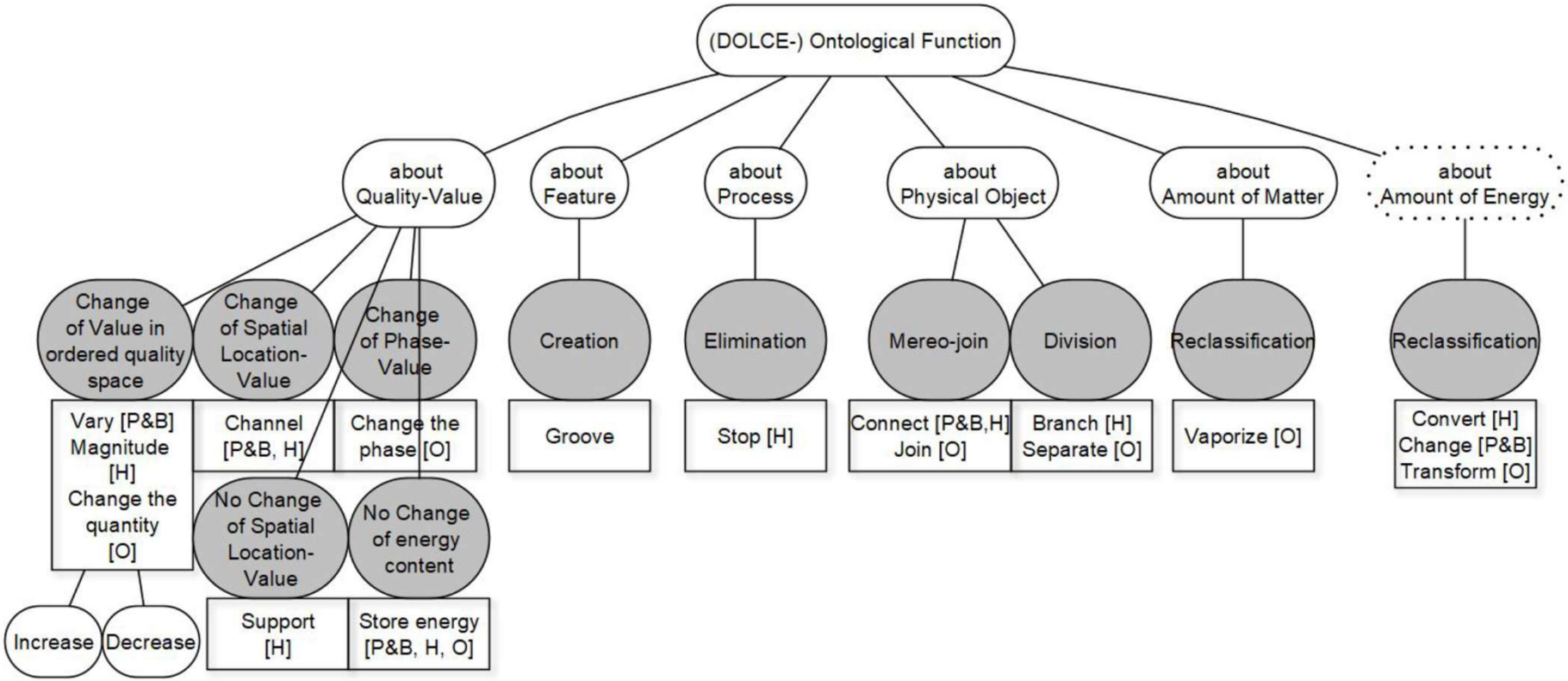
From SAP Asset Reliability Engineering page

Under the hood in SAP APM – reuse of ISO 14224 concepts



From SAP Asset Reliability Engineering page

DOLCE Ontological Function



Ref; Compagno Thesis 2024 Fig 3.2

Thinking about how to distinguish between ISO 14224 failure mechanisms

Failure mechanism	FM subdivision	Involves fluid or hydraulic force	Involves electrical or magnetism force	Involves kinetic energy	Involves change in material properties	Involves loss or gain of material from equip	Involves nothing happening when it should	Involves an output or path being not as desired	Involves thermal energy	Failure mechanism	FM subdivision	Involves fluid or hydraulic force	Involves electrical or magnetism force	Involves kinetic energy	Involves change in material properties	Involves loss or gain of material from equip	Involves nothing happening when it should	Involves an output or path being not as desired	Involves thermal energy
Mechanical failure	General									Instrument failure	General								
	Leakage	Y									Control failure						Y		
	Vibration			Y							No signal/ indication/ alarm						Y		
	Clearance/ alignment			Y							Faulty signal/ indication/ alarm							Y	
	Deformation			Y							Out of adjustment							Y	
	Looseness			Y							Software error							Y	
	Sticking			Y							Common cause/ common mode								
Material failure	General									Electrical failure	General								
	Cavitation	Y			Y						Short circuit		Y					Y	Y
	Corrosion	Y	Y		Y						Open circuit		Y				Y		
	Erosion	Y			Y	Y					No power/voltage						Y		
	Wear			Y	Y	Y					Faulty power/ voltage		Y					Y	
	Breakage			Y	Y						Earth/ isolation fault		Y					Y	Y
	Fatigue			Y	Y					External influence	General								
	Overheating				Y				Y		Blockage/ plugged	Y							
	Burst			Y	Y						Contamination	Y							
											Misc. external influence								

IEC 81346 functions

IEC81346 MaintIE link IEC81346 ontology link

IEC 81346 functional objects (top-level)
sensing
storing
emitting
protecting
generating
matter processing
Information processing
driving
covering
presenting
controlling
restricting
human interaction
transforming
holding
guiding
interfacing

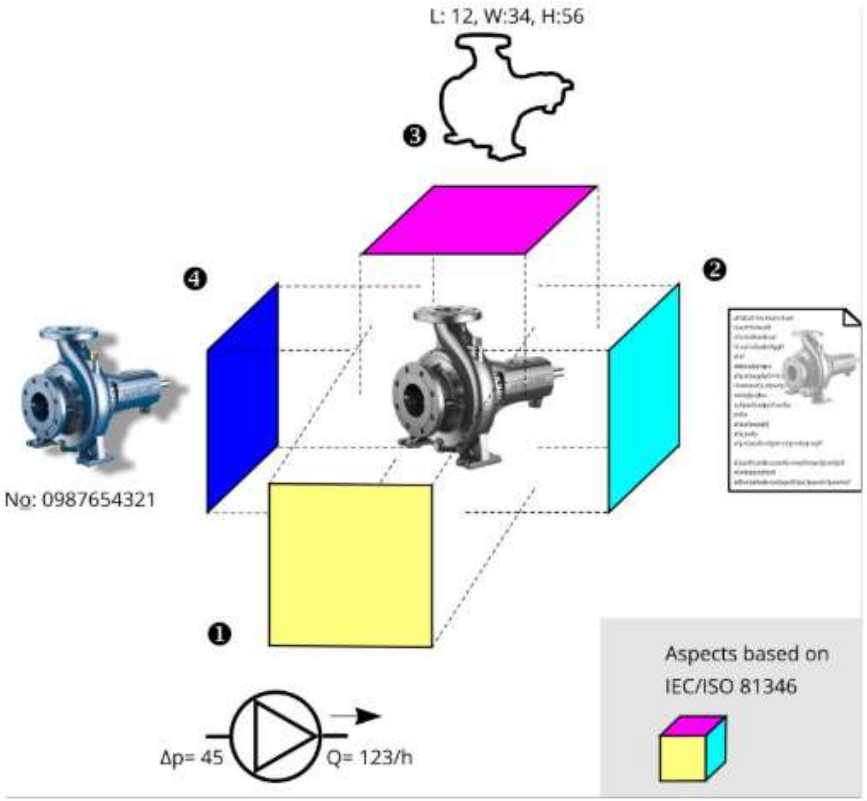
PhysicalObject/Sensing/Energy	BH	**EXAMPLES OF EQUIPMENT CLASSES**
PhysicalObject/Sensing/Energy/DefinedEnergyDensityFlow	BHA	flow energy meter, energy cooling meter, energy meter, energy sensor, gas energy meter
PhysicalObject/Sensing/Energy/DefinedHeatCapacityThermalFlow	BHB	thermal energy meter, condensate sensor, energy cooling meter, energy meter, energy sensor
PhysicalObject/Sensing/Energy/ElectricityFlow	BHC	electric energy meter, kWh sensor
PhysicalObject/Sensing/Power	BJ	
PhysicalObject/Sensing/Power/ScalarOutput	BJA	power meter, kW meter
PhysicalObject/Sensing/Power/BooleanOutput	BJB	power limit switch
PhysicalObject/Sensing/Time	BK	
PhysicalObject/Sensing/Time/ScalarOutput	BKA	time sensor, clock, time information device

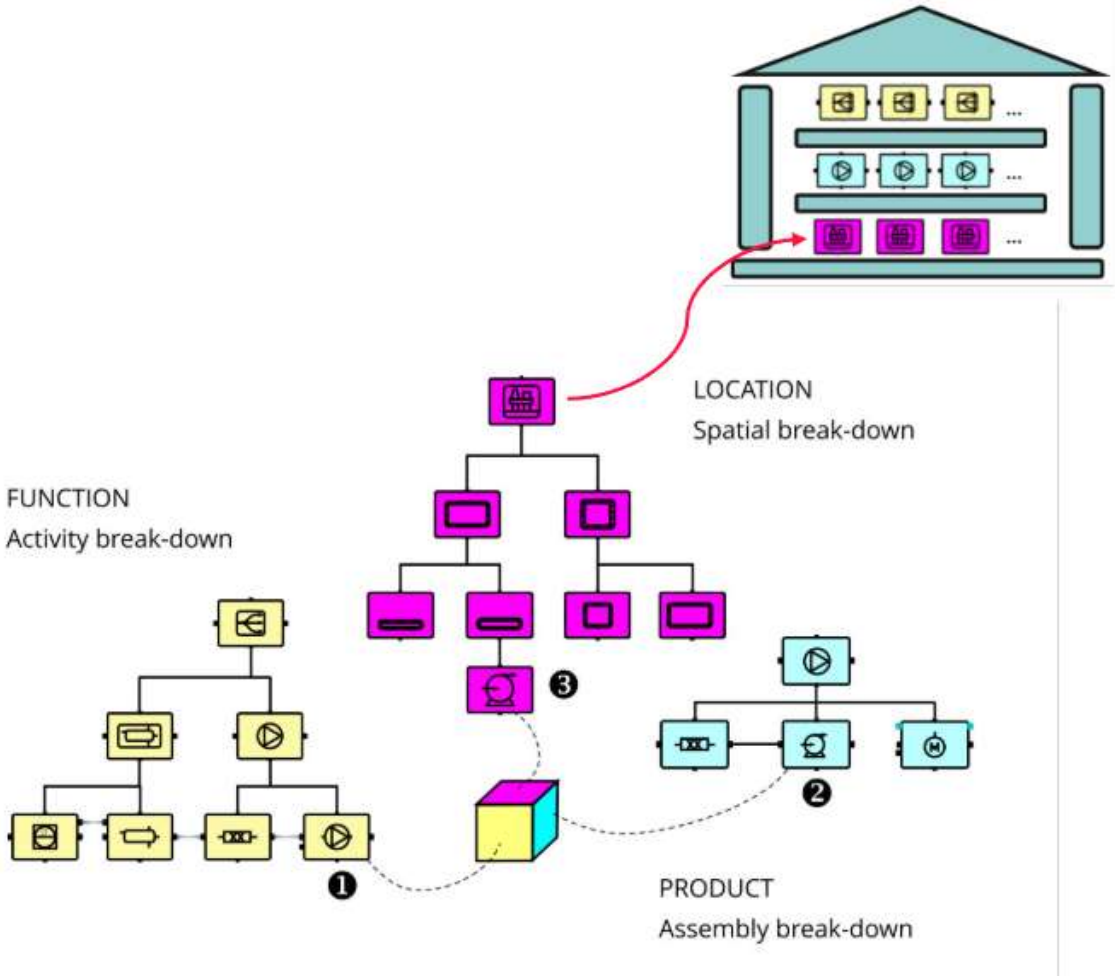
PhysicalObject/Guiding/ClosedEnclosure	WP	**EXAMPLES OF EQUIPMENT CLASSES**
PhysicalObject/Guiding/ClosedEnclosure/CircularRigidForm	WPA	pipe
PhysicalObject/Guiding/ClosedEnclosure/NonCircularRigidForm	WPB	duct, chimney
PhysicalObject/Guiding/ClosedEnclosure/FlexibleForm	WPC	hose
PhysicalObject/Guiding/MechanicalEnergy	WQ	
PhysicalObject/Guiding/MechanicalEnergy/Shaft	WQA	drive axle, axle
PhysicalObject/Guiding/MechanicalEnergy/Belt	WQB	drive belt, moving line, v-belt
PhysicalObject/Guiding/MechanicalEnergy/Chain	WQC	drive chain, chain
PhysicalObject/Guiding/MechanicalEnergy/Linkage	WQD	drive link
PhysicalObject/Guiding/MechanicalEnergy/Wheel	WQE	wheel, cogwheel, gearwheel
PhysicalObject/Guiding/MechanicalEnergy/ToothedBar	WQF	toothed bar
PhysicalObject/Guiding/MechanicalEnergy/FluidLink	WQG	hydraulic hose, hydraulic pipe, pneumatic hose, pneumatic pipe

Ref: IEC 81346-2 contains a mapping for ’00’s equipment to an IEC functional object and sub-functional object

IEC 81346 aspects

Reserved Aspects in IMF extending ISO/IEC 81346





Thought experiment – function first ....

IEC 81346 functional objects	DOLCE ontological function	Comment
sensing	Convert/transform (reclassification of energy)	A structure detects a stimulus and converts it into a signal
emitting	Reclassification (of energy or matter)	To send out a beam, noise, smell or gas
matter processing	Reclassification (of matter)	To convert something into something else
presenting	?	
generating	Reclassification (of energy)	Convert ....
driving		
transforming		
protecting		
storing		
human interaction		
holding		
covering		
interfacing		
restricting		
Information processing		
guiding		

Example Failure Data from Maintenance Work Order

ID	Date	Unstructured Text	NLP Identified Item	NLP 14224 Failure mode	NLP Identified Activity	NLP Identified Subunit	Work Order Type
1	2012-10-18	pressure switch undersize	pressure switch		none	control and monitoring	corrective
2	2013-02-14	remove pressure switch	pressure switch	Unknown	remove	control and monitoring	corrective
3	2013-03-19	calibrate pressure switch	pressure switch	Abnormal instrument reading	calibrate	control and monitoring	corrective
4	2013-04-29	pump not pumping well	pump	Low output	none	pump unit	corrective
5	2013-05-21	pressure switch leaking	pressure switch	External leakage - process medium	none	control and monitoring	corrective
6	2013-06-03	calibrate pressure switch	pressure switch	Abnormal instrument reading	calibrate	control and monitoring	corrective
7	2013-06-18	18M electrical service motor	motor		service	driver and electrical	preventative
8	2013-06-28	calibrate pressure switch	pressure switch	Abnormal instrument reading	calibrate	control and monitoring	corrective
9	2013-08-07	calibrate pressure switch	pressure switch	Abnormal instrument reading	calibrate	control and monitoring	corrective
10	2013-10-06	calibrate pressure switch	pressure switch	Abnormal instrument reading	calibrate	control and monitoring	corrective
11	2013-10-06	valbe needs replacing	valve	Unknown	remove	piping and valves	corrective
12	2013-12-23	Investigate oil leak	oil	External leakage - utility medium	investigate	lubrication	corrective
13	2014-02-10	seal leaking	mechanical seal	External leakage - utility medium	none	pump unit	corrective
14	2014-03-20	pressure switch unserviceable	pressure switch	Unknown	none	control and monitoring	corrective
15	2014-05-31	check pressure switch	pressure switch	Unknown	check	control and monitoring	corrective
16	2014-07-01	pump not pumping	pump	Low output	none	pump unit	corrective
17	2014-11-04	install new pressure switch	pressure switch		install	control and monitoring	corrective
18	2014-12-16	78W electrical service motor	motor		service	driver and electrical	preventative
19	2014-12-31	26W mechanical service pump	pump		service	pump unit	preventative
20	2015-03-25	pressure switch failure	pressure switch	Unknown	none	control and monitoring	corrective
21	2015-04-20	replace pressure switch	pressure switch	Unknown	replace	control and monitoring	corrective
22	2015-05-16	motor tripping on high amps	motor	Spurious shutdown	none	driver and electrical	corrective
23	2015-05-19	repair pressure switch	pressure switch	Unknown	repair	control and monitoring	corrective
24	2015-06-05	26W mech service pump	pump		service	pump unit	preventative
25	2015-11-24	26W mech service pump	pump		service	pump unit	preventative
26	2016-06-17	78W electrical service motor	motor		service	driver and electrical	preventative
27	2017-06-04	replace pump	pump	Unknown	replace	pump unit	corrective
28	2017-06-12	78W electrical service motor	motor		service	driver and electrical	preventative
29	2018-06-15	change oil	oil	Unknown	change	lubrication	corrective
30	2018-07-03	oil leak from housing seal	mechanical seal	External leakage - utility medium	none	pump unit	preventative
31	2019-01-06	pump is tripping	pump	Spurious shutdown	none	pump unit	corrective
32	2019-06-06	78W electrical service motor	motor		service	driver and electrical	preventative
33	2019-11-26	faulty flowmeter	flowmeter	Unknown	none	control and monitoring	corrective
34	2020-02-19	repair pump	pump	Unknown	repair	pump unit	corrective
35	2020-04-14	pressure switch faulty	pressure switch	Unknown	none	control and monitoring	corrective
36	2020-04-22	replace pressure switch	pressure switch	Unknown	replace	control and monitoring	corrective

Source:PumpdatafroMaintActivityOntolgy.csv