Reliability Dynamics

Industry Standard Solution for Plant Maintenance (ISPM®)

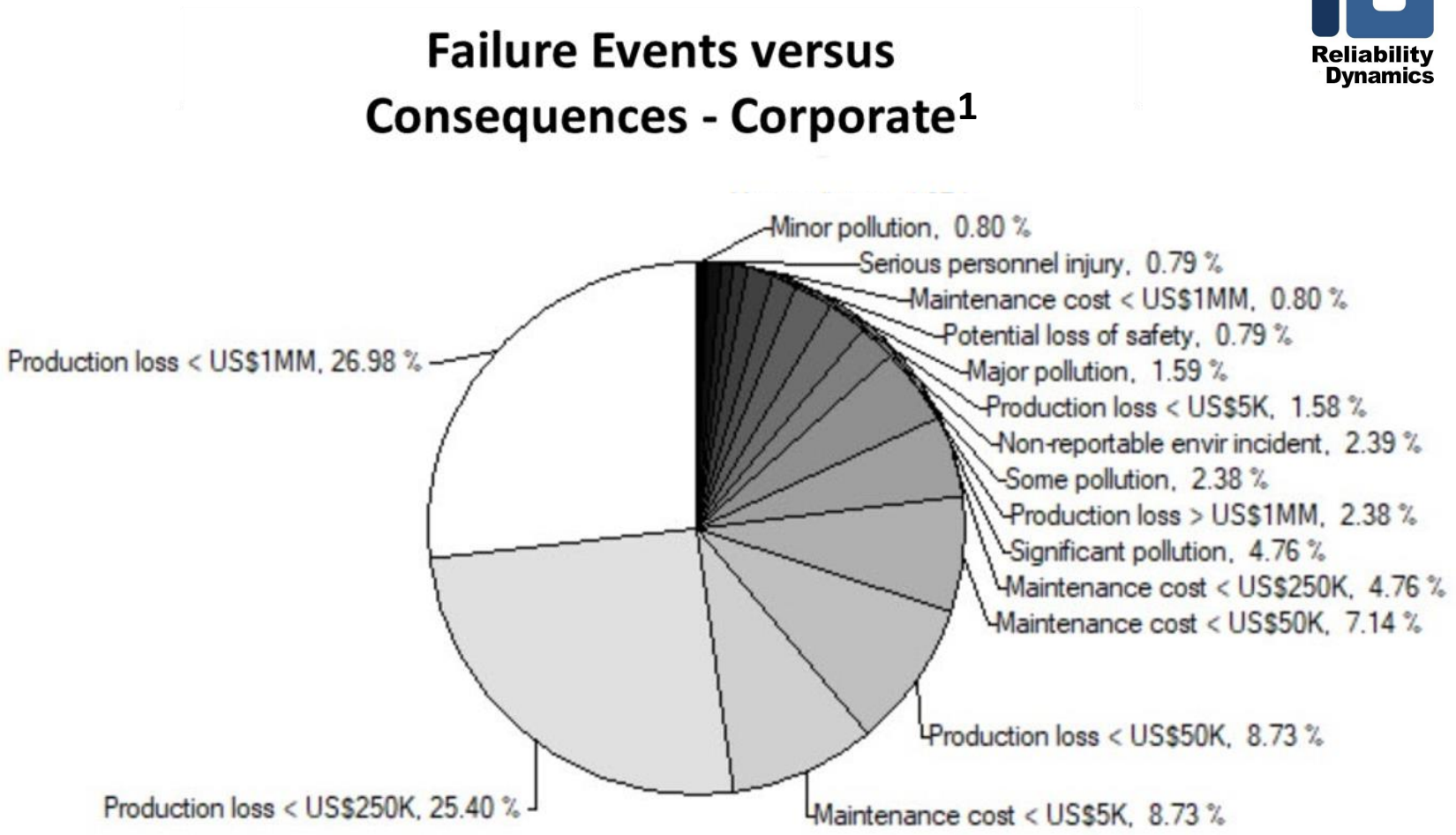
SAP® Certified
Integration with SAP S/4HANA®

Objectives and Business Benefits:

- Use high-quality equipment performance data to optimize equipment decisions and plant operations
- Reduce risk and improve production throughput and profitability

Key Business Metrics

- Corporate view of data
- Identify, analyze, and resolve equipment issues



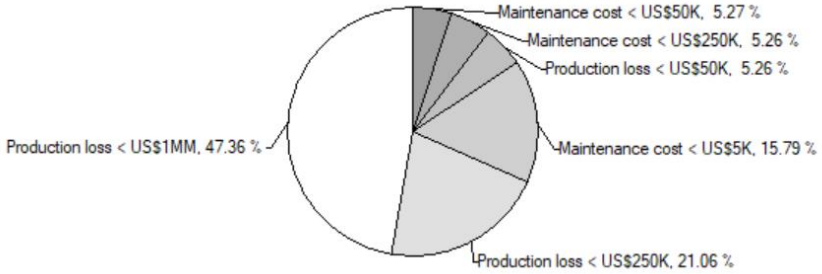
Notes
1. Value set adapted from ISO 14224:2016, Table C.2

Analyze

Durco Pumps in Claus Service

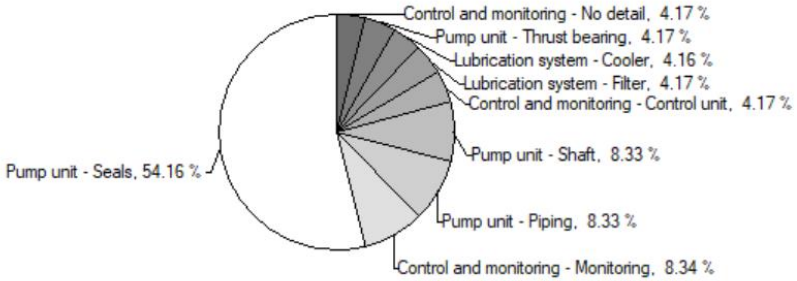
Failure Consequences

Ref. ISO 14224:2016, Table C.2



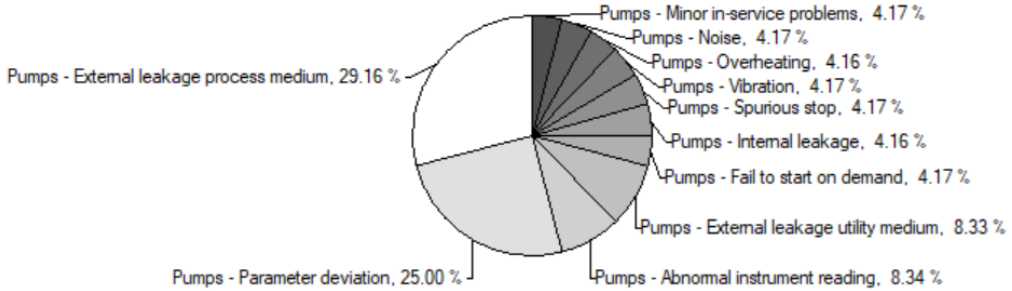
Primary Failure Components

Ref. ISO 14224:2016, Table A.21



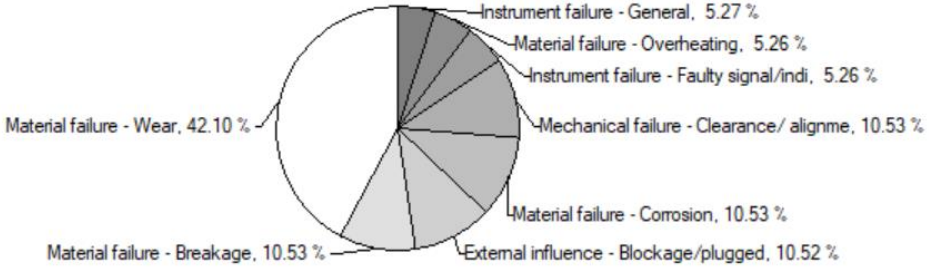
Failure Modes

Ref. ISO 14224:2016, Table B.6



Failure Mechanisms

Ref. ISO 14224:2016, Table B.2



Problem

- While **Equipment performance data** support safety and reliability decisions,
  - High-quality data are unavailable, due to pervasive deficiencies in corporate software solutions
  - Low-quality data compromise equipment decisions, increase risk, and decrease profitability
  - AI and ML models are compromised; only as good as the data inputs

Current Solutions are Nonviable

- While **ERP software** is capable, solutions for equipment performance data are consistently nonviable
- **Failure and maintenance event details** are impractical to reconstruct after time passes
- **Natural Language Processing (NLP)** cannot fix poor quality failure and maintenance event data
- **Industry databases and handbooks** compile low-quality data from a few individual companies

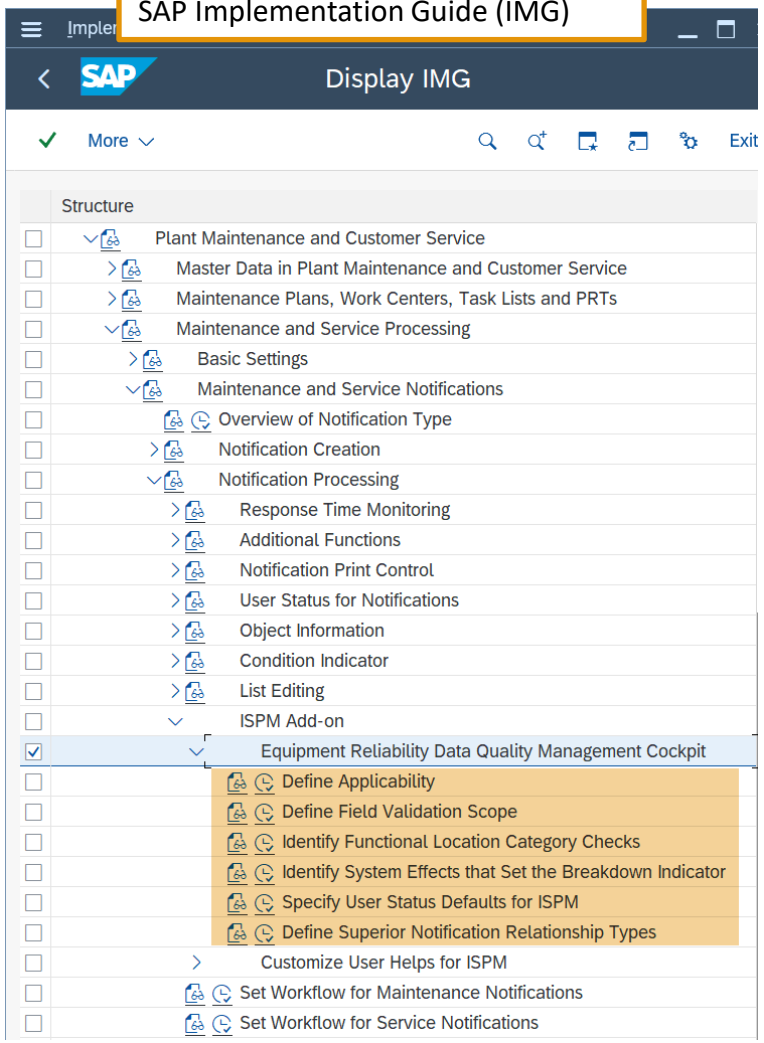
Solution

1. **Taxonomy and data structure** for the digitalization of equipment performance data
2. **ERP software app** to make equipment performance data high-quality at inception

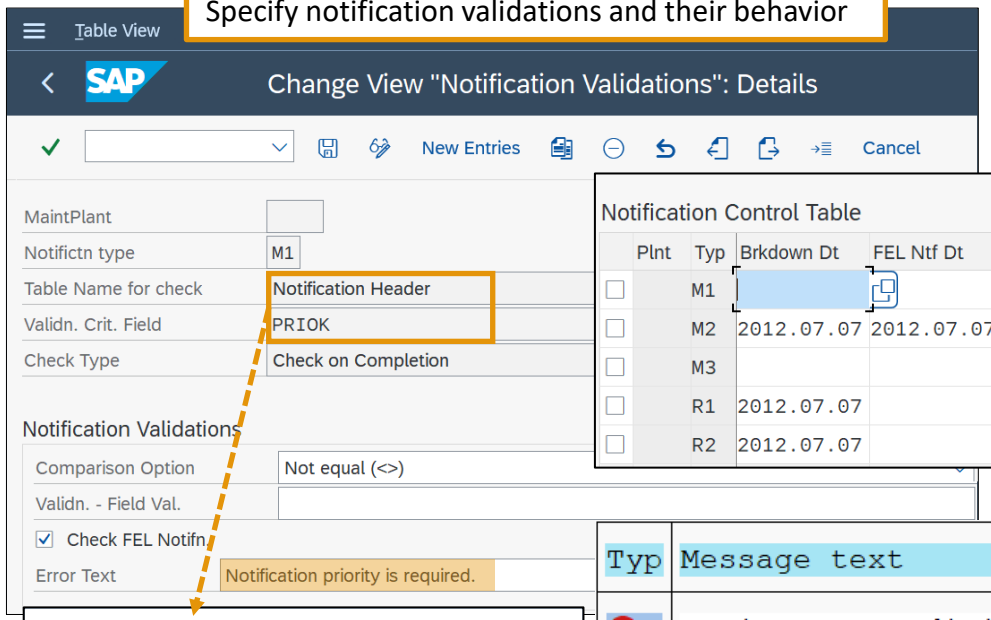
LOWER COSTS	DECREASE RISK	INCREASE PRODUCTION
Capital and operating costs	Optimize inspection intervals	Higher equipment availability

Equipment Performance Data QM Cockpit

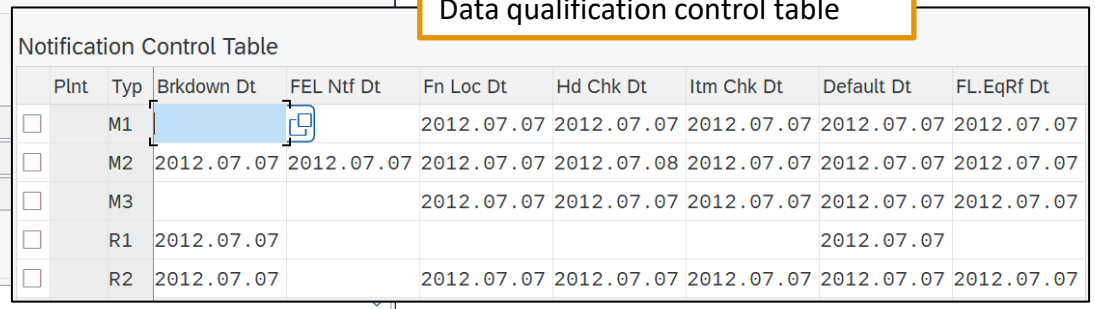
SAP Implementation Guide (IMG)



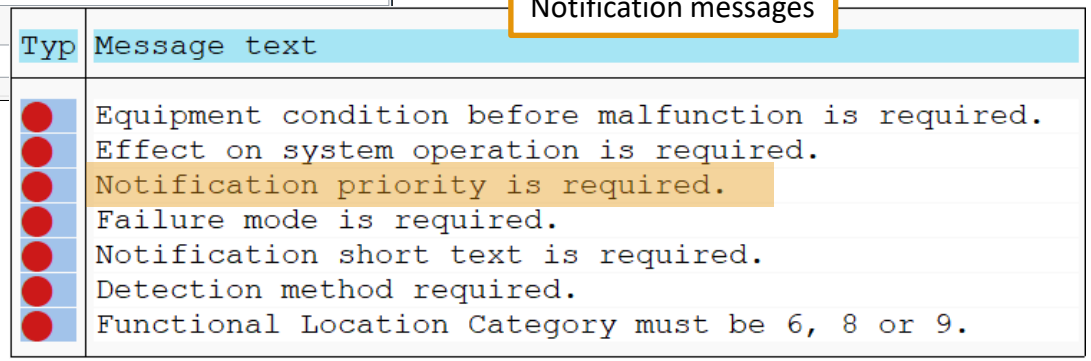
Specify notification validations and their behavior

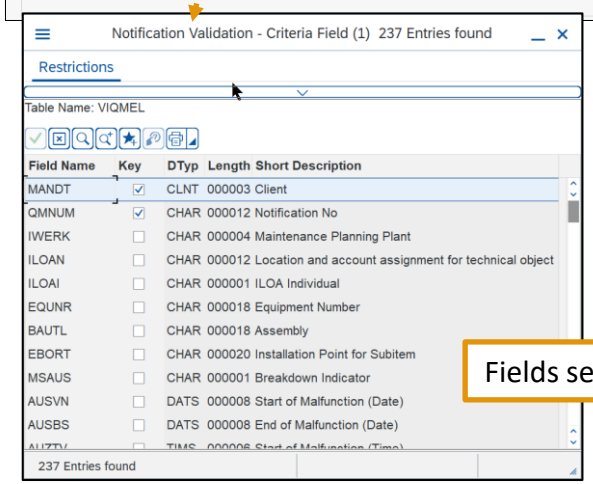


Data qualification control table



Notification messages





Fields selections for specified table

Technical Hierarchy Example

4	LLAK-8400	STEAM GENERATION
5	LLAK-8400-BG	BUILDINGS
5	LLAK-8400-CL	CONTROL UNITS
5	LLAK-8400-CR	CRANES, HOISTS, AND MONORAILS
5	LLAK-8400-FG	FIRE AND GAS DETECTORS
5	LLAK-8400-HB	OTSG STEAM GENERATORS
5	LLAK-8400-HE	EXCHANGERS
5	LLAK-8400-HT	HEAT TRACING
5	LLAK-8400-LI	LIGHTING
5	LLAK-8400-PD	POWER DISTRIBUTION
5	LLAK-8400-PI	8400 PIPING BY COMMODITY
5	LLAK-8400-PU	PUMPS
5	LLAK-8400-P-001	LP BFW BOOSTER PUMPS
5	LLAK-8400-P-002	HP BFW PUMPS
6	LLAK-8400-P-002-A	HP BFW PUMP A
	10055213	PUMP-UTILITY GRADE, MULTISTAGE, RING SEC
7	LLAK-8400-P-002-A-02	PUMP UNIT
7	LLAK-8400-P-002-A-03	CONTROL AND MONITORING
7	LLAK-8400-P-002-A-04	LUBRICATION SYSTEM
8	LLAK-8400-E-010-A	COOLER-LUBE OIL-HP BFW PUMP
8	LLAK-8400-F-001-A	FILTER-LUBE OIL-BFW PUMP
8	LLAK-8400-P-004-A	PUMP, LUBE OIL, HP BFW PUMP
8	LLAK-8400-P-005-A	PUMP, LUBE OIL, HP BFW PUMP
8	LLAK-8400-P-006-A	PUMP, HP BFW PUMP AUXILIARY OIL
8	LLAK-8400-RS-001-A	RESERVOIR-LUBE OIL-BFW PUMP
5	LLAK-8421-CM-207	8400-P-005A HP BFW LUBE OIL
6	LLAK-8400-P-002-A-M	MOTOR-HP BFW PUMP A
6	LLAK-8400-CV-001-A	VALVE, CHECK - P-002-A DISCHARGE
6	LLAK-8400-P-002-B	HP BFW PUMP B

Pump boundary

ISO 14224:2016(E)

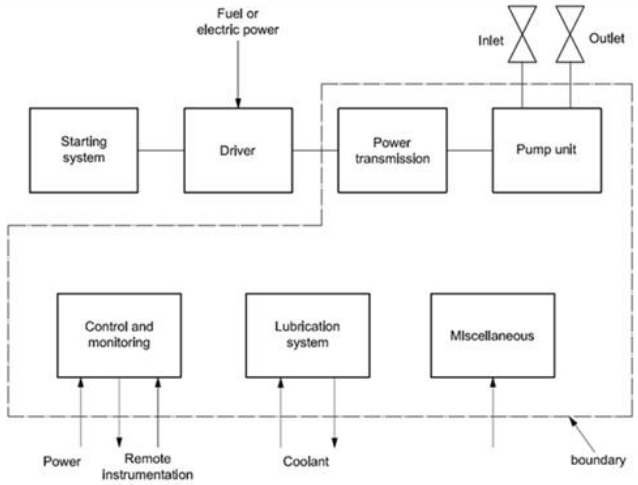


Figure A.7 — Boundary definition — Pumps

Table A.21 — Equipment subdivision — Pumps

Equipment unit	Pumps				
Subunit	Power transmission	Pump unit	Control and monitoring	Lubrication system	Miscellaneous
Maintainable items	Gearbox/ variable drive Bearing Seals Coupling to driver Coupling to driven unit Belt/sheave	Support Casing Impeller Shaft Radial bearing Thrust bearing Seals Valves Piping Cylinder liner Piston Diaphragm	Actuating device Control unit Internal power supply Monitoring Sensors [a] Valves Wiring Piping Seals	Reservoir Pump Motor Filter Cooler Valves Piping Oil Seals	Purge air Cooling/heating system Cyclone separator Pulsation damper Flange joints

[a] Specify type of sensor, e.g. pressure, temperature, level, etc.

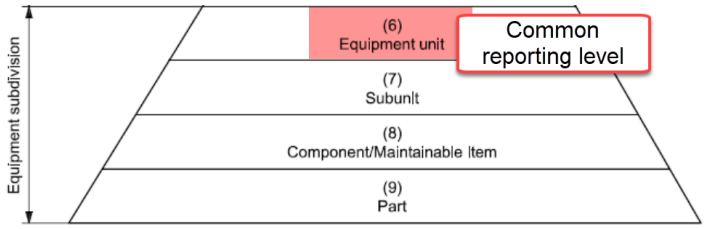


Figure 3 — Taxonomy classification with taxonomic levels

Failure Report Example

- Specifications of required data per work category[2,3,4]
- Discrete fields with structured input for each required data[1,2]
- System-validations to ensure compliance with specifications

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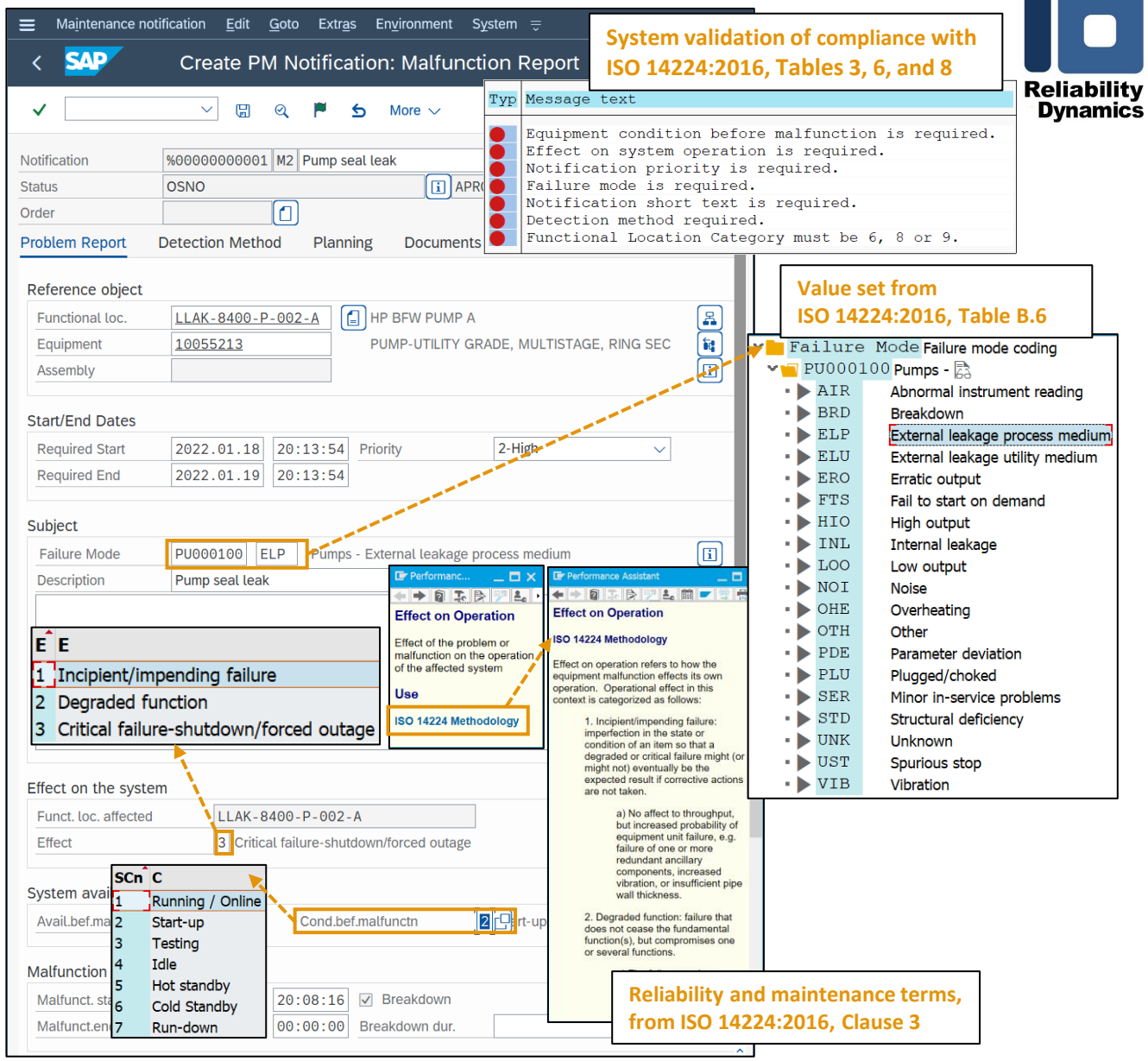
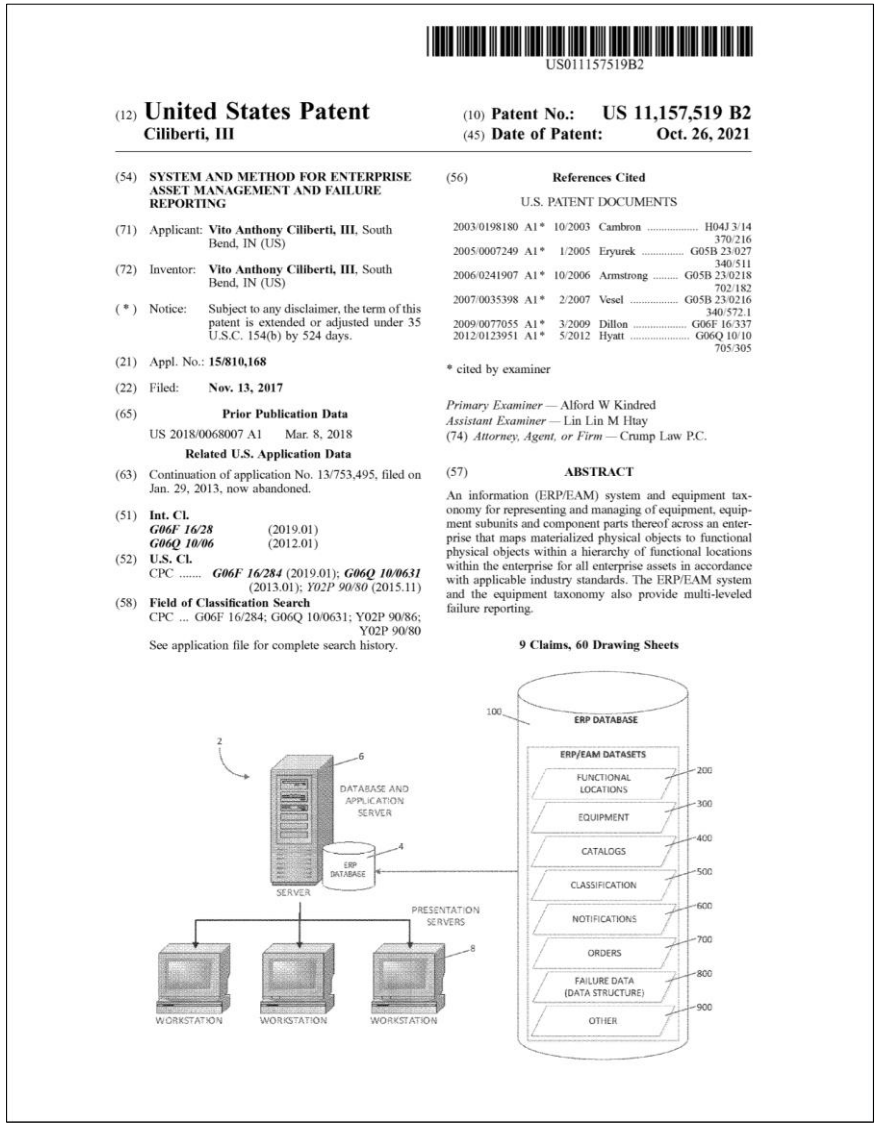
Notes - ISO 14224:2016

1. Table 6 – Failure data
2. Table 8 – Maintenance data
3. Table 3 – Reliability and maintenance parameters in relation to taxonomy levels



The ISPM Add-on for SAP

- SAP solution extension, certified for S/4HANA On-premise and Cloud
- ISO 14224:2016 compliant[1]
- 19 years of application in industry
- Patented system and methods (US011157519)



US011157519B2

(12) **United States Patent**
Ciliberti, III

(10) **Patent No.: US 11,157,519 B2**
(45) **Date of Patent: Oct. 26, 2021**

(54) **SYSTEM AND METHOD FOR ENTERPRISE ASSET MANAGEMENT AND FAILURE REPORTING**

(71) Applicant: **Vito Anthony Ciliberti, III**, South Bend, IN (US)

(72) Inventor: **Vito Anthony Ciliberti, III**, South Bend, IN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 524 days.

(21) Appl. No.: **15/810,168**

(22) Filed: **Nov. 13, 2017**

(65) **Prior Publication Data**

US 2018/0068007 A1 Mar. 8, 2018

Related U.S. Application Data

(63) Continuation of application No. 13/753,495, filed on Jan. 29, 2013, now abandoned.

(51) **Int. Cl.**
G06F 16/28 (2019.01)
G06Q 10/06 (2012.01)

(52) **U.S. Cl.**
CPC ***G06F 16/284*** (2019.01); ***G06Q 10/0631*** (2013.01); *Y02P 90/80* (2015.11)

(58) **Field of Classification Search**
CPC ... G06F 16/284; G06Q 10/0631; Y02P 90/86; Y02P 90/80
See application file for complete search history.

(56) **References Cited**

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* cited by examiner

Primary Examiner — Alford W Kindred
Assistant Examiner — Lin Lin M Htay
(74) *Attorney, Agent, or Firm* — Crump Law P.C.

(57) **ABSTRACT**

An information (ERP/EAM) system and equipment taxonomy for representing and managing of equipment, equipment subunits and component parts thereof across an enterprise that maps materialized physical objects to functional physical objects within a hierarchy of functional locations within the enterprise for all enterprise assets in accordance with applicable industry standards. The ERP/EAM system and the equipment taxonomy also provide multi-leveled failure reporting.

9 Claims, 60 Drawing Sheets

Notes:

1. Compliant with ISO/TC67/WG4/PG1 guidance to industry, in ISO Course *Use of ISO 14224 for optimizing Safety and Profitability in the Oil and Gas Industry – in a digitalized perspective*.

Customers

Graham Macleod, Vice President of Asset Integrity and QMS, Precision Drilling
"I really liked the way that [Reliability Dynamics] interpreted a complex standard [ISO 14224] in relation to our application…it was exactly what we were looking for…its simplicity [for users] is what makes it great…insights from our [data/reports] are absolutely everything we possibly need."

Organization	Software	Work Scope
US Department of Energy	SAP	Add-on software and content implementation for Strategic Petroleum Reserves
Precision Drilling	SAP	Add-on content and configuration, corporate-global
Pembina Pipeline	SAP	Add-on software and content, corporate-global
QGOG-Constellation	Maximo	Content and methods, offshore drilling fleet
Maersk Drilling	SAP	Taxonomy definition development for offshore drilling equipment
Nexen Energy	SAP	1. Content and methods implementation for Yemen Masila Block, methods later adopted corporate-wide 2. Technical hierarchy restructuring for Long Lake Facility (oil sands)
Marathon Oil	SAP	Content and methods for corporate template development and implementation for Alvheim FPSO
Fortis-Alberta	SAP	Failure reporting and warranty management for AMI

Case History: The Nexen Masila Block

Nexen used ISO 14224 methods to increase Masila Block profits by US $8.2 million annually

- Reduced maintenance costs for field power gen units by 64%
- Increased associated oil production by 53%

Digital Analytics and Condition-Based Maintenance Net $8.2 Million Annually for...

Tony Ciliberti PE on LinkedIn

Overview The Masila Block Oil Field is in the Yemen Hadhramaut Desert. Oil production...

13 · 4 Comments

Thank you

Tony Ciliberti PE

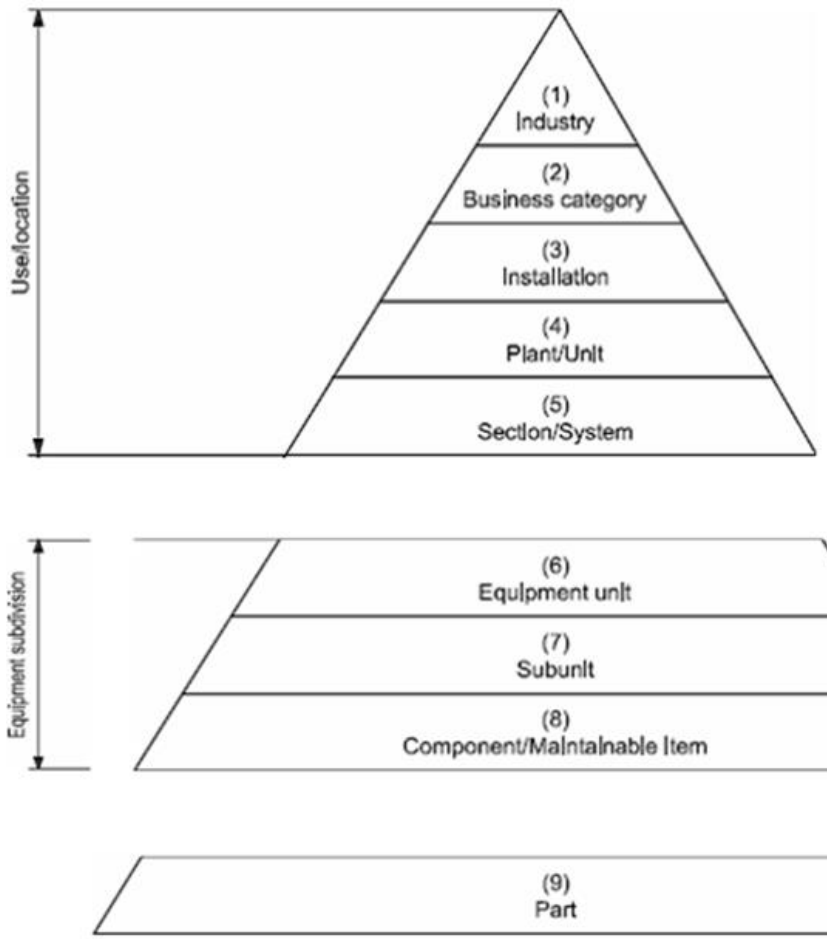
US Expert ISO/TC67/WG4 Reliability engineering & technology

Principal Engineer, Reliability Dynamics

ISPM Master Data Overview

ISPM/ISO 14224 Data Mapping

ISO 14224:2016 Figure 3 — Taxonomy classification with taxonomic levels



ISO 14224:2016, Tables 5, A1-A3

Specified for technical tags using class and characteristics.

ISO 14224:2016, Annexes A and B

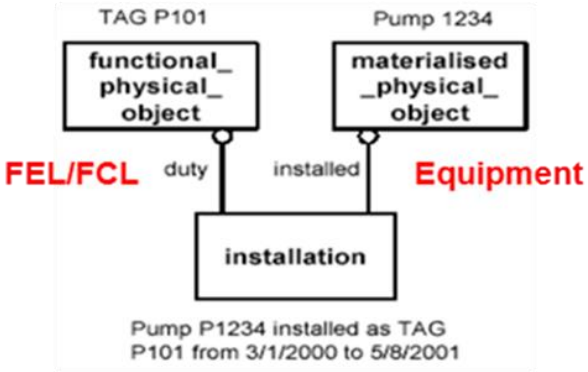
Equipment class boundary envelope represented in two ways:

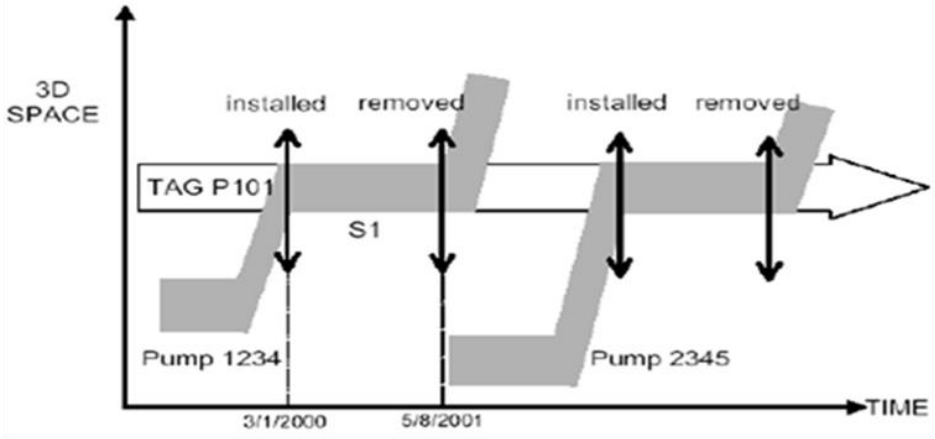
- Technical hierarchy, Levels 6-8
- Catalog codes (equipment subdivision)

Specified within malfunction report as attribute of failed maintainable item(s)

Functional Location / Equipment Relationship

ISO 15926-2:2003, Section E.3.3[1]





The duty represented by TAG P101, and Pump 1234 are coincident for the period of the installation, i.e. the state S1 of Pump 1234 that is installed as TAG P101 is in fact also a state of TAG P101. TAG P101 consists of those states of the pumps that are installed in this location.

ISO 15926-2 (Data Model) Industrial automation systems and integration—Integration of life-cycle data for process plants including oil and gas production facilities, Figures E.9 and E.10.

1. ISO 15926-2, Section E3.3 is referenced in ISO 14224:2016, Table 5, Footnote b.

Classification Structure

Class Structure

- EQ All equipment
  - GP General application
    - NP Non process equipment
    - PE Process equipment
      - PE_CO Communications Equipment
      - PE_ME Mechanical
        - PE_ME_AT Atmospheric tanks
        - PE_ME_BU Buildings
        - PE_ME_CR Cranes
        - PE_ME_HE Heat exchangers
        - PE_ME_LA Loading arms
        - PE_ME_OC Overhead cranes
        - PE_ME_PI Piping
        - PE_ME_SE Steam ejectors
        - PE_ME_SW Swivels
        - PE_ME_WI Winches
        - PE_ME_WS Water screen systems
        - PE_ME_CP Compactors, agglomeration
          - PE_ME_CP_FL Compactors, floating gap
          - PE_ME_CP_FI Compactors, fixed gap
        - PE_ME_CV Conveyors
        - PE_ME_HB Heaters and boilers
        - PE_ME_HS Hoses
        - PE_ME_MB CALM buoys (SPM)
        - PE_ME_PL Pipeline
        - PE_ME_TA Storage tanks
        - PE_ME_TU Turrets
        - PE_ME_VE Vessels
      - PE_EL Electrical
      - PE_HS HSE equipment
      - PE_LA Lifting appliances
      - PE_RO Rotating equipment

Characteristics: Compactors, functional

	A	B	C	D
1	Characteristic Name	Char. description	Characteristic Inherited	Imparting Class
2	MAX_PRESSING_FORCE	Maximum pressing force		
3	ROLLER_DIAMETER	Roller diameter		
4	EXTRUSION_THICKNESS	Extrusion thickness		
5	ROLLER_SPEED_RANGE	Roller speed range		
6	ROLLED_SHEET_OUTPUT_MAX	Maximum rolled sheet output		
7	GRANULAR_SIZE_RANGE	Maximum granular size		
8	FINAL_PRODUCT_OUTPUT_MAX	Maximum product output		
9	TOTAL_MAIN_DRIVE_POWER	Total main drive power		
10	INDUSTRY	Industry	✓	EQ
11	BUSINESS_CATEGORY	Business category	✓	EQ
12	INSTALLATION_CATEGORY	Installation category	✓	EQ
13	PLANT_UNIT_CATEGORY	Plant/Unit category	✓	EQ
14	SECTION_SYSTEM	Section/System	✓	EQ
15	OPERATION_CATEGORY	Operation category	✓	EQ
16	NO_REDUNDANT_UNITS	Number of redundant units	✓	EQ
17	NORMAL_OPERATING_MODE	Normal operating mode	✓	EQ
18	AMBIENT_CONDITIONS	Ambient conditions	✓	EQ
19	UTILIZATION_OF_CAPACITY	Utilization of rated capacity	✓	EQ
20	RELEVANT_STANDARDS	Relevant Standards and Regs	✓	EQ
21	PID_NUMBER	Process and Instr. Diagram No.	✓	EQ
22	LEGACY_ID	Legacy ID	✓	EQ

Value set adapted from ISO 14224:2016, Table A.4

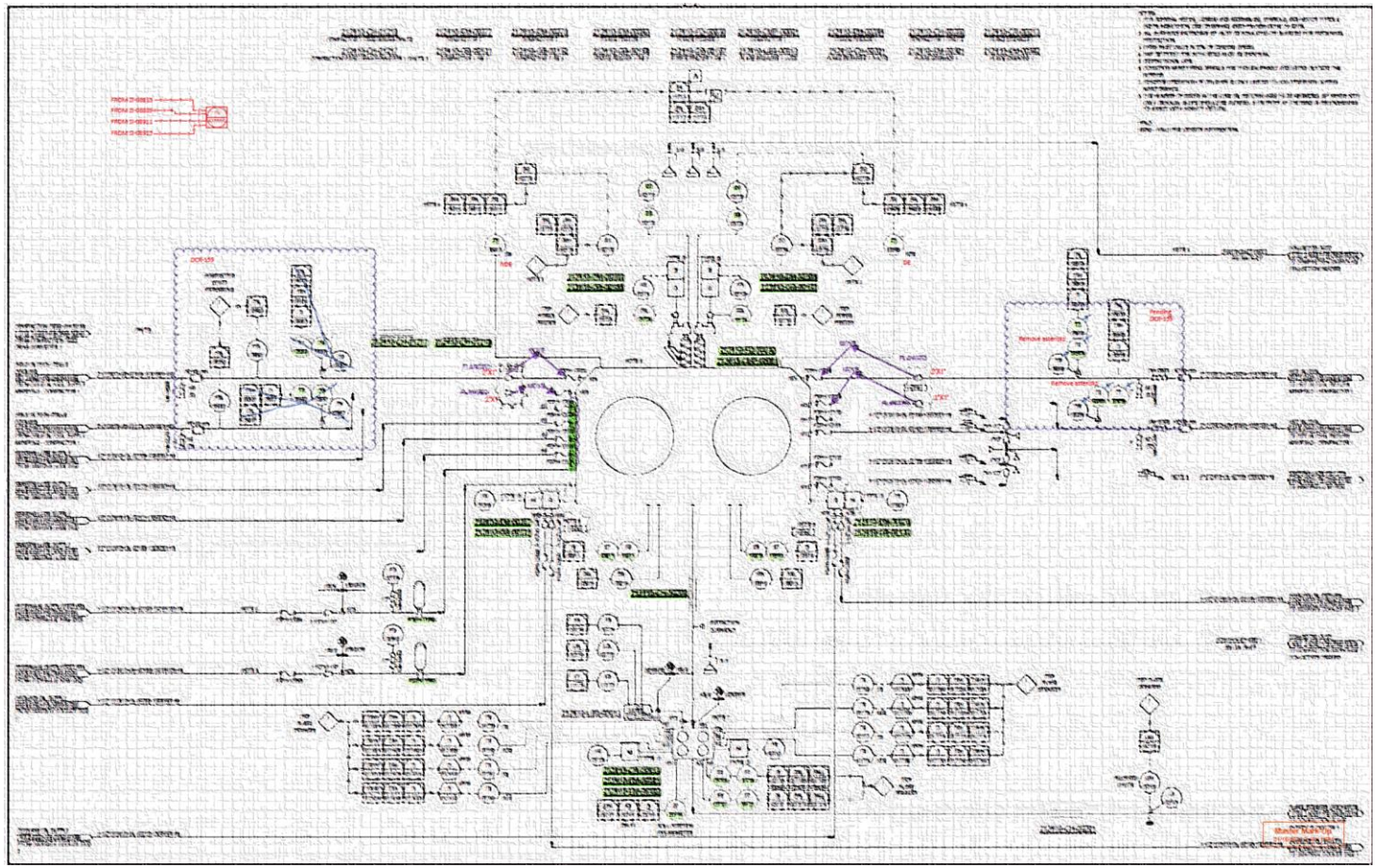
Value set: Section/System

SECTION_SYSTEM

Display Hierarchy	Description
06	General utilities
07	Auxiliaries
08	Fertilizer
08.01	Mining and extraction (ME)
08.01.01	ME Sub-Surface
08.01.02	ME Hydro
08.01.03	ME Surface
08.01.04	ME In-situ Leaching
08.01.05	ME Dredging
08.02	Processing plant
08.02.01	Ore crushing and pre-screeni
08.02.02	Ore milling and pre-sizing
08.02.04	Sylvite flotation
08.02.05	NaCl leaching from floatn co
08.02.06	Hydro-thkg & dehy of tailings
08.02.07	Hydro-sizing & dehy of conc
08.02.08	Concentrate drying
08.02.09	Preparation of chemicals
08.02.10	Granulation of KCL
08.02.11	Granules refining

Construction of Technical Hierarchy
Example

- Compile a tabular list of all technical tags from engineering drawings, SCADA, etc.



Equipment Boundary for Compactors

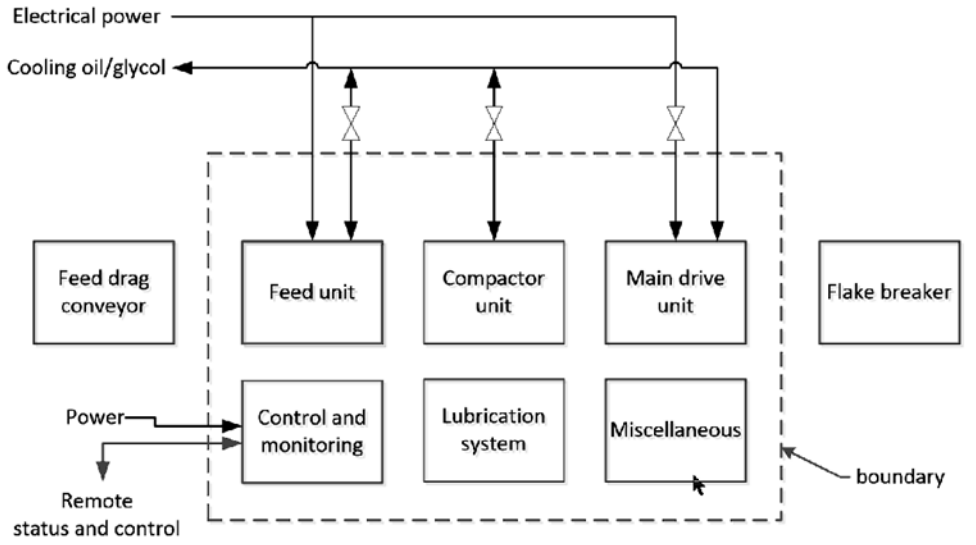
Extended ISO 14224:2016 Content

- Determine which tags numbers are within the equipment boundary

Equipment Class: Compactors, agglomeration

Taxonomy ID: PE_ME_CP

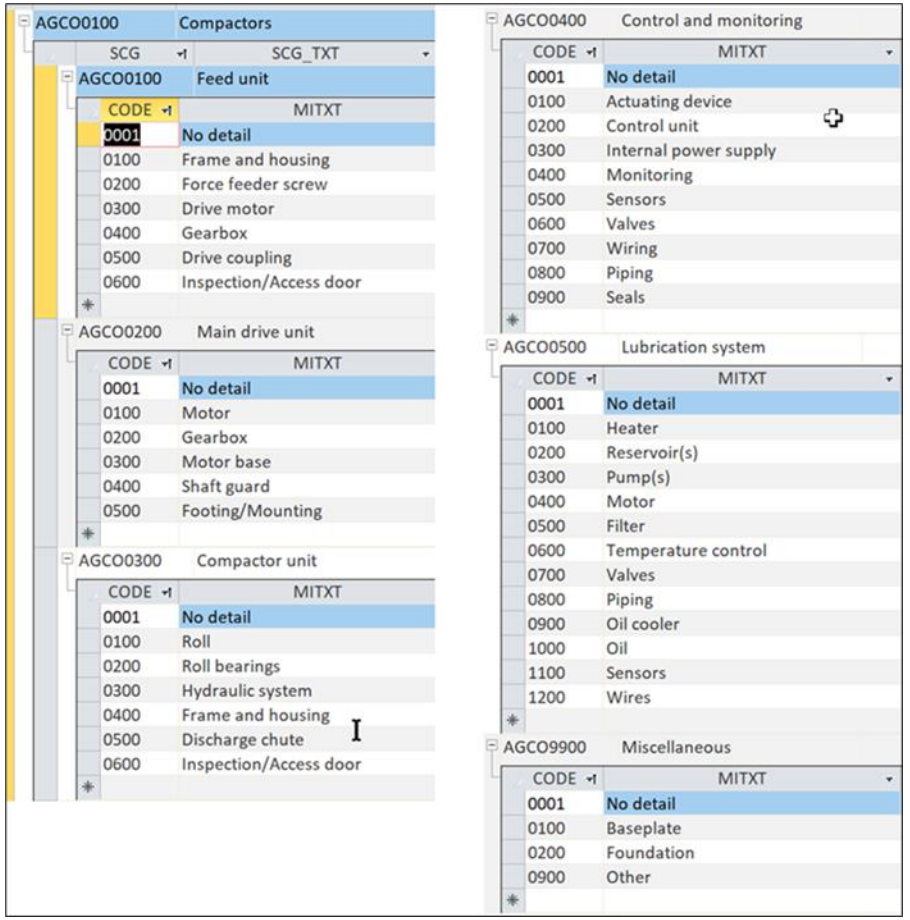
Equipment Types	Taxonomy ID
Compactors, fixed gap	PE_ME_CP_FI
Compactors, floating gap	PE_ME_CP_FL



Boundary definition – Compactors

Equipment Subdivision for Compactors

1. Identify the main unit
2. Map component tags into subunits
3. Assign subunit structures to the main unit



AGCO0100 Compactors

SCG	SCG_TXT
AGCO0100	Feed unit

CODE	MITXT
0001	No detail
0100	Frame and housing
0200	Force feeder screw
0300	Drive motor
0400	Gearbox
0500	Drive coupling
0600	Inspection/Access door

AGCO0200 Main drive unit

CODE	MITXT
0001	No detail
0100	Motor
0200	Gearbox
0300	Motor base
0400	Shaft guard
0500	Footing/Mounting

AGCO0300 Compactor unit

CODE	MITXT
0001	No detail
0100	Roll
0200	Roll bearings
0300	Hydraulic system
0400	Frame and housing
0500	Discharge chute
0600	Inspection/Access door

AGCO0400 Control and monitoring

CODE	MITXT
0001	No detail
0100	Actuating device
0200	Control unit
0300	Internal power supply
0400	Monitoring
0500	Sensors
0600	Valves
0700	Wiring
0800	Piping
0900	Seals

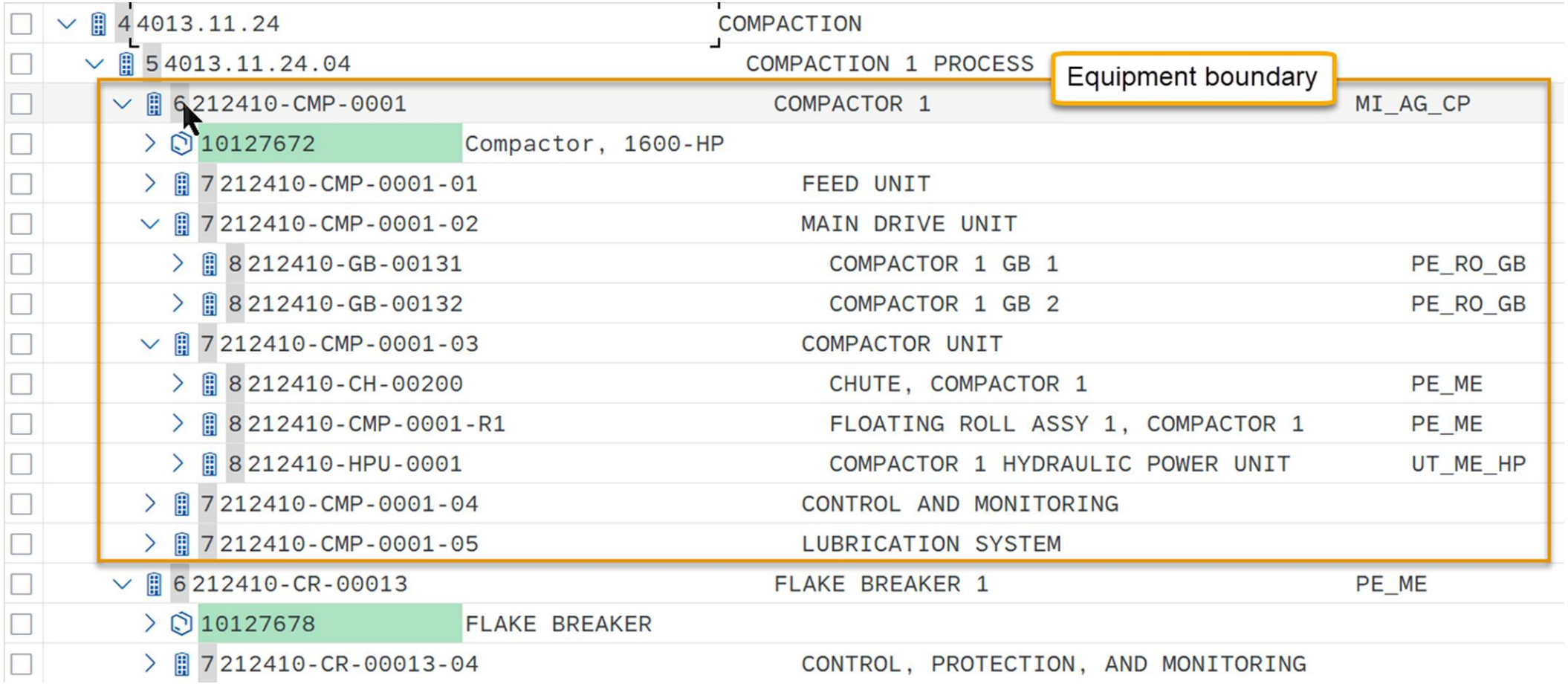
AGCO0500 Lubrication system

CODE	MITXT
0001	No detail
0100	Heater
0200	Reservoir(s)
0300	Pump(s)
0400	Motor
0500	Filter
0600	Temperature control
0700	Valves
0800	Piping
0900	Oil cooler
1000	Oil
1100	Sensors
1200	Wires

AGCO9900 Miscellaneous

CODE	MITXT
0001	No detail
0100	Baseplate
0200	Foundation
0900	Other

Compactor 1 Boundary Definition in the Technical Hierarchy



Equipment-Specific Data for Compactors

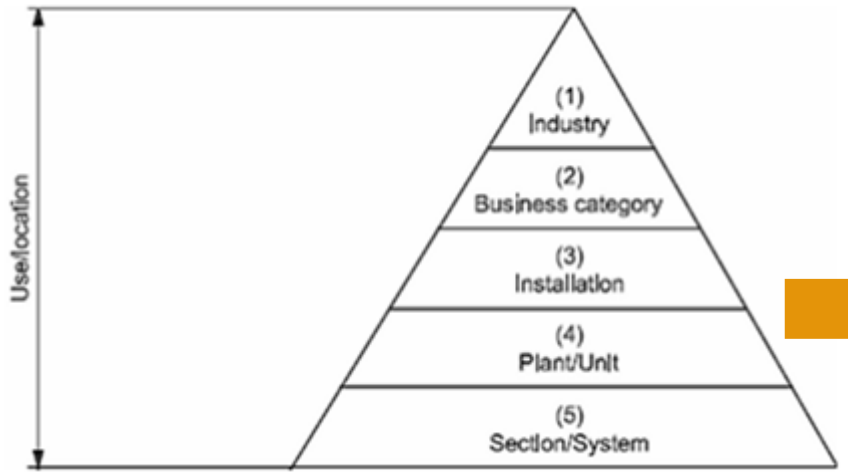
For each technical tag, assign:

- Relevant classification ID
- Use/Location and equipment specific characteristics
- Reference examples in ISO 14224:2016, Table 5 and Annex A

PE_ME_CP	Compactors, agglomeration			
Characteristic ID/Char. Values	**Descriptions**	**UOM**	**APPL**	**PR**
FINAL_PRODUCT_OUTPUT_MAX	Maximum product output	kg/h	CO	H
GRANULAR_SIZE_RANGE	Maximum granular size	mm	CO	H
MAX_PRESSING_FORCE	Maximum pressing force	kN	CO	H
TOTAL_MAIN_DRIVE_POWER	Total main drive power	KW	CO	H
ROLLER_SPEED_RANGE	Roller speed range	rpm	CO	H
NUMBER_MAIN_DRIVE_MOTORS	Number of main drive motors	EA	EQ	H
ROLLER_DIAMETER	Roller diameter	mm	CO	M
EXTRUSION_THICKNESS	Extrusion thickness	mm	CO	M
ROLLED_SHEET_OUTPUT_MAX	Maximum rolled sheet output	kg/h	CO	M
MAIN_DRIVE_MOTORS_TYPE	Main drive motors type		EQ	M
01	Electrical			
02	Hydraulic			

Use/Location Data
Assigned to All Tag Numbers

- Compliant with ISO 14224 taxonomy classification
- Structured data input
- Standard schemata



Object

Functional loc.	212410-CMP-0001
Description	COMPACTOR 1
Class Type	003

Functional Location

Assignments

Class	Description
PE_ME_CP_FL	Compactors, floating gap

Entry 1

Values for Class PE_ME_CP_FL - Object 212410-CMP-0001

Use/Loc | Coincident | Reference

Characteristic Description	Value
Industry	Fertilizer
Business category	Potash
Installation category	Muriate of Potash (MOP)
Plant/Unit category	Processing plant
Section/System	Ore crushing and pre-screening
Operation category	Manned
Number of redundant units	2 EA
Normal operating mode	Intermittent
Utilization of rated capacity	100 %
Ambient conditions	Outdoors-not enclosed

Value Hierarchy for Char...	Desc.
Plant/Unit category	
	No Entry
01	Upstream (E & P)
02	Midstream
03	Downstream
04	Petrochemical
05	Water
06	Renewable energy
07	Fertilizer
07.01	Potash
07.01.01	Mining and extraction
07.01.02	Processing plant

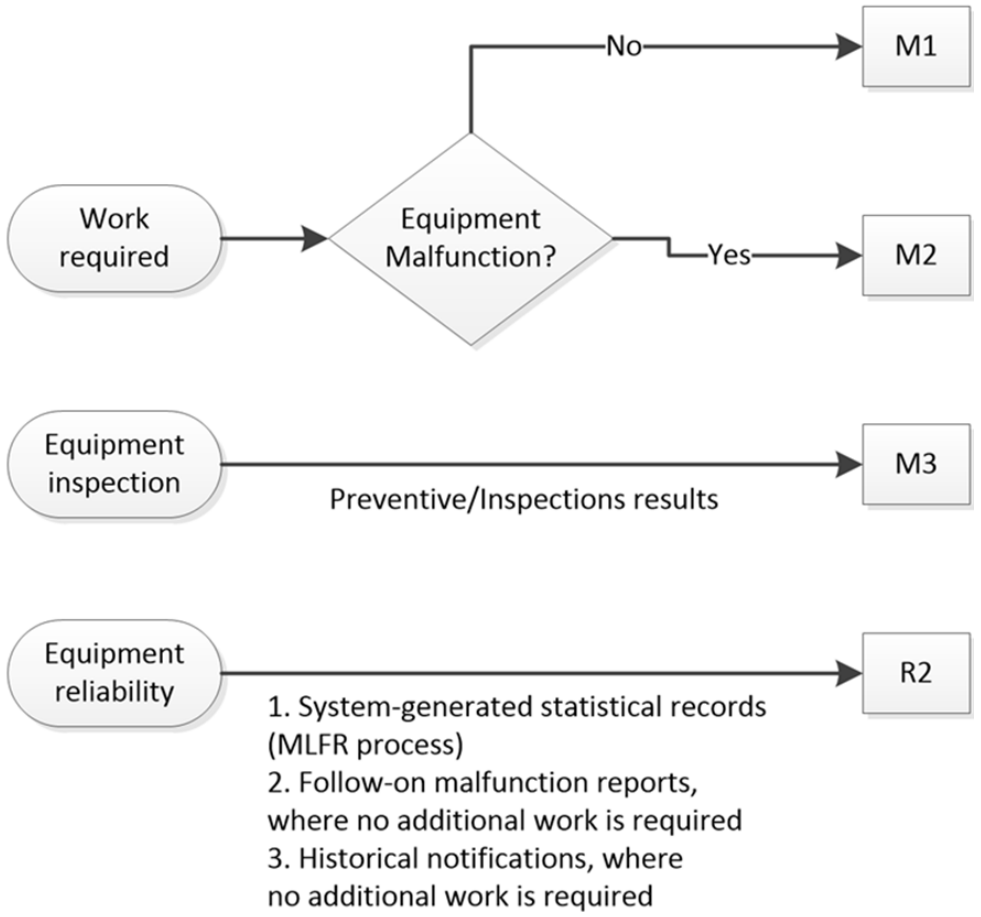
Value set adapted from ISO 14224:2016, Table A.1

ISPM Transactional Data Overview

Maintenance Categorization

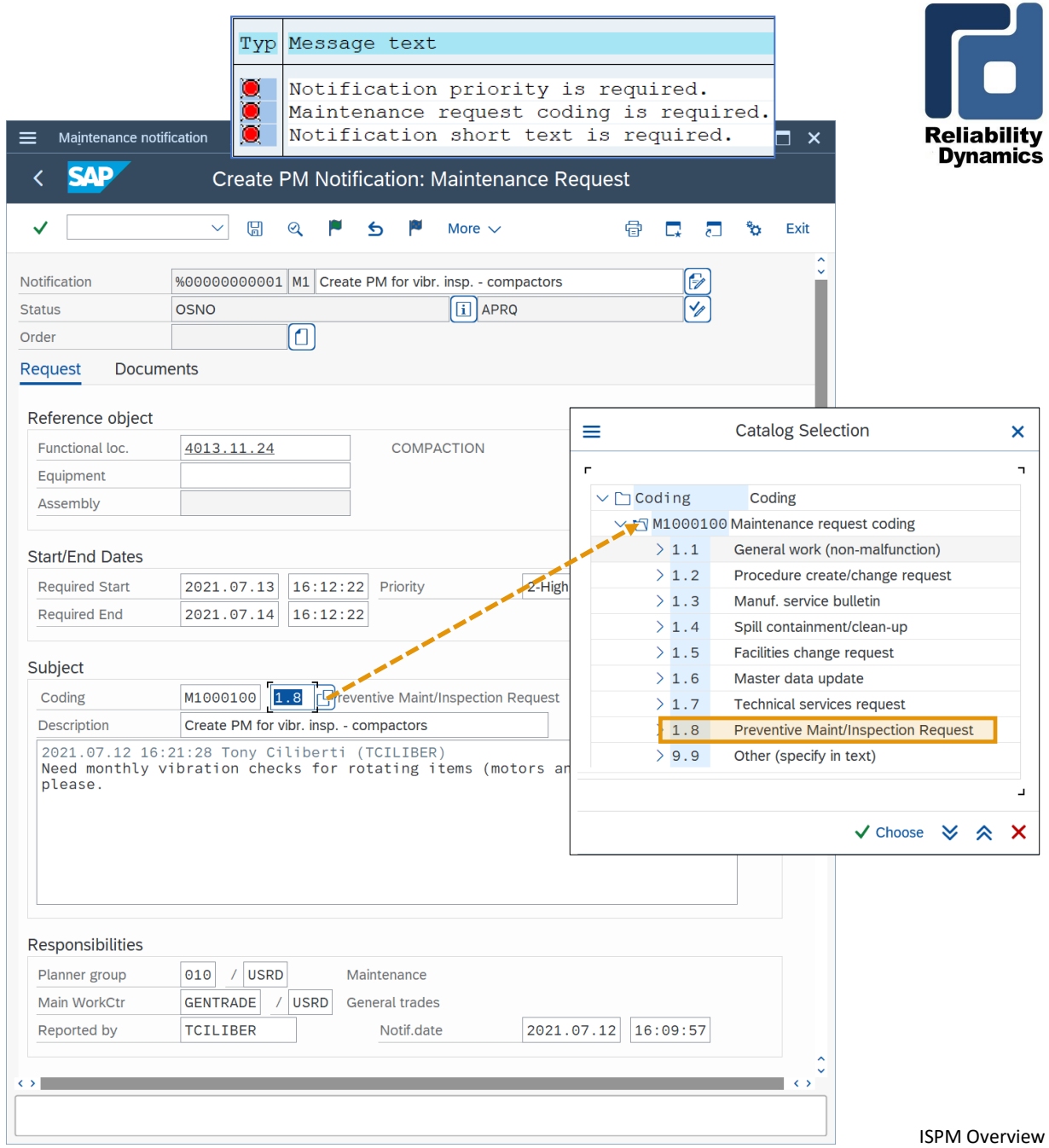
Aligned with Data Requirements

- Three distinct categories and datasets
  - M1 – Maintenance Request
  - M2 – Failure/Malfunction Report
  - M3 – Prev. Condition Report
- Each has different data requirements
  - Separation is important for data relevancy
  - Only relevant fields can be validated
  - Reference ISO 14224:2016, Figure 6



Maintenance Request

- Any non-malfunction request
- Coding is used to differentiate between work types
- Can be linked to other work by notification hierarchy



Malfunction Report

Work Initiation

- Logical work categorization, with one input form per category[1]
- Specifications of required data per work category[2,3,4]
- Discrete fields with structured input for each required datum
- System-validations to ensure compliance with specifications

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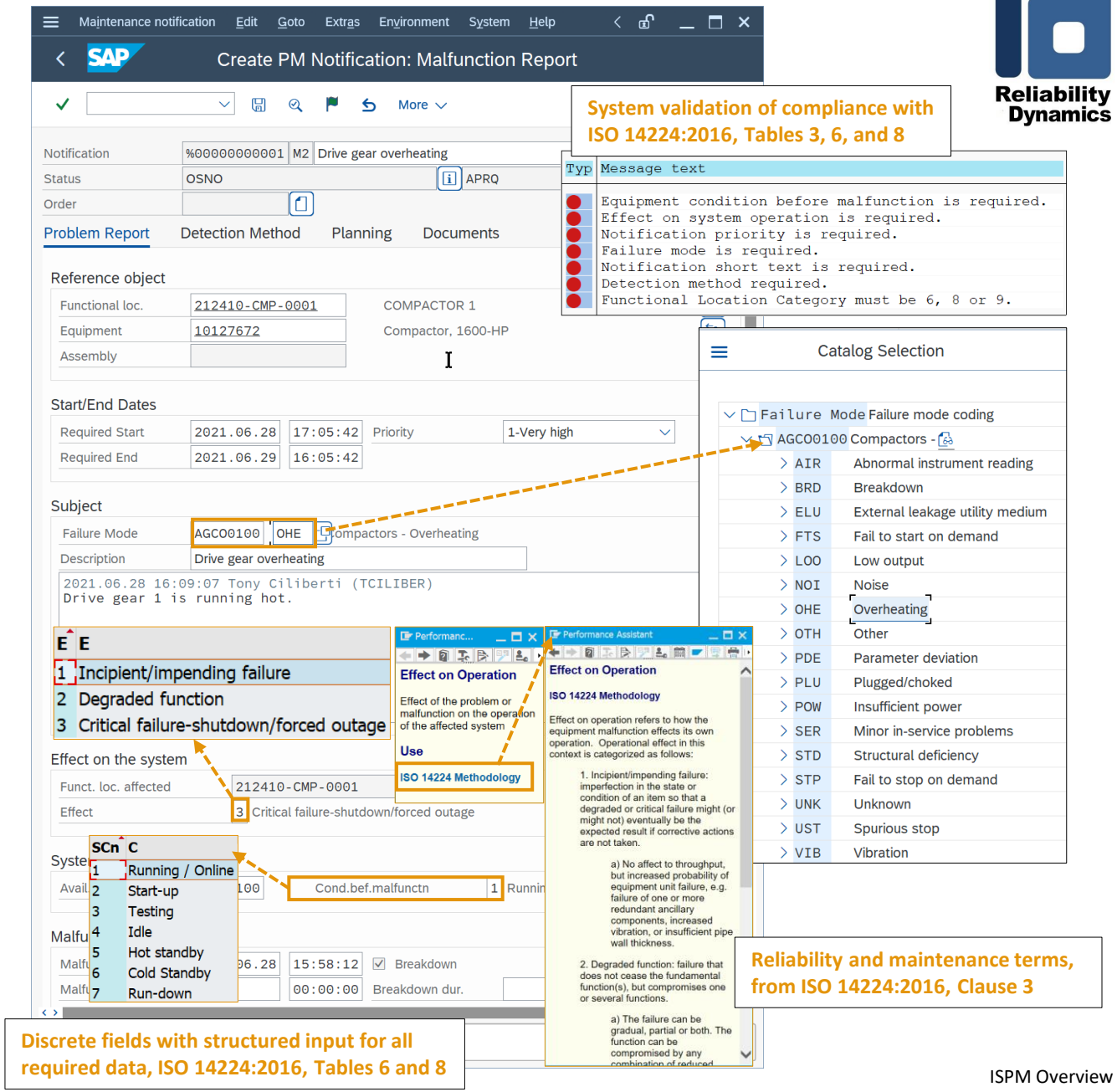
Notes - ISO 14224:2016

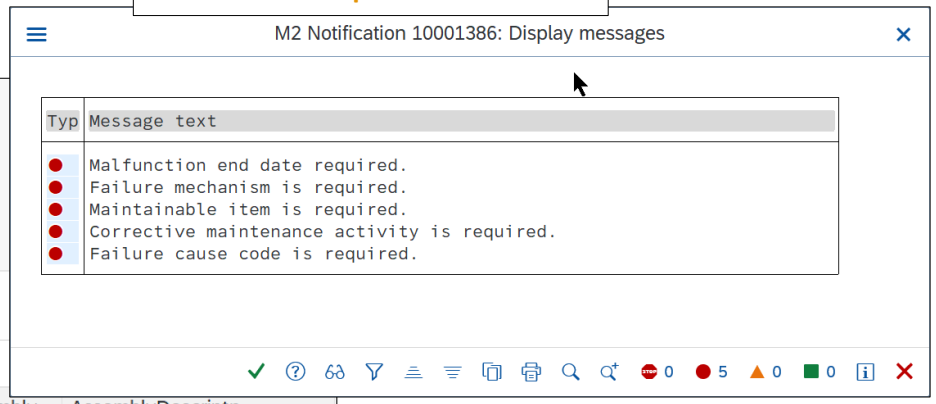
1. Figure 6 – Maintenance categories
2. Table 6 – Failure data
3. Table 8 – Maintenance data
4. Table 3 – Reliability and maintenance parameters in relation to taxonomy levels



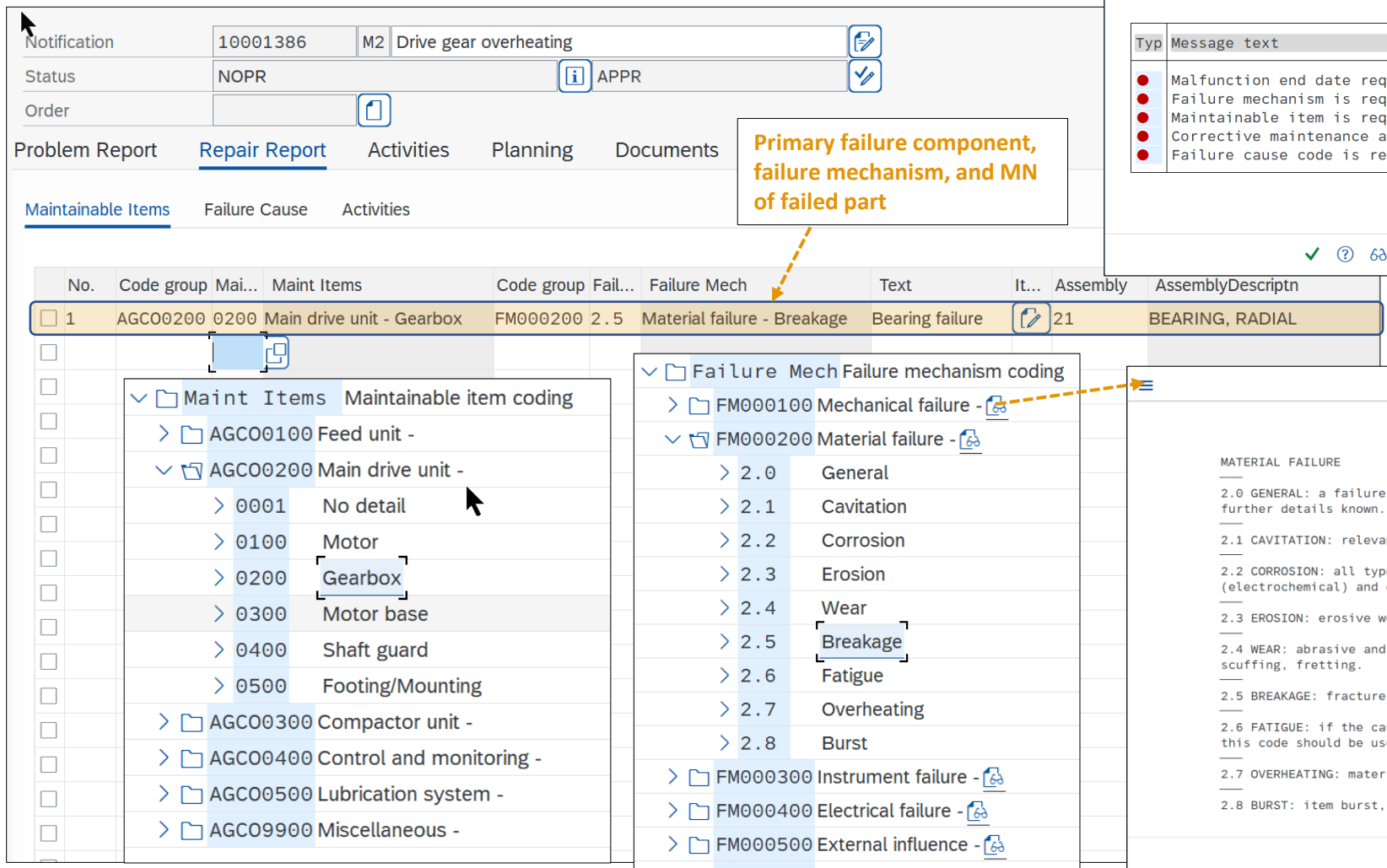
Malfunction Report

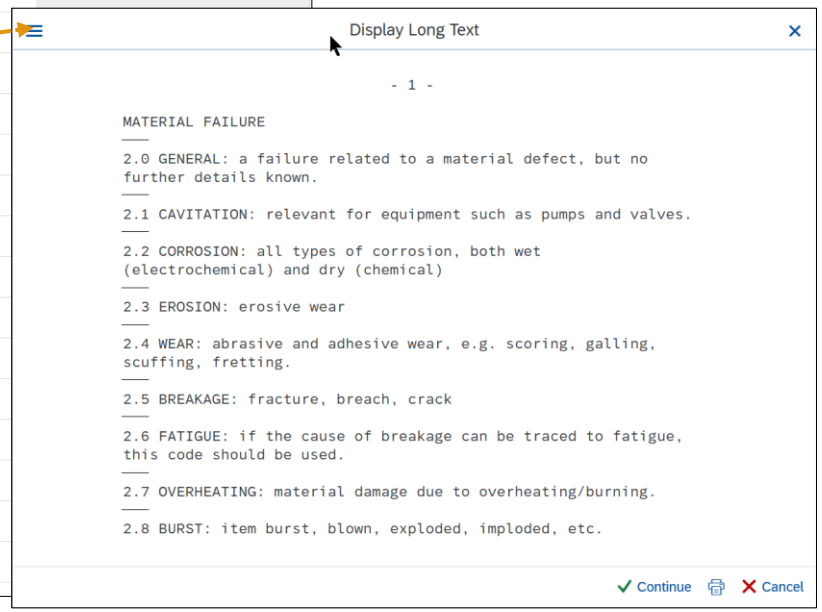
Work Close-out

Validations check compliancy with ISO 14224:2016, Tables 6 and 8, on notification completion



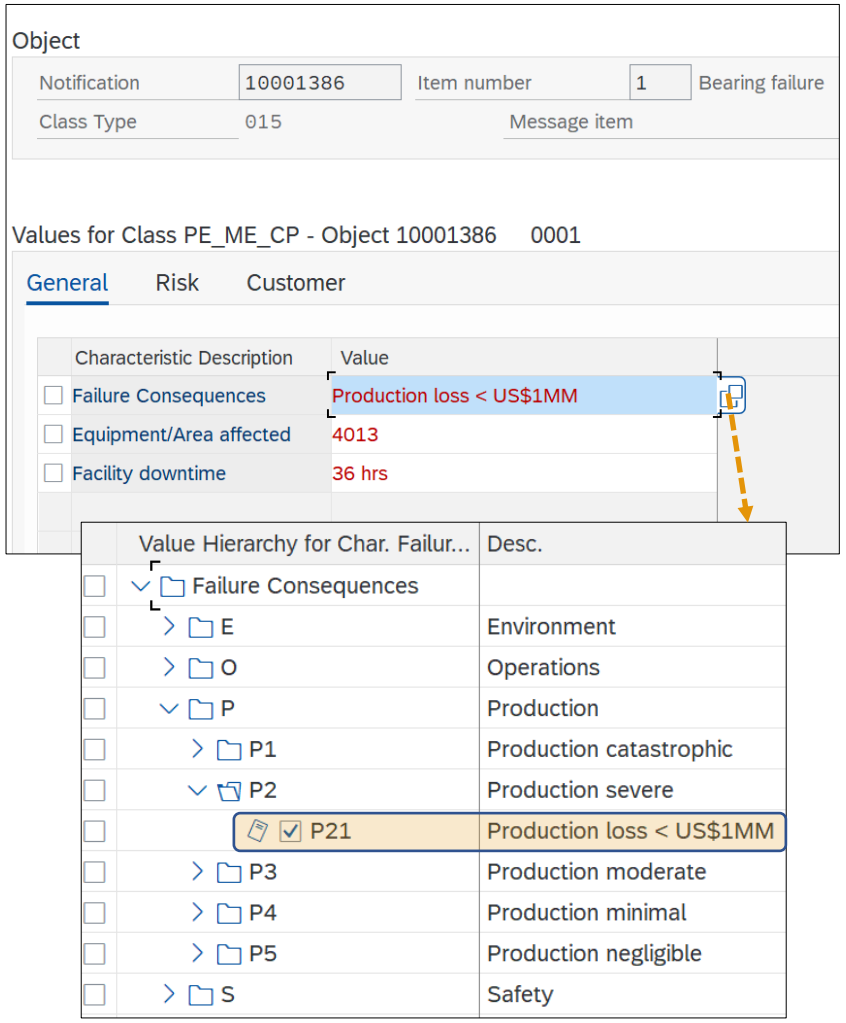
Primary failure component, failure mechanism, and MN of failed part





Malfunction Report

Consequence Classification



ISO 14224:2016, Table C.2 – Failure consequence classification

Consequences	Category			
	Catastrophic Failure that results in death or system loss	**Severe** Severe injury, illness or major system damage	**Moderate** Minor injury, illness or system damage	**Minor** Less than minor injury, illness or system damage
Safety	I — Loss of lives — Vital safety-critical systems inoperable	V — Serious personnel injury — Potential for loss of safety functions	IX — Injuries requiring medical treatment — Limited effect on safety functions	XIII — Injuries not requiring medical treatment — Minor effect on safety function
Environmental	II Major pollution	VI Significant pollution	X Some pollution	XIV No, or negligible, pollution
Production	III Extensive stop in production/operation	VII Production stop above acceptable limit [a]	XI Production stop below acceptable limit [a]	XV Production stop minor
Operational	IV Very high maintenance cost	VIII Maintenance cost above normal acceptable [a]	XII Maintenance cost at or below normal acceptable [a]	XVI Low maintenance cost

[a] It is necessary to define acceptable limits for each application.

PM Condition Report

Preventive Maintenance Results Recording

- One PM Condition Report per technical tag inspected, to record:
  - Inspection verdict
  - Condition details
  - Measurements taken
- Inspections linked to follow-on work by use of notification hierarchy
  - Follow-on notification generation is automated by the system
  - Notification hierarchy can be displayed and edited