



Exploration & Production

GENERAL SPECIFICATION

Field Operations

GS EP EXP 405

Standard reliability data report

01	01/2012	Update following the EP reorganisation, march 2011
00	01/2011	First Issue
Rev.	Date	Notes

Owner: OPS/EXP

Managing entity: OPS/EXP



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1. Scope

This specification proposes a set of reliability data which have been checked and validated by reliability experts from EXP/SRI.

This data set has to be used preferably for all production availability studies (**GS EP EXP 403**), SIL assessment or SIL achievement studies (**GS EP SAF 260**) and all other studies involving the use of reliability data.

The use of other data sets must be validated by EXP/SRI.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
ISO 14224	Petroleum, petrochemical and natural gas industries -- Collection and exchange of reliability and maintenance data for equipment

Professional Documents

Reference	Title
Not applicable	

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	



Total General Specifications

Reference	Title
GS EP EXP 403	Production availability studies of oil and gas Facilities
GS EP SAF 260	Design of High Integrity Protection Systems (HIPS)

3. Terms & Definitions

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

Accumulated Active Repair Time: Accumulated duration of the individual maintenance times used by all maintenance personnel for corrective maintenance action, excluding logistic delays.

Active Repair Time: Part of the maintenance time during which a maintenance action is performed on an item, either automatically or manually, excluding logistic delays.

Availability: Ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided.

Boundary: Interface between an item and its surroundings.

Calendar Time: Interval of time (surveillance time) between the start date and end date of Reliability/Maintenance data collection.

Corrective Maintenance: Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function.

Critical Failure: Failure of an equipment unit that causes an immediate cessation of the ability to perform a required function.

Degraded Failure: Failure that does not cease the fundamental function(s), but compromises one or several functions.

Demand: Activation of the function (includes functional, operational and test activation).

Equipment Class: Class of similar type of equipment units (e.g. all compressors).

Equipment Data: Technical, operational and environmental parameters characterizing the design and use of an equipment unit.

Equipment Unit: Specific equipment unit within an equipment class as defined by its boundary (e.g. one pump).

Failure Data: Data characterizing the occurrence of a failure event.

Failure mode: Effect by which a failure is observed on the failed item.

Fail while running: Failures occurring while running.

Fail to start: Failure discovered during an on-demand attempt to activate an equipment unit (e.g. safety valve fail to close on ESD signal, fail to start a gas turbine on demand)

Incipient Failure: Imperfection in the state or condition of an item so that a degraded or critical failure might (or might not) eventually be the expected result if corrective actions are not taken.

Installation: Number of areas in which the item is located.

Lower/Upper: Confidence intervals are used to indicate the reliability of an estimate. Concerning failure and repair rates, the χ^2 distribution will be used to estimate the bounds (Lower and Upper) of the 90% confidence interval.

Operating Time: Time interval during which an item is in operating state.

Population: The total number of items of one particular type in service during the period of the event data surveillance.

Reliability: Ability of an item to perform a required function under given conditions for a given time interval.

Severity Classification: Describes effect on operational status and the severity of loss of output from the system. The severity classification is connected to the ability of the item in question to perform its function.

Subunit: Assembly of items that provides a specific function that is required for the equipment unit within the main boundary to achieve its intended performance.

Taxonomy: Systematic classification of items into generic groups based on factors possibly common to several of the items.

Unknown Failure: Too little information to define a failure mode.

4. Abbreviation & Symbols

λ	Failure Rate
γ	Probability of Failure due to Demands
μ	Active Repair Rate
BDV	Blow Down Valve
BOP	Blow Out Preventer
EIREDA	European Industry REliability DAta
ESDV	Emergency Shut Down Valve
EXIDA	Safety equipment reliability data
HPU	Hydraulic Power Unit
HSE	Health and Safety Executive
LNG	Liquefied Natural Gas
MTTF	Mean Time To Failure
MTTR	Mean active Time To Repair
NA	Non Applicable
OREDA	Offshore Reliability DAta
PSDV	Process Shut Down Valve
PSD	Process Safety Valve
RIAC	Reliability Information Analysis Center

SCM	Subsea Control Module
SDV	Shut Down Valve
SEM	Subsea Electronic Module
TR-SCSSV	Tubing Retrievable Surface Controlled Sub Surface Valve
WellMaster	Reliability of Well Completion Equipment

5. Structure of the reliability data set

5.1 Taxonomy

The structure of data follows the taxonomy used in the [ISO 14224](#), illustrated in the figure 1, and considers an approach by equipment.

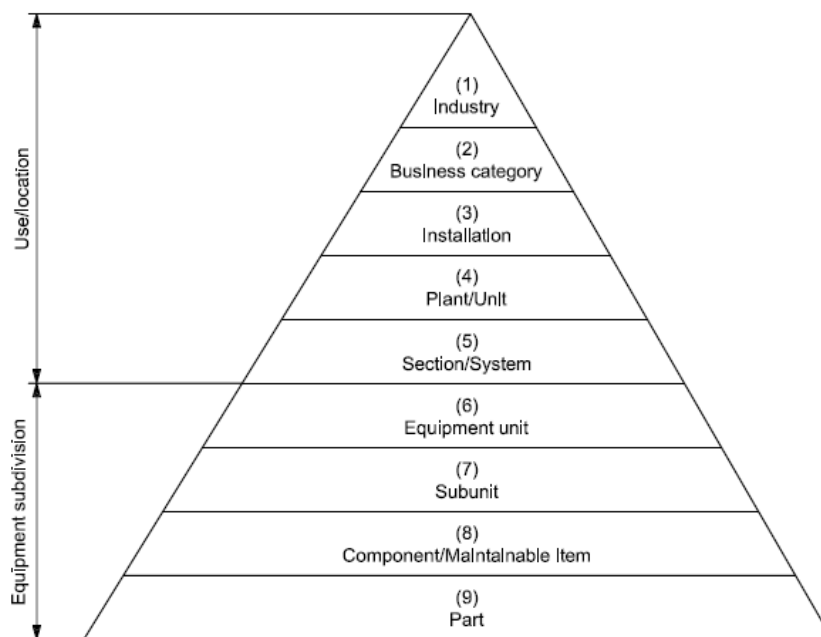


Figure 1. Taxonomy

The equipment subdivision enables the following hierarchy to be defined:

- Topside data:
 - Equipment Unit
 - Subunit
 - Maintainable Item.
- Subsea data:
 - Equipment Unit
 - Subunit
 - Component.



5.2 Quality issues

In statistics, good estimations require to use a large sample size. That's why the following quality rule has been used for failure and repair data:

The data population should contain at least:

- 2 installations
- 30000 hours of calendar or operational time
- 10 inventories OR more than 30 failures.

A quotation of the quality of each sample has been achieved, according to the above-mentioned quality rules and the data source used, in order to have information about the level of confidence which can be placed on estimates.

5.3 Limits

This data set excludes the reliability data for:

- Electronic components like microprocessors
- Control systems
- Human error
- LNG equipment
- Mining, arctic and other particular environment.

5.4 Assumptions

It is assumed that all equipment is in its useful life phase and therefore that the failure rate function is presumed to be constant.

In the same way, the repair rate function is presumed to be constant. This parameter has been preferred to the MTTR in order to avoid that the repair time can be considered as a deterministic event.

6. Use of another reliability database

The use of other reliability databases shall be explained, justified and referenced for equipments which are not dealt within the appendices. The correct conduct of data research shall follow the hierarchy presented below.

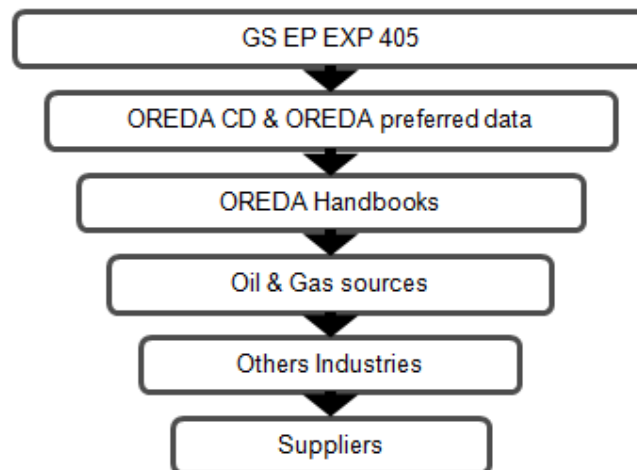


Figure 2 - Data sources hierarchy

7. Reliability data tables

The preferred reliability data are presented in the following appendices:

- Appendix 1: Rotating equipment
- Appendix 2: Electrical equipment
- Appendix 3: Mechanical equipment
- Appendix 4: Safety & Control
- Appendix 5: Subsea Equipment
- Appendix 6: BOP & Well
- Appendix 7: Conversion Table.

This classification is based on the [ISO 14224](#). The Appendix 7 presents equivalence for any equipment on which no data is available.



Bibliography

Reference	Title
ISO 20815-05: 2008	Petroleum, petrochemical and natural gas industries – Production assurance and reliability management
EXIDA handbook 2007	Safety equipment reliability handbook 3 rd edition
OREDA handbook 2002	Offshore Reliability Data 4 th Edition
OREDA handbook 1997	Offshore Reliability Data 3 rd Edition
OREDA handbook 1992	Offshore Reliability Data 2 nd Edition
OREDA handbook 1984	Offshore Reliability Data 1 st Edition
OREDA RE-01-09-01	Topside Equipment Preferred Data Set, August 11? 2009
SINTEF STF75 F87007	Reliability of subsea BOP systems phase IV 1987
Fractal Système report	Sélection de données de fiabilité, revision 3, January 02, 2007
OREDA Software	Release 10.1.7, September 2008

Appendix 1 Rotating equipment

Appendix 1.1: Compressors

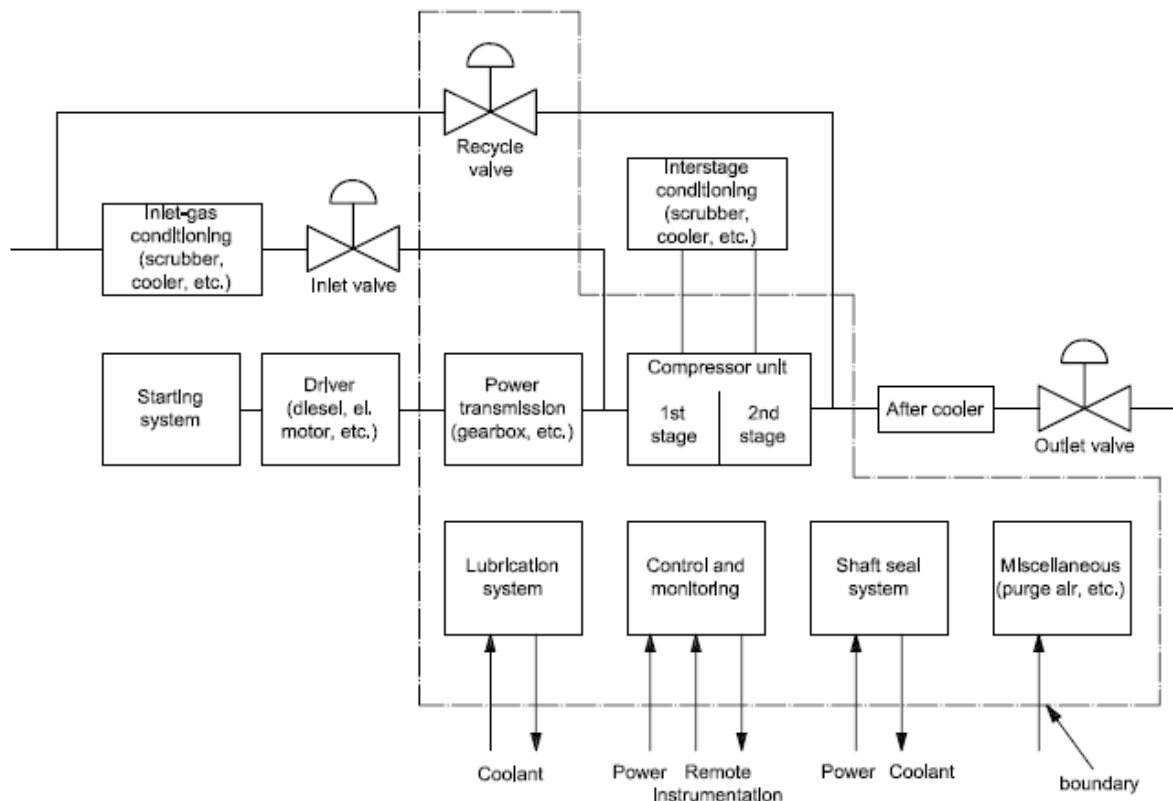


Figure 3 - Boundary Definition – Compressors

- Compressors/All.

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands					
Inv. Equipment Class = COMPRESSORS AND Inv. OREDA Phase > 3				Operational Time			Probability (γ)		MTTR (in hours)			
				4,362779								
Installation		Population		Failure Data			Repair Data					
44		164		Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class		Failure Mode				Lower	λ	Upper		Lower	μ	Upper
Critical		Fail while running		696	0,7	149,58	159,53	169,71	17,04	5,51	5,87	6,23
Degraded		All		1545	0.3	339.31	354.13	369.19	19.59	4,85	5.11	5.36

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Compressors/Centrifugal/All.

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = COMPRESSORS							Probability (γ)		MTTR (in hours)		
AND Inv. Equipment Type = Centrifugal				Operational Time							
AND Inv. OREDA Phase > 3				3,088114			5,60E-03		27,04		
Installation	Population		Failure Data				Repair Data				
23	94		Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode				Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running		248	1,4	71,92	80,31	89,04	29,14	3,09	3,43	3,80
Degraded	All		875,5	0,4	267,75	283,51	299,60	24,19	3,90	4,13	4,37

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Compressors/Centrifugal/Electric motor driven.

Data source			Aggregated Time-in-service (10 ⁶ hours)		Failure due to Demands					
Inv. Equipment Class = COMPRESSORS					Probability (γ)		MTTR (in hours)			
AND Inv. Equipment Type = Centrifugal										
AND Inv. Att. Type of driver = Electric motor			1,751063		6,70E-03		33,98			
Installation	Population	Failure Data					Repair Data			
13	47	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	119	1,7	57,71	67,96	78,82	40,88	2,13	2,45	2,80
Degraded	All	361	0,6	188,31	206,16	224,60	27,08	3,46	3,69	3,93

The sample respects the set of quality rules defined in point 5.4. The level of confidence which can be placed on these results is relatively **high**.

- Compressors/Centrifugal/Gas turbine driven.

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = COMPRESSORS							Probability (γ)	MTTR (in hours)			
AND Inv. Equipment Type = Centrifugal											
AND Inv. Att. Type of driver = Turbine				0,918227			6,70E-03	28,50			
Installation	Population		Failure Data				Repair Data				
11	29		Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode				Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running		77	1,4	68,14	83,86	100,77	17,63	4,41	5,67	7,20
Degraded	All		361,5	0,3	359,63	393,69	428,89	29,36	3,18	3,41	3,63

The sample respects the set of quality rules defined in point 5.4. The level of confidence which can be placed on these results is relatively **high**.

- Compressors/Reciprocating.

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands			
Inv. Equipment Class = COMPRESSORS AND Inv. Equipment Type = Reciprocating AND Inv. OREDA Phase > 3							Probability (γ)		MTTR (in hours)	
				Operational Time			1,90E-04		34,50	
Installation	Population	Failure Data				Repair Data				
12	36	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	381	0,2	509,87	556,79	605,23	9,30	9,86	10,76	11,68
Degraded	All	515.5	0.2	698.77	753.35	809.44	5.86	15.78	17.06	18.37

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Compressors/Screw.

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands			
Inv. Equipment Class = COMPRESSORS AND Inv. Equipment Type = Screw AND Inv. OREDA Phase > 3							Probability (γ)		MTTR (in hours)	
				Operational Time			1,80E-04		5,86	
Installation	Population	Failure Data					Repair Data			
16	33	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	67	1,0	90,83	113,68	138,39	16,13	5,01	6,20	7,60
Degraded	All	149.5	0.5	219.53	253.65	289.59	9.58	8.99	10.44	12.05

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

Appendix 1.2: Gas turbines

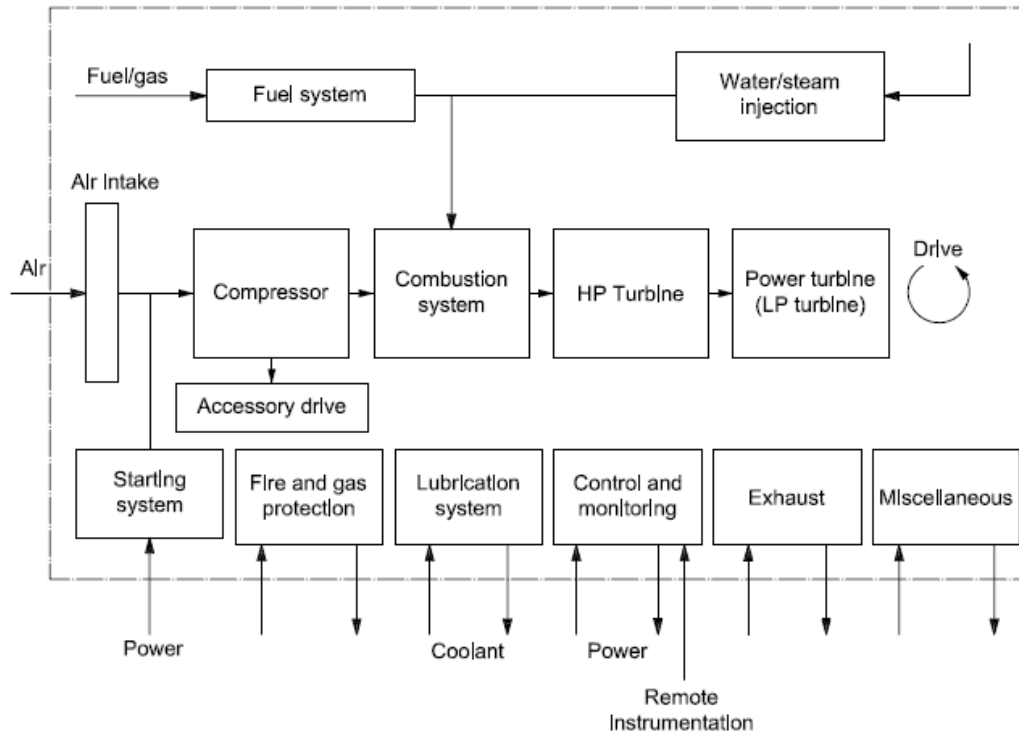


Figure 4 - Boundary Definition - Gas turbines

- Gas turbines/All.

Data source			Aggregated Time-in-service (10 ⁶ hours)				Failure due to Demands				
Inv. Equipment Class = Gas Turbine AND Inv. OREDA Phase > 3			Operational Time				Probability (γ)	MTTR (in hours)			
			2,499425				1,60E-02	25,65			
Installation	Population	Failure Data						Repair Data			
25	94	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)			
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper	
Critical	Fail while running	694	0,4	260,33	277,66	295,41	25,33	3,72	3,95	4,18	
Degraded	All	1658,5	0,2	636,75	663,55	690,76	14,22	6,70	7,03	7,37	

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Gas turbines/Aeroderivative/All.

Data source			Aggregated Time-in-service (10 ⁶ hours)				Failure due to Demands				
Inv. Equipment Class = Gas Turbine			Operational Time				Probability (γ)		MTTR (in hours)		
AND Inv. Equipment Type = Aeroderivative											
AND Inv. OREDA Phase > 3			1,598641				1,60E-02		22,35		
Installation	Population	Failure Data						Repair Data			
14	49	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)			
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper	
Critical	Fail while running	475	0,4	274,70	297,13	320,20	20,88	4,45	4,79	5,14	
Degraded	All	991	0,2	587,51	619,90	652,93	12,34	7,63	8,10	8,59	

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Gas turbines/Aeroderivative/Driving a compressor.

Data source			Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = Gas Turbine AND Inv. Equipment Type = Aeroderivative AND Inv. OREDA Phase > 3 AND Inv. Att.Driver application = COMPRESSOR						Probability (γ)		MTTR (in hours)		
			Operational Time							
			0,729829			1,60E-02		11,87		
Installation	Population	Failure Data					Repair Data			
7	22	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	136	0,6	160,06	186,35	214,09	14,44	5,94	6,93	7,97
Degraded	All	325	0.3	404.68	445.31	487.37	13.55	6,53	7,38	8,26

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Gas turbines/Aeroderivative/Driving a generator.

Data source			Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = Gas Turbine AND Inv. Equipment Type = Aeroderivative AND Inv. OREDA Phase > 3 AND Inv. Att.Driver application = GENERATOR						Probability (γ)		MTTR (in hours)		
			0,4941			1,60E-02		24,62		
Installation	Population	Failure Data					Repair Data			
7	16	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	315	0,2	578,44	637,52	698,72	22,53	4,07	4,44	4,82
Degraded	All	628	0.1	1187.57	1271.00	1356.51	11.93	7.81	8.38	8.97

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Gas turbines/Aeroderivative/Driving a pump.

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands			
Inv. Equipment Class = Gas Turbine AND Inv. Equipment Type = Aeroderivative AND Inv. OREDA Phase > 3 AND Inv. Att.Driver application = PUMP							Probability (γ)		MTTR (in hours)	
				0,374712			1,60E-02		24,62	
Installation	Population	Failure Data					Repair Data			
3	11	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	24	1,8	42,54	64,05	88,67	22,53	4,07	4,44	4,82
Degraded	All	44	1,0	88,31	117,42	149,54	11,93	7,81	8,38	8,97

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Gas turbines/Industrial/All.

Data source			Aggregated Time-in-service (10 ⁶ hours)				Failure due to Demands				
Inv. Equipment Class = Gas Turbine AND Inv. Equipment Type = Industrial AND Inv. OREDA Phase > 3							Probability (γ)		MTTR (in hours)		
			Operational Time			1,80E-02		30,49			
0,900784											
Installation	Population	Failure Data						Repair Data			
14	45	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)			
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper	
Critical	Fail while running	219	0,5	216,10	243,12	271,32	34,56	2,61	2,89	3,21	
Degraded	All	667.5	0.2	693.84	741.02	789.34	17.56	5,26	5,70	6.16	

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Gas turbines/Industrial/Driving a compressor.

Data source			Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = Gas Turbine						Operational Time		Probability (γ)		MTTR (in hours)
AND Inv. Equipment Type = Industrial										
AND Inv. OREDA Phase > 3										
AND Inv. Att.Driver application = COMPRESSOR			0,414249			1,80E-02		22,75		
Installation	Population	Failure Data					Repair Data			
6	18	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	68	0,7	131,41	164,15	199,55	38,18	2,17	2,62	3,10
Degraded	All	223	0.2	479.03	538.32	600.17	19.69	4.38	5.08	5.81

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Gas turbines/Industrial/Driving a generator.

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = Gas Turbine							Probability (γ)	MTTR (in hours)			
AND Inv. Equipment Type = Industrial											
AND Inv. OREDA Phase > 3											
AND Inv. Att.Driver application = GENERATOR				0,415963			1,80E-02		37,77		
Installation	Population		Failure Data					Repair Data			
9	24		Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode				Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running		130	0,4	267,44	312,53	360,19	31,75	2,72	3,15	3,60
Degraded	All		373,5	0,1	821,49	897,92	976,84	13,62	6,54	7,34	8,18

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Gas turbines/Industrial/Driving a pump.

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = Gas Turbine				Operational Time			Probability (γ)		MTTR		
AND Inv. Equipment Type = Industrial											
AND Inv. OREDA Phase > 3				0,070572			1,80E-02		37,77		
AND Inv. Att.Driver application = PUMP											
Installation	Population		Failure Data				Repair Data				
1	3		Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode				Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running		130	0,1	1576,34	1842,09	2123,03	31,75	2,72	3,15	3,60
Degraded	All		373,5	0,0	4842,02	5292,47	5757,68	13,62	6,54	7,34	8,18

The sample does not respect the quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **low**; **this data should be used carefully**.

Appendix 1.3 Pumps

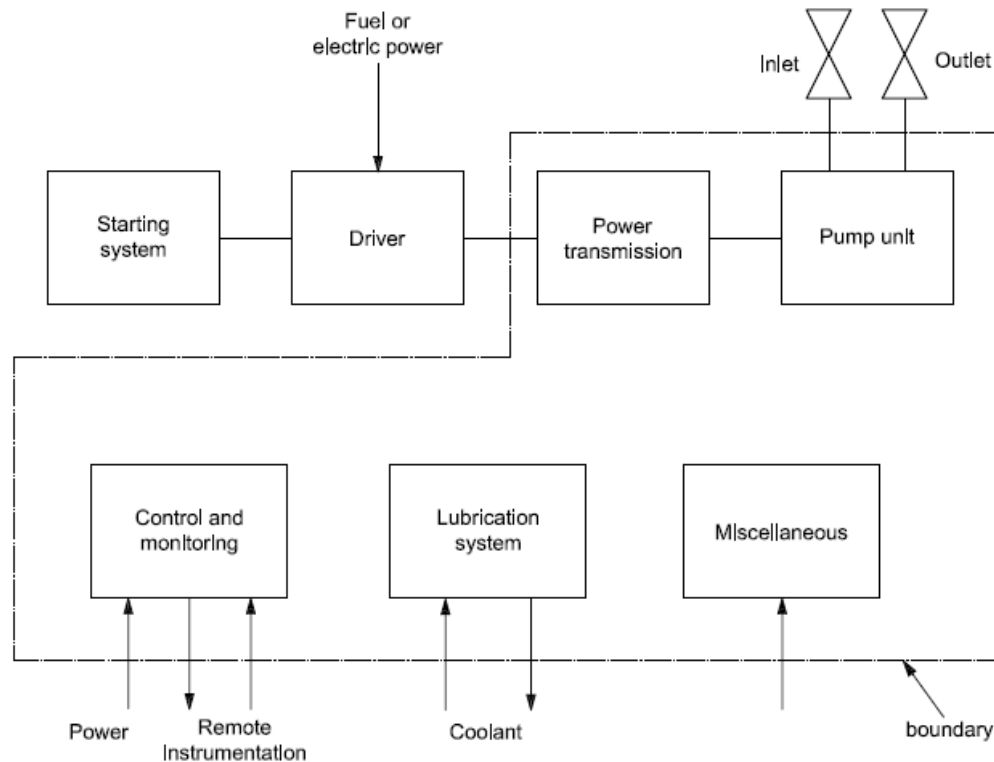


Figure 5 - Boundary Definition - Pumps

• Pumps/All.

Data source			Aggregated Time-in-service (10 ⁶ hours)				Failure due to Demands			
Inv. Equipment Class = PUMPS AND Inv. OREDA Phase > 3			Operational Time				Probability (γ)		MTTR (in hours)	
			12,881569				1,80E-03		56,13	
Installation	Population	Failure Data					Repair Data			
73	580	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	598	2,5	43,30	46,42	49,63	37,97	2,45	2,63	2,82
Degraded	All	1703	0,9	126,93	132,20	137,55	17,82	5,34	5,61	5,89

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Pumps/Centrifugal/All.**

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands					
Inv. Equipment Class = PUMPS AND Inv. Equipment Type = Centrifugal AND Inv. OREDA Phase > 3							Probability (γ)		MTTR (in hours)			
				Operational Time								
				9,784761			1,80E-03		58,97			
Installation		Population		Failure Data			Repair Data					
71		470		Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class		Failure Mode				Lower	λ	Upper		Lower	μ	Upper
Critical		Fail while running		543	2,1	51,58	55,49	59,52	40,05	2,32	2,50	2,68
Degraded		All		1376	0.8	134,39	140,63	146,97	18,87	5,03	5,30	5,57

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Pumps/Centrifugal/Condensate processing.**

Data source			Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = PUMPS			Operational Time			Probability (γ)	MTTR (in hours)			
AND Inv. System = Condensate processing										
AND Inv. Equipment Type = Centrifugal			0,527286			1,80E-03	58,97			
AND Inv. OREDA Phase > 3										
Installation	Population	Failure Data					Repair Data			
5	22	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	21	2,9	26,69	39,83	57,35	9,69	5,14	10,32	18,63
Degraded	All	94	0.6	149.14	178.27	211.61	9.17	8.02	10.91	14.52

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Pumps/Centrifugal/Crude oil handling.**

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands						
Inv. Equipment Class = PUMPS AND Inv. System = Crude oil handling AND Inv. Equipment Type = Centrifugal AND Inv. OREDA Phase > 3							Probability (γ)		MTTR (in hours)				
				Operational Time									
				0,44014			1,80E-03		58,97				
Installation		Population		Failure Data						Repair Data			
5		14		Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)			
Severity Class		Failure Mode				Lower	λ	Upper		Lower	μ	Upper	
Critical		Fail while running		25	2,0	39,49	56,80	79,33	25,08	2,30	3,99	6,46	
Degraded		All		144	0.3	282.32	327.17	374.44	26.57	3,13	3,76	4.50	

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

Pumps/Centrifugal/Gas processing.

Data source			Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = PUMPS AND Inv. System = Gas processing AND Inv. Equipment Type = Centrifugal AND Inv. OREDA Phase > 3			Operational Time			Probability (γ)		MTTR (in hours)		
			1,01442							
						1,80E-03		58,97		
Installation	Population	Failure Data					Repair Data			
4	34	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	28	4,1	19,62	27,60	37,84	11,42	6,37	8,76	11,61
Degraded	All	70.5	1.6	55.88	69.50	84.19	6.68	12.00	14.98	18.49

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

• Pumps/Centrifugal/Oil export.

Data source			Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = PUMPS AND Inv. System = Oil export AND Inv. Equipment Type = Centrifugal AND Inv. OREDA Phase > 3						Probability (γ)		MTTR (in hours)		
			Operational Time			1,80E-03		58,97		
Installation	Population	Failure Data					Repair Data			
8	26	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	82	1,0	91,29	110,58	132,87	49,79	1,66	2,01	2,39
Degraded	All	177	0,5	209,18	238,69	269,63	30,02	2,92	3,33	3,79

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

• Pumps/Centrifugal/Sea water lift.

Data source			Aggregated Time-in-service (10 ⁶ hours)		Failure due to Demands					
Inv. Equipment Class = PUMPS AND Inv. System = Sea water lift AND Inv. Equipment Type = Centrifugal AND Inv. OREDA Phase > 3					Probability (γ)	MTTR (in hours)				
			Operational Time							
			0,903571		4,10E-03	190,80				
Installation	Population	Failure Data					Repair Data			
8	34	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	31	3,3	24,84	34,31	46,30	145,75	0,45	0,69	0,98
Degraded	All	72.5	1.4	64.74	80.24	96.95	16.18	4.38	6.18	8.50

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Pumps/Centrifugal/Water fire fighting.**

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands						
Inv. Equipment Class = PUMPS AND Inv. System = Water fire fighting AND Inv. Equipment Type = Centrifugal AND Inv. OREDA Phase > 3							Probability (γ)		MTTR (in hours)				
				Operational Time									
				0,726402			9,40E-04		9,38				
Installation		Population		Failure Data						Repair Data			
45		141		Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)			
Severity Class		Failure Mode				Lower	λ	Upper		Lower	μ	Upper	
Critical		Fail while running		25	3,3	23,93	34,42	48,07	45,55	1,49	2,20	3,14	
Degraded		All		145	0,6	172.35	199.61	228.35	14.66	5,86	6,82	7.91	

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Pumps/Centrifugal/Water injection.**

Data source			Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = PUMPS			Operational Time			Probability (γ)		MTTR (in hours)		
AND Inv. System = Water injection										
AND Inv. Equipment Type = Centrifugal			2,5089			3,00E-03		87,41		
AND Inv. OREDA Phase > 3										
Installation	Population	Failure Data					Repair Data			
12	79	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	187	1,5	65,80	74,53	84,14	45,79	0,73	2,18	1,72
Degraded	All	437,5	0,7	160,90	174,38	188,51	21,91	4,18	4,56	4,97

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Pumps/Reciprocating/All.**

Data source			Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = PUMPS			Operational Time			Probability (γ)		MTTR (in hours)		
AND Inv. Equipment Type = Reciprocating										
AND Inv. OREDA Phase > 3			3,064072			7,02E-03		16,50		
Installation	Population	Failure Data					Repair Data			
10	109	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	42	8,3	10,23	13,71	17,55	7,84	8,28	12,75	17,91
Degraded	All	308	1,1	91,10	100,52	110,28	4,31	18,67	23,18	28,04

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Pumps/Reciprocating/Chemical injection.**

Data source			Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands				
Inv. Equipment Class = PUMPS AND Inv. System = Chemical injection AND Inv. Equipment Type = Reciprocating AND Inv. OREDA Phase > 3			Operational Time			Probability (γ)		MTTR (in hours)		
			1,11524							
						7,02E-03		16,50		
Installation	Population	Failure Data						Repair Data		
4	37	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	18	7,1	10,43	16,14	23,93	5,94	8,38	16,84	30,39
Degraded	All	153.5	0.8	119.89	137.64	157.36	3.75	11.61	26.67	52.63

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Pumps/Reciprocating/Gas processing.**

Data source			Aggregated Time-in-service (10 ⁶ hours)		Failure due to Demands					
Inv. Equipment Class = PUMPS AND Inv. System = Gas processing AND Inv. Equipment Type = Reciprocating AND Inv. OREDA Phase > 3					Probability (γ)	MTTR (in hours)				
			Operational Time							
			1,692228		7,02E-03	16,50				
Installation	Population	Failure Data					Repair Data			
3	51	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	14	13,8	5,00	8,27	12,93	6,00	8,29	16,67	29,03
Degraded	All	121,5	1,6	61,08	71,80	83,15	3,22	24,13	31,09	39,50

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.

- Pumps/Reciprocating/Gas treatment.**

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands			
Inv. Equipment Class = PUMPS AND Inv. System = Gas treatment AND Inv. Equipment Type = Reciprocating AND Inv. OREDA Phase > 3				Operational Time			Probability (γ)		MTTR (in hours)	
				0,10889			7,02E-03		16,50	
Installation	Population	Failure Data					Repair Data			
3	9	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	9	1,4	43,12	82,65	144,23	13,33	2,04	7,50	18,22
Degraded	All	22	0.6	131.19	202.04	283.67	5.00	8,71	20,00	39.47

The sample does not respect the set of the quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is sufficient to be considered **satisfactory**.

• **Pumps/Rotary.**

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands			
Inv. Equipment Class = PUMPS AND Inv. Equipment Type = Rotary AND Inv. OREDA Phase > 3							Probability (γ)		MTTR (in hours)	
				Operational Time						
				0,032736			1,80E-03		56,13	
Installation	Population	Failure Data					Repair Data			
1	1	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	13	0,3	234,90	397,12	631,37	7,71	7,84	12,96	20,27
Degraded	All	14	0,3	258,55	427,66	668,58	3,22	18,56	31,03	48,92

The sample does not respect the quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **low**; **this data should be used carefully.**

Appendix 1.4: Combustion engines

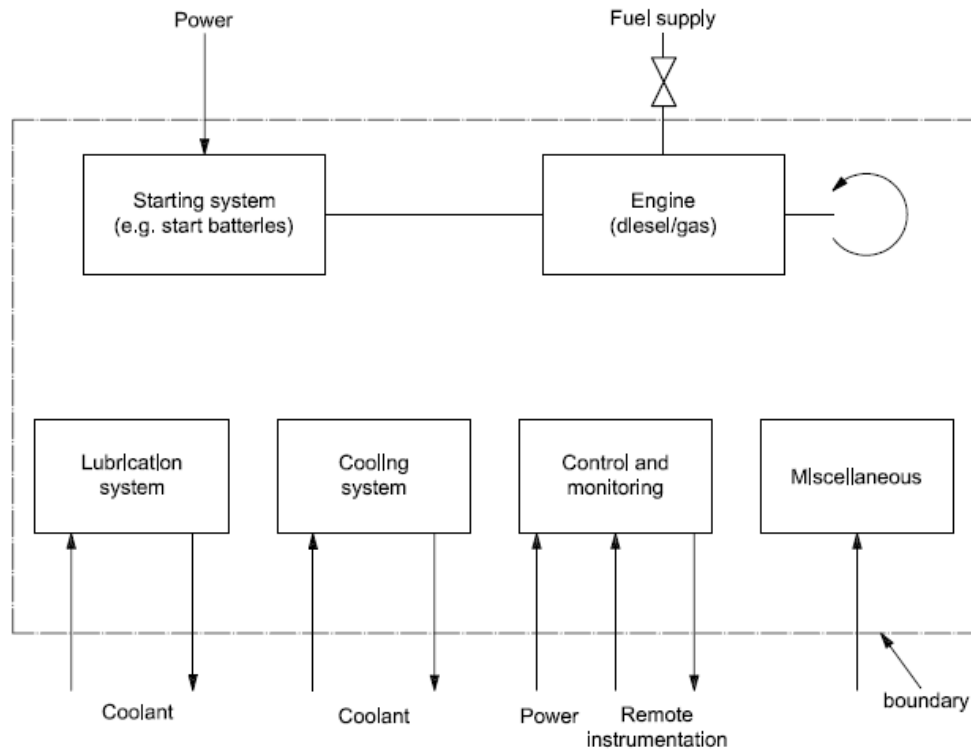


Figure 6 - Boundary Definition - Combustion Engine

- Combustion engines/All.

Data source				Aggregated Time-in-service (10 ⁶ hours)			Failure due to Demands			
Inv. Equipment Class = COMBUSTION ENGINES AND Inv. OREDA Phase > 3							Probability (γ)		MTTR (in hours)	
				Operational Time						
			0,981001			1,50E-03		16,64		
Installation	Population	Failure Data					Repair Data			
77	156	Nb of Failures	MTTF (in years)	Failure Rate (per 10 ⁶ hours)			MTTR (in hours)	Active repair rate (per 10 ² hours)		
Severity Class	Failure Mode			Lower	λ	Upper		Lower	μ	Upper
Critical	Fail while running	58	1,9	46,35	59,12	73,02	42,69	1,92	2,34	2,83
Degraded	All	525	0,2	496,75	535,17	574,64	15,90	5,79	6,29	6,82

The sample respects the set of quality rules defined in point 5.4. The **level of confidence** which can be placed on these results is relatively **high**.