FMEA of CO_2 Air Conditioning Systems

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The RISA Company

- Founded in 1990, situated in Berlin, Germany
- 10 specialized engineers from research institutes of the Technical University of Berlin
- Working areas are safety analysis and software development (databases)
- Customers from nuclear-, automotive- and LPG-industry

Where this kind of Analysis is needed (examples):

- Higher amount of energy in a small amount of space (high energy density)
- Nuclear Power Plants: reactor core cooling, pressure
- Automotive: velocity, pressure
- LPG: great amount of inflammable and explosive fluid/gas mixture

Initiators and Core Team members

RiSA








- Robert Mager, BMW AG (Chairman)
- Jürgen Wertenbach, DaimlerChrysler AG
- Baroto Adiprasito, Volkswagen AG
- Ralf Köneke, Denso Automotive Deutschland
- Frank Obrist, Obrist Engineering

Aims of the analysis for a prototypical CO_2 AC-System

- Diagnosis of potential effects of failure events
- Determination of countermeasures
- Proof of mastering all relevant effects
- Confirmation of the usability of CO_2-technology regarding to safety and product liability
- System-FMEA as a basis for a design-FMEA

Form of the Analysis

- System-FMEA based on SAE J-1739
- Additional classification for consequences to human health
- Instructions to reduce the risk priority number if it is greater than 108 to get a balanced risk level over all failure events

Risk Priority Number

RPN = Severity x Occurrence x Detection

Severity	1 - 10	(8 = Very High, 9 Hazardous with warning)
Occurrence	1 - 10	(4 - 6 = Moderate)
Detection	1 - 10	(3 = High)
Þ RPN	1 - 1000	(9 x 4 x 3 = 108, according to an engineering judgement)

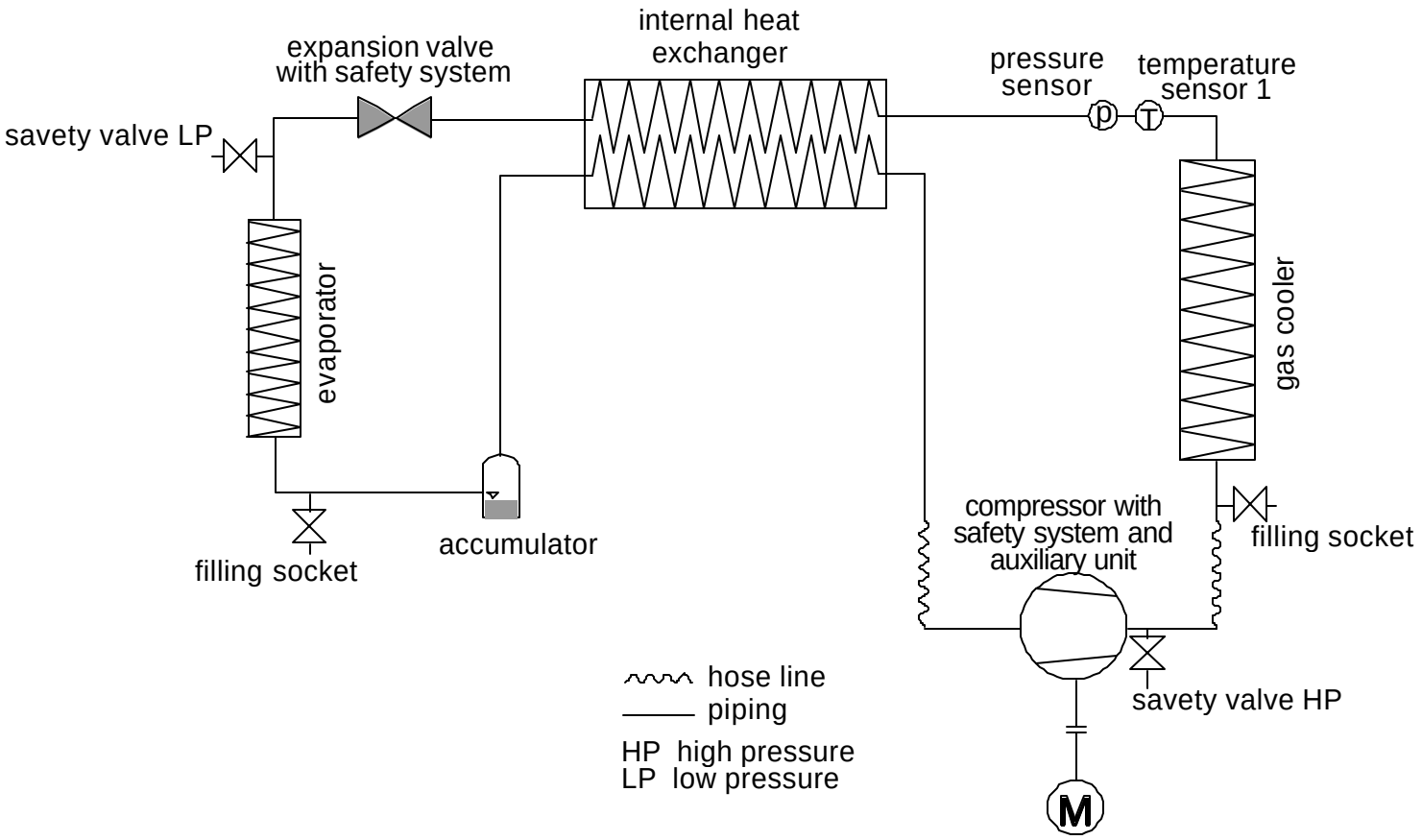
Table-Layout

Item	Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	RPN	Recommended Action(s)	Responsibility (for the Recommended Action)	Actions Taken	Sev	Occ	Det	RPN
Compressor	Transports the medium; Compresses the medium	Loosening of fastenings	Refrigerant pipe detaches, external leaks	9	B	Material faults, loosening of fastenings	1	Quality control	2	18	Oscillation tests			9	1	1	9
Gas cooler	Conducts heat to the external environment	Blockage in refrigerant flow	Low cooling capacity, increase in pressure	6	A	Bends, blockages	2	Deformation guard, layout; design of component	10	120	Parallel procedures, pressure sensor switched in front of the gas cooler, plausibility control via regulation control			6	2	6	72

Scope of the Analysis

- 23 components within the system with
- 107 failure events
  in respect to
  - 3 operating modes,
  - 3 (+2) vehicle running modes and
  - 3 environment conditions

PI-Diagram


internal heat exchanger
expansion valve with safety system
pressure sensor
temperature sensor 1
savety valve LP
p
T
evaporator
gas cooler
accumulator
filling socket
compressor with safety system and auxiliary unit
filling socket
savety valve HP
hose line
piping
HP high pressure
LP low pressure
M

Results

- An automotive CO_2 AC-system is safe:
  - General rules for the arrangement of the components have to be taken into account
  - Safety components and/or systems have to be present
- Critical components are detected

Outlook

- Development of common safety-standards for an automotive CO_2 AC-system
- Systematic sampling of all failure events from existing prototype-systems
- Evaluation of specific failure rates during the operation of prototype system hours
- Performing a fault- and event tree analysis

Further Activities

- Further activities should be done to gain international acceptance