

PAS 7060:2021

Electric vehicles – Safe and environmentally-conscious design and use of batteries – Guide



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Foreword

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Relationship with other publications

- PAS 7061 – *Batteries for vehicle propulsion electrification – Safe and environmentally-conscious handling of battery packs and modules – Code of practice*
- PAS 7062 – *Electric vehicle battery cells – Health and safety, environmental and traceability considerations in cell manufacturing and finished cell – Code of Practice*

These PAS publications and PAS 7060 are structured to cover the different systems levels for electrically-propelled vehicles and battery systems, from vehicle level design (PAS 7060), to battery modules and pack assembly (PAS 7061), to battery cells (PAS 7062).

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Presentational conventions

The guidance in this PAS is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. "organization" rather than "organisation").

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This PAS does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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0 Introduction

0.1 General

The adoption of battery electric vehicles and plug-in hybrid electric vehicles (and other alternative fuelled vehicles) is set to increase substantially over the next decade as many governments legislate to reduce both carbon and particulate emissions, and customers and users seek to lower running costs and to support their environmental objectives.

The UK is investing in innovation to improve not only the performance and cost of traction batteries, but also how the UK uses, manufactures, services and disposes of batteries safely and in an environmentally-friendly way.

Whilst battery electric vehicles share many similarities with their internal combustion-powered forebears, they have several important differences that drive new approaches to their design, use and second life, including disposal. The most significant differences are the total or partial replacement of the internal combustion engine with an electric motor and the replacement of the fuel and fuel tank with a battery.

Batteries that can provide motive power for a typical passenger or light goods vehicle can store a substantial amount of energy, operate at high voltage and generate high temperature. They are also sensitive to impact, vibration and dynamic loads and therefore require careful management of their initial design, manufacture, installation, operation, re-use and dismantling. The design, operation and maintenance of the battery electric vehicle can also be adjusted to accommodate their requirements and appropriate training may be provided to the user, manufacturing and service operatives, emergency services and vehicle dismantlers to ensure their safe and efficient operation, end of vehicle life re-use and disposal.

0.2 Traction battery supply chain and manufacturing process

The supply chain and manufacturing process of batteries is a complex and global system. As UK capability progresses within different sectors of the system, capturing and codifying good practice will save time, wasted effort and resources and build a UK knowledge base that reduces significant risks in this new manufacturing sector. The intention is to ensure the UK can continue to influence and manufacture exports, delivering EV battery products to international standards.

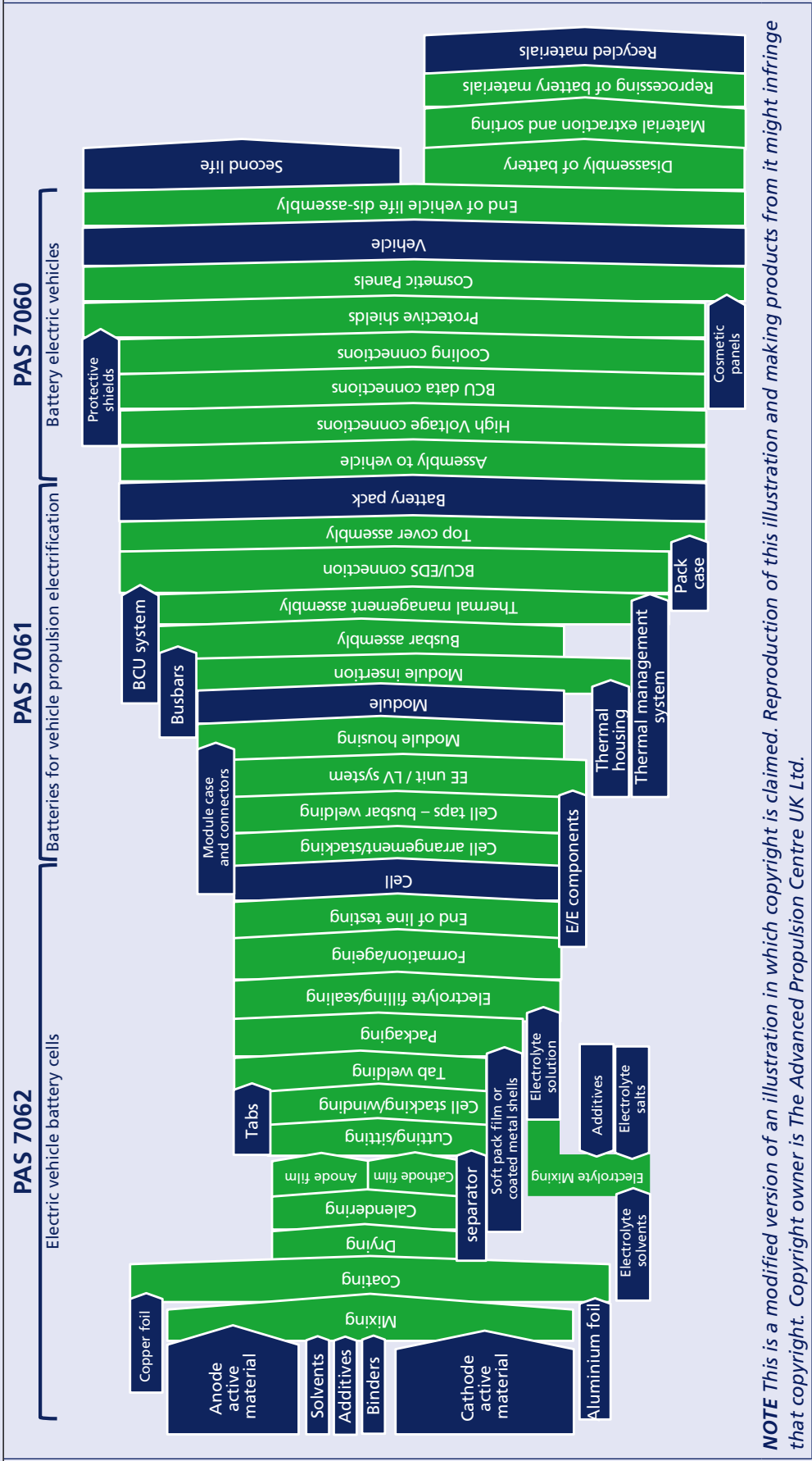
0.3 Battery supply chain and manufacturing process system boundaries

Due to the complexity of the battery supply chain and manufacturing process system, the system has been divided into three sub-systems, which are each covered by three separate PASs:

- PAS 7060 – covering vehicle design;
- PAS 7061 – covering pack and module; and
- PAS 7062 – covering electrode and cell.

A diagram to illustrate the system boundaries that are covered by each of these PASs is shown in Figure 1.

Figure 1 – Generic boundary diagram of supply chain and manufacturing process



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0.4 The approach taken for this PAS

Initial development of this PAS was undertaken using a combination of “top down” and “bottom-up” approaches.

The top-down approach started from considering the existing business frameworks which drive a common approach in the management of business activities. The principal areas being quality, environmental and safety systems, with the recommendations for the PAS being structured around these systems.

The bottom-up approach started from the existing sets of legislation, regulation and guidance in existence across these systems that have been produced for generic application, cross-sector application of lithium-ion batteries and automotive-specific application.

The PAS includes the following Annexes:

- a) Annex A: Alternative battery chemistries; and
- b) Annex B: Examples of fire incidents.

0.5 Review process

In this new, emerging and quickly-growing field, it is important that all organizations review and update their documentation as to what is current good practice. Good practice is learnt from world-wide incidents, events and newly developed protocols.

1 Scope

This PAS provides guidance for vehicle categories: motorcycles L1e, L2e, L3e, L4e, L5e, L6e, L7e; passenger cars M1, M2; light goods vehicles N1.

NOTE 1 *The vehicle categories are defined in the European Regulation (EU) No 168/2013 [1] and (EU) No 2018/858 [2].*

NOTE 2 *It is recommended that this PAS be used in conjunction with and be limited by the scopes of PAS 7061 and PAS 7062.*

This PAS gives guidance for the health, safety and environmental considerations in the process of vehicle design, battery integration and battery use for EVs and PHEVs.

This PAS is intended to create efficiencies in the vehicle manufacturing cycle, de-risk batteries in use, optimize re-use and recycling of vehicle batteries and ultimately improve consumer confidence in EVs and PHEVs.

This PAS covers general health, safety (including fire), competency and environmental impact considerations in vehicle design and use, and provides a specific focus on:

- vehicle manufacture;
- repair and recycling;
- interaction with battery management systems;
- mechanical and electrical integrity and isolation post-crash;
- vehicle dismantling;
- preparing for second life use of battery; and
- health data.

It does not cover vehicles other than those listed above, charging systems that do not form part of the vehicle and the health, safety and environmental requirements and considerations in the manufacture of battery cells (and electrodes), battery packs and modules which are being addressed separately.

This PAS is for use by battery and automotive manufacturers.

This PAS is also of interest to commercial vehicle manufacturers (M3, N2 and N3 categories), off-highway vehicle and rail vehicle manufacturers, government, regulators, insurance companies, local authorities, shipping, automotive distributors, dealerships, repairers and dismantlers and emergency services.

2 Terms, definitions and abbreviations

2.1 Terms and definitions

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

2.1.1 accident

any unplanned event that resulted in injury or ill-health of people, or damage or loss to property, plant, materials or the environment or a loss of business opportunity

[SOURCE: Health and Safety Executive, HSR25 [3]]

2.1.2 battery

two or more cells which are electrically connected together, fitted with devices necessary for use, for example, case, terminals, marking and protective devices

NOTE 1 A single cell battery is considered a "cell".

NOTE 2 A battery can also include some or more attachments, such as electrical bypass devices, charge control electronics, heaters, temperature sensors, thermal switches and thermal control elements.

NOTE 3 Units that are commonly referred to as "battery packs", "modules", or "battery assemblies" having the primary function of providing a source of energy for vehicle propulsion are, for the purposes of this PAS, treated as batteries.

[SOURCE: BS ISO 17546:2016, 3.4, modified]

2.1.3 battery control unit (BCU)

electronic device that controls, manages, detects or calculates electric and thermal functions of the battery system and that provides communication between the battery system and other vehicle controllers

NOTE Battery management system can be used as alternative to battery control unit.

[SOURCE: BS ISO 12405-4:2018, 3.1]

2.1.4 battery module

single unit containing one cell, or a set of cells electrically connected and mechanically assembled

[SOURCE: BS EN 1987-1:1997, 3.2]

2.1.5 battery pack

energy storage device that includes cells or cell assemblies normally connected with cell electronics, power supply circuits and overcurrent shut-off device, including electrical interconnections, interfaces for external systems

NOTE Examples of external systems are cooling, voltage class B, auxiliary voltage class A and communication.

[SOURCE: BS ISO 12405-4:2018, 3.2]

2.1.6 battery system

energy storage device that includes cells or cell assemblies or battery pack(s) as well as electrical circuits and electronics

NOTE 1 Battery system components can also be distributed in different devices within a vehicle.

NOTE 2 Examples of electronics are the BCU and contactors.

[SOURCE: BS ISO 12405-4:2018, 3.3]

2.1.7 capacity

total number of ampere-hours that can be withdrawn from a fully charged rechargeable energy storage system (RESS) under specified conditions

[SOURCE: BS ISO 6469-1:2019, 3.2]

2.1.8 competence

ability to apply knowledge and skills to achieve intended results

[SOURCE: BS ISO 44001:2017, 3.10]

2.1.9 component

entity or system that forms a part of a larger system

[SOURCE: PAS 11281:2018, 2.1.6]

2.1.10 crash

collide with an obstacle or another vehicle resulting in damage

2.1.11 development process

set of steps performed to turn concepts and ideas into a finished product

2.1.12 design specification

set of requirements that are met in order for the product or process to be successful

2.1.13 dismantle

to take (machine or structure) to pieces

2.1.14 electrical hazard

potential source of harm when electric energy is present in an electrical installation

NOTE 1 The term “harm” in this context relates to damage to either persons and/or electrical installations.

NOTE 2 The electrical conditions where such a hazard occurs are when the voltage between live components is greater than 30 V ac or 60 V dc (and < 1 000 V ac or 1 500 V dc) and the short circuit current where work is being performed exceeds the value of 3 mA ac or 12 mA dc or the energy exceeds 350 mJ (source: BGI/GUV-I 8686 E [4]), or if between a live part and an adjacent dead metal part or between live parts of different polarity, there exists a potential of 2 V or more and either an available continuous power level of 240 W or more, or an energy level of 20 J or more (source: UL 478 [5]).

[SOURCE: IEC Vocabulary (<http://www.electropedia.org/>) IEV ref 651-26-05, modified].

2.1.15 electrically-propelled vehicle (EV)

vehicle with one or more electric drive(s) for vehicle propulsion

NOTE An “electrically-propelled vehicle” includes electric vehicle (EV), hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV) and fuel cell hybrid electric vehicle (FCHEV).

[SOURCE: BS ISO 6469-3:2018+A1:2020, 3.15]

2.1.16 explosion

sudden release of energy sufficient to cause pressure waves and/or projectiles that might cause structural and/or physical damage to the surrounding area

[SOURCE: BS ISO 6469-1:2019, 3.10, modified]

2.1.17 failure mode

manner in which an equipment or machine failure can occur

2.1.18 failure modes and effects analysis (FMEA)

analytical procedure in which each potential failure mode in every component of a product is analysed to determine its effect on the reliability of that component and, by itself or in combination with other possible failure modes, on the reliability of the product or system and on the required function of the component; or the examination of a product (at the system and/or lower levels) for all ways that a failure may occur

NOTE 1 For each potential failure, an estimate is made of its effect on the total system and of its impact. In addition, a review is undertaken of the action planned to minimize the probability of failure and to minimize its effects – see Project Management Institute, A Guide to the Project Management Body of Knowledge (PMBOK® Guide) [6].

NOTE 2 Procedure can be applied as design failure mode and effect analysis (DFMEA) and process failure mode and effect analysis (PFMEA).

[SOURCE: ISO/IEC/IEEE 24765:2017, 3.1562, modified]

2.1.19 gravimetric efficiency

maximum energy stored divided by the total mass of the storage system

NOTE Usually measured at cell, module, pack and vehicle levels.

2.1.20 hazard

potential source of harm

[SOURCE: BS EN ISO 17409:2020, 3.29]

2.1.21 high voltage system (HV system)

electric component or circuit with a maximum working voltage between 30 V ac (rms) and 1 000 V ac (rms) or between 60 V dc and 1 500 V dc

NOTE The definition of high voltage varies across industries.

2.1.22 infotainment system

vehicle system that combines entertainment and information delivery to drivers and passengers

2.1.23 life-cycle assessment

compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

[SOURCE: BS EN ISO 14044:2006, 3.2]

2.1.24 packaging

process or organization used to determine the geometric layout of a vehicle

2.1.25 pack marriage

process of assembly of the battery pack to the vehicle

2.1.26 poka yoke

prevention method designed as a simple technique to prevent either:

- anyone from making unplanned or unwanted changes to a system; or
- any errors from negatively impacting on a system

[SOURCE: BS ISO 13053-2:2011, 2.19]

2.1.27 propulsion system

combination of power source and powertrain for vehicle propulsion

[SOURCE: BS ISO 6469-2:2018, 3.12]

2.1.28 reasonably practicable

balancing the level of risk against the measures needed to control the real risk in terms of money, time or trouble¹⁾

2.1.29 reasonably predicted

use of risk assessment and other such commonly used tools to make a prediction

NOTE *In the automotive industry this includes tools such as Design Failure Mode Effects Analysis (DFMEA) and Process Failure Mode Effect Analysis (PFMEA).*

2.1.30 rechargeable energy storage system (RESS)

rechargeable system that stores energy for delivery of electric energy for the electric drive

[EXAMPLE: Battery, capacitor, flywheel]

[SOURCE: BS ISO 6469-1:2019, 3.22]

2.1.31 risk

effect of uncertainty on objectives

[SOURCE: BS ISO 31000:2018, 3.1]

2.1.32 risk assessment

overall process of risk identification, risk analysis and risk evaluation

NOTE *Risk assessment involves the process of identifying internal and external threats and vulnerabilities, identifying the likelihood and impact of an event arising from such threats or vulnerabilities, defining critical functions necessary to continue the organization's operations, defining the controls in place necessary to reduce exposure and evaluating the cost of such controls.*

[SOURCE: BS EN ISO 22300:2018, 3.203]

2.1.33 risk management

co-ordinated activities to direct and control an organization with regard to risk

NOTE *Risk management generally includes risk assessment, risk treatment, risk acceptance, and risk communication.*

[SOURCE: BS EN ISO 31000:2018, 3.2]

2.1.34 running cost

money spent regularly to keep a system or organization operating

2.1.35 safety

state of being protected from or unlikely to cause danger, risk, or injury

[SOURCE: Oxford English Dictionary]

2.1.36 second life

second-use application of battery modules or pack at end of useful vehicle life

2.1.37 state of charge (SOC)

available capacity of a rechargeable energy storage system (RESS) or RESS subsystem expressed as a percentage of rated capacity

[SOURCE: BS ISO 6469-1:2019, 3.26]

¹⁾ The Health and Safety Executive (HSE) gives advice on the concept of As Low As Reasonably Practicable (ALARP) in their guidance which can be found at <https://www.hse.gov.uk/managing/theory/index.htm>

2.1.38 supply chain

network of organizations, directly or indirectly interlinked and interdependent, resources, activities and technology involved in the creation and sale of products and/or systems, and any related services, from the delivery of source material(s) from the supplier(s) to the manufacturing organization, through to eventual delivery to the end user

[SOURCE: PAS 11281:2018, 2.1.26]

2.1.39 system

interacting or interdependent set of things working together and forming an integrated whole

NOTE *Systems can be made up of smaller systems, or subsystems.*

[SOURCE: PAS 11281:2018, 2.1.27]

2.1.40 systems engineering

interdisciplinary approach governing the total technical and managerial effort required to transform a set of customer needs, expectations, and constraints into a solution and to support that solution throughout its life

[SOURCE: BS ISO/IEC/IEEE 24765:2017, 3.4127]

2.1.41 thermal event

condition when the temperature within the battery pack is significantly higher (as defined by the manufacturer) than the maximum operating temperature (even at reduced power)

[SOURCE: UNECE Draft global technical regulation on electric vehicle safety [7], modified]

2.1.42 thermal runaway

uncontrollable condition whereby a cell or battery might overheat and reach very high temperatures in very short periods (seconds) through internal heat generation caused due to an internal short or due to an abusive condition

[SOURCE: ISO 17546:2016, 3.37, modified]

2.1.43 traction battery

collection of all battery packs, which are electrically connected, for the supply of electric power to the electric drive and conductively connected auxiliary system, if any

[SOURCE: BS ISO 13063:2012, 3.32]

2.1.44 vehicle end-of-life

vehicle prepared to be scrapped but containing all essential components necessary for normal usage

NOTE 1 *The vehicle communication network and the power supply to the pyrotechnic devices in the vehicle are functioning.*

NOTE 2 *"To be scrapped" is defined for the purposes of this PAS as any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force.*

[SOURCE: BS ISO 26021-1:2008, 3.3 modified]

2.1.45 volumetric efficiency

maximum energy stored divided by the volume occupied by the storage system, usually measured at cell, module, pack and vehicle levels

2.2 Abbreviations

For the purpose of this PAS, the following abbreviations apply.

ac	alternating current
ALARP	as low as reasonably practicable
BCU	battery control unit
dc	direct current
DFMEA	design failure modes and effects analysis
EMS	environmental management system
EoL	end of life
ESD	electrostatic discharge
EV	electric vehicle (also known as electrically-propelled vehicle)
HSE	Health and Safety Executive
HV	high voltage
ICE	internal combustion engine
IDIS	international dismantlers information system
OEM	original equipment manufacturer (vehicle manufacturer)
PFMEA	process failure modes and effects analysis
PHEV	plug-in hybrid electric vehicle
PDI	pre-delivery inspection
QMS	quality management system
SOC	state of charge
V	volt
VIN	vehicle identification number

3 Quality

3.1 Quality policy and systems

3.1.1 The organization should have a documented quality management policy and system.

NOTE 1 *Within the automotive and vehicle industry BS EN ISO 9001 and IATF 16949 are the benchmarks for companies to demonstrate improvement in customer satisfaction, stakeholder relationships, legal compliance, operating costs and risk management.*

NOTE 2 *Attention is drawn to BS ISO 26262.*

3.1.2 From design of the product through to design of the manufacturing process, quality tools and techniques should be applied to ensure controls and countermeasures can either be applied at the product design stage or within the manufacturing process.

NOTE *An example of an applied quality tool is design failure modes and effects analysis (DFMEA) and process failure modes and effects analysis (PFMEA) to identify critical characteristics and significant characteristics which can be addressed during the product or process design stages or, if a design solution is not achievable, manage the risk through application of a manufacturing process control plan.*

3.2 Product quality

3.2.1 Through appropriate control plans, an organization should have systems for the detection of defective and damaged battery modules and packs through the manufacturing process.

NOTE *Examples of quality detection systems are:*

- a) *the application of chemical sensors at battery pack marriage to detect the presence of relevant chemicals which would identify internal failure modes;*
- b) *visual human or automated camera sensing for pack casing damage post pack marriage;*
- c) *the application of a positive pressure to the battery pack assembly to a defined pressure value to validate a pack assembly sealing design requirement.*

3.2.2 A product traceability system should be in place to ensure traceability of materials and components that are delivered into the manufacturing plant and are then used for controlled processing and assembly into battery modules and pack.

NOTE *A traceability system is normal business within a product manufacturing environment, however for battery module and pack manufacturing, it becomes critical to manage product quality and environmental traceability during manufacture, vehicle use and through to end-of-life.*

3.2.3 A documented process should be in place to describe each task in a manufacturing process, vehicle dealership or vehicle end of life/recycling process.

3.2.4 Total quality management (TQM) principles and tools such as mistake proofing (Poka Yoke) can be used to reduce risk of errors and hence improve safety.