BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

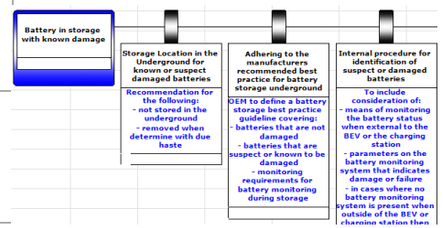
Red = need to confirm Blue = add on content

Battery in storage or being charged

Barriers & Escalation Factors (Original)	Revised Barries & Escalation Factors (working content)
Storage Location in the Underground for known or suspect damaged batteries ***Recommendation for the following:*** - store at least 100 m away (too specific) from of explosive storage or flammable / combustible material storage - store in the return air system - in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors - area to be remotely monitored (e.g. tied to remotely monitored system and camera) - in an area or through means that is protected from damage (blast, ground fall, etc.) - with a maximum quantity stored in location underground to be defined in the standard (consult ANSI standards and define for example based on ventilation capacity or ventilation risk assessment or something similar)	**Storage Location in the Underground for known or suspect damaged batteries** **Recommendation for the following:** - store at proper proximity distance from explosive storage or flammable / combustible material storage for safe installation, operation, maintenance and accessing in emergency situations. Also keep proper distance to minimize flame propagation to the next battery package - store in the return air system that directly flows to surface (i.e. does not flow across a drift, or level) - in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors, equipped with man door and fire monitoring system. - ensure storage location far away from ref. station or emergency egress - area to be remotely monitored (e.g. tied to remotely monitored system and camera) - in an area or through means that is protected from damage (blast, ground fall, etc.) - with a maximum quantity (tool to assess the max. quantity?) stored in storage/shop? location underground to be defined in the standard (consult ANSI standards and define for example based on ventilation capacity or ventilation risk assessment or something similar)
Adhering to the manufacturers recommended best practice for battery storage or in charging underground OEM to define a battery storage best practice guideline covering: - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during storage	**Adhering to the manufacturers recommended best practice for battery storage or in charging underground** OEM to define a battery storage best practice guideline covering: - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during storage
Internal procedure for battery storage or in charging specific to the site ***To include consideration of:*** - Job hazard / safety assessment - task based risk assessment - Battery storage requirements (including location, duration, enclosures) - Battery monitoring requirements (e.g. thermal cameras during monitoring etc.) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery storage or in charging specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - Battery storage requirements (including location, duration, enclosures) - Battery monitoring requirements (e.g. thermal cameras during monitoring etc.) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site
Monitoring capability ***Recommendation to have:*** - means of remotely monitoring the status of the batteries - means of remotely diagnosing issues associated with the batteries	**Monitoring capability** **Recommendation to have:** - means of remotely monitoring the status of the batteries from surface - means of remotely diagnosing issues associated with the batteries - means of monitoring the status of the batteries locally - find way to monitor the battery malfunction status if wireless communication is not available

Battery in storage with known damage

Barriers & Escalation Factors	Barriers & Escalation Factors (working content)
Storage Location in the Underground for known or suspect damaged batteries ***Recommendation for the following:*** - not stored in the underground - removed when determine with due haste	**Storage Location in the Underground for known ~~or suspect~~ damaged batteries** **Recommendation for the following:** - not stored in the underground - removed when determine with due haste
Adhering to the manufacturers recommended best practice for battery storage underground ***OEM to define a battery storage best practice guideline covering:*** - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during storage	**Adhering to the manufacturers recommended best practice for battery storage underground** **OEM to define a battery storage best practice guideline covering:** - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during storage



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

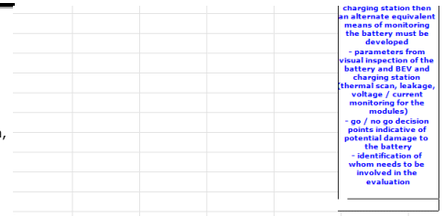
Internal procedure for identification of suspect or damaged batteries ***To include consideration of:*** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation	**Internal procedure for identification of ~~suspect or~~ damaged batteries** **To include consideration of:** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation

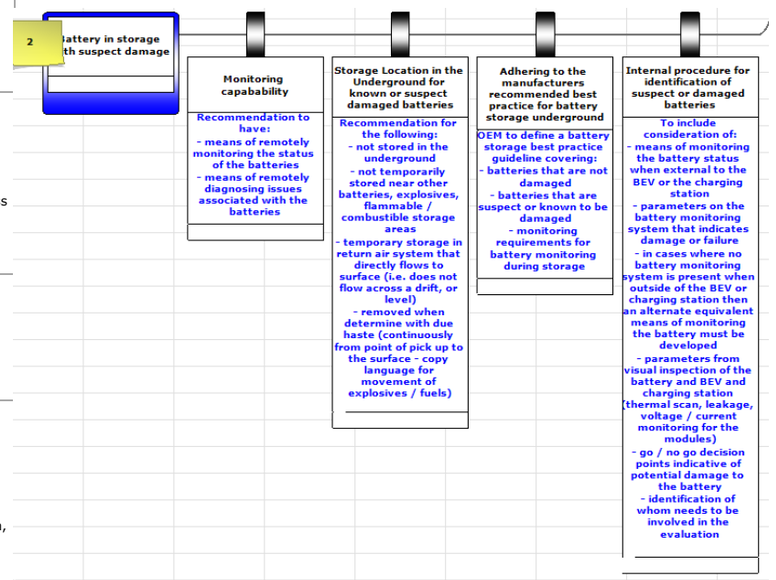
Battery in storage with suspect damage

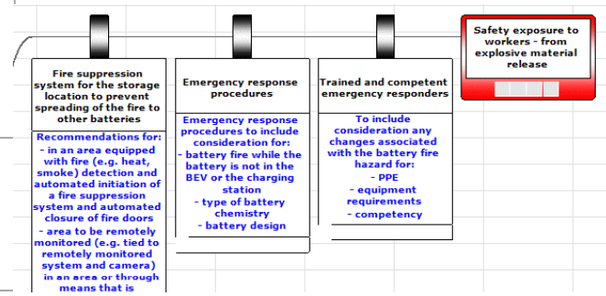
Barriers & Escalation Factors	Barriers & Escalation Factors
Monitoring capability ***Recommendation to have:*** - means of remotely monitoring the status of the batteries - means of remotely diagnosing issues associated with the batteries	**Monitoring capability** **Recommendation to have:** - means of remotely monitoring the status of the batteries - means of remotely diagnosing issues associated with the batteries
Storage Location in the Underground for known or suspect damaged batteries ***Recommendation for the following:*** - not stored in the underground - not temporarily stored near other batteries, explosives, flammable / combustible storage areas - temporary storage in return air system that directly flows to surface (i.e. does not flow across a drift, or level) - removed when determine with due haste (continuously from point of pick up to the surface - copy language for movement of explosives / fuels)	**Storage Location in the Underground for ~~known or~~ suspect damaged batteries** **Recommendation for the following:** - not stored in the underground - not temporarily stored near other batteries, explosives, flammable / combustible storage areas - temporary storage in return air system that directly flows to surface (i.e. does not flow across a drift, or level) - removed when determine with due haste (continuously from point of pick up to the surface - copy language for movement of explosives / fuels)
Adhering to the manufacturers recommended best practice for battery storage underground ***OEM to define a battery storage best practice guideline covering:*** - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during storage	**Adhering to the manufacturers recommended best practice for battery storage underground** **OEM to define a battery storage best practice guideline covering:** - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during storage
Internal procedure for identification of suspect or damaged batteries ***To include consideration of:*** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation	**Internal procedure for identification of suspect ~~or~~ damaged batteries** **To include consideration of:** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation

Safety exposure to workers - from explosive material release

Barriers & Escalation Factors	Barriers & Escalation Factors
Fire suppression system for the storage location to prevent spreading of the fire to other batteries ***Recommendations for:*** - in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors - area to be remotely monitored (e.g. tied to remotely monitored system and camera) - in an area or through means that is protected from damage (blast, ground fall, etc.)	**Fire suppression system for the storage location to prevent spreading of the fire to other batteries** **Recommendations for:** - in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors - area to be remotely monitored (e.g. tied to remotely monitored system and camera) - in an area or through means that is protected from damage (blast, ground fall, etc.)
Emergency response procedures ***Emergency response procedures to include consideration for:*** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design	**Emergency response procedures** **Emergency response procedures to include consideration for:** ~~- battery fire while the battery is not in the BEV or the charging station~~ - battery fire while the battery in the BEV, charging station and storage location - during tranporting the damaged battery to surface - type of battery chemistry - battery design







BowTie Group: New BowTie Group

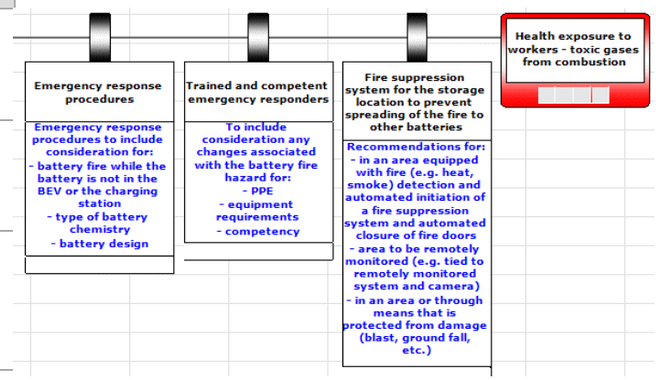
Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Trained and competent emergency responders ***To include consideration any changes associated with the battery fire hazard for:*** - PPE - equipment requirements - competency	**Trained and competent emergency responders** **To include consideration any changes associated with the battery fire hazard for:** - PPE based on SDS - equipment requirements - competency

_SDS

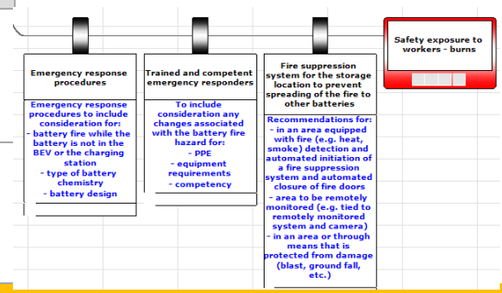
Health exposure to workers - toxic gases from combustion

Barriers & Escalation Factors	Barriers & Escalation Factors
Emergency response procedures ***Emergency response procedures to include consideration for:*** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design	**Emergency response procedures** **Emergency response procedures to include consideration for:** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design
Trained and competent emergency responders ***To include consideration any changes associated with the battery fire hazard for:*** - PPE - equipment requirements - competency	**Trained and competent emergency responders** **To include consideration any changes associated with the battery fire hazard for:** - PPE - equipment requirements - competency
Fire suppression system for the storage location to prevent spreading of the fire to other batteries ***Recommendations for:*** - in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors - area to be remotely monitored (e.g. tied to remotely monitored system and camera) - in an area or through means that is protected from damage (blast, ground fall, etc.)	Fire suppression system for the storage location to prevent spreading of the fire to other batteries Recommendations for: - in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors - area to be remotely monitored (e.g. tied to remotely monitored system and camera) - in an area or through means that is protected from damage (blast, ground fall, etc.)



Safety exposure to workers - burns

Barriers & Escalation Factors	Barriers & Escalation Factors
Emergency response procedures ***Emergency response procedures to include consideration for:*** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design	**Emergency response procedures** **Emergency response procedures to include consideration for:** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design
Fire suppression system for the storage location to prevent spreading of the fire to other batteries ***Recommendations for:*** - in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors - area to be remotely monitored (e.g. tied to remotely monitored system and camera) - in an area or through means that is protected from damage (blast, ground fall, etc.)	**Fire suppression system for the storage location to prevent spreading of the fire to other batteries** **Recommendations for:** - in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors - area to be remotely monitored (e.g. tied to remotely monitored system and camera) - in an area or through means that is protected from damage (blast, ground fall, etc.)



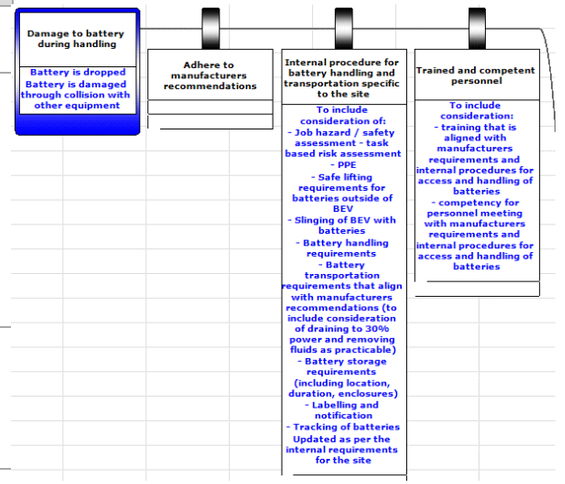
BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**
Hazard	**Rechargeable battery for battery electric vehicles**
Top event	**Battery fire during access and handling in the underground**

Damage to battery during handling

Battery is dropped
Battery is damaged through collision with other equipment

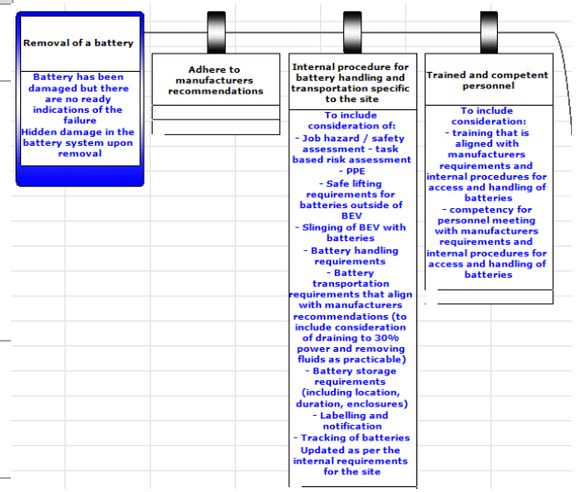
Barriers & Escalation Factors	
Adhere to manufacturers recommendations	**Adhere to manufacturers recommendations**
Internal procedure for battery handling and transportation specific to the site ***To include consideration of:*** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging of BEV with batteries - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations (to include consideration of draining to 30% power and removing fluids as practicable) - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery handling and transportation specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging of BEV with batteries - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations (to include consideration of draining to 30% power and removing fluids as practicable) - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site
Trained and competent personnel ***To include consideration:*** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries	**Trained and competent personnel** **To include consideration:** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries



Removal of a battery

Battery has been damaged but there are no ready indications of the failure
Hidden damage in the battery system upon removal

Barriers & Escalation Factors	Barriers & Escalation Factors
Adhere to manufacturers recommendations	**Adhere to manufacturers recommendations**
Internal procedure for battery handling and transportation specific to the site ***To include consideration of:*** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging of BEV with batteries - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations (to include consideration of draining to 30% power and removing fluids as practicable) - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery handling and transportation specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging of BEV with batteries - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations (to include consideration of draining to 30% power and removing fluids as practicable) - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site
Trained and competent personnel ***To include consideration:*** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries	**Trained and competent personnel** **To include consideration:** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries



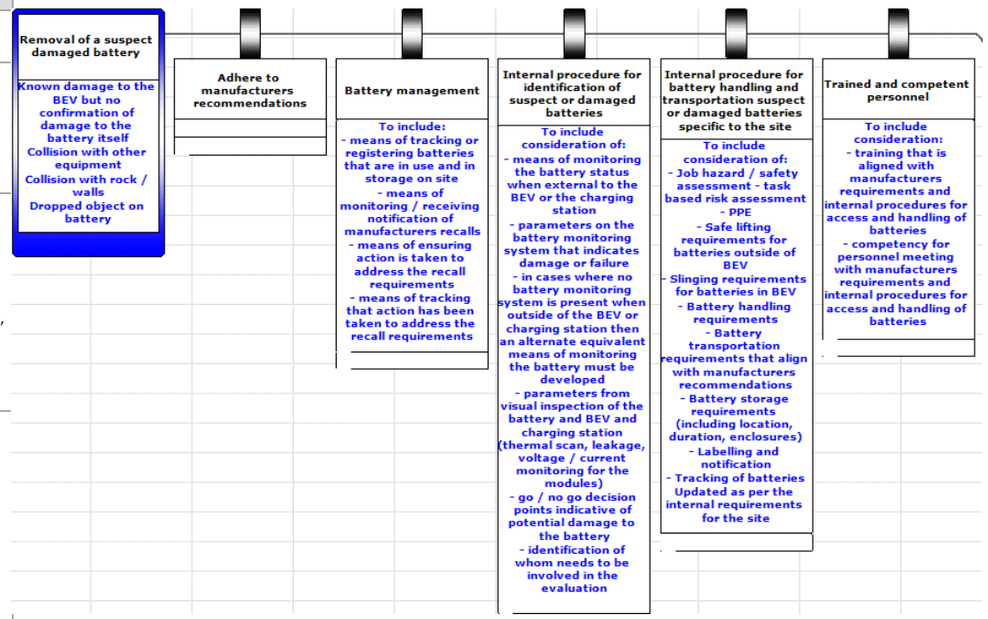
Removal of a suspect damaged battery

BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Known damage to the BEV but no confirmation of damage to the battery itself
Collision with other equipment
Collision with rock / walls
Dropped object on battery

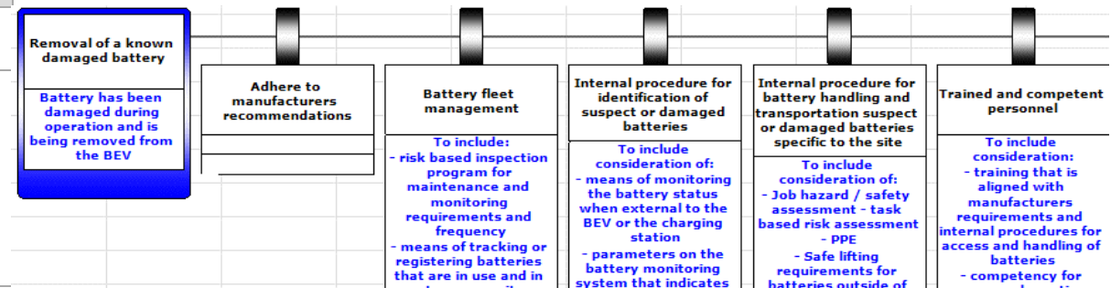
Barriers & Escalation Factors	
Adhere to manufacturers recommendations	**Adhere to manufacturers recommendations**
Battery management ***To include:*** - means of tracking or registering batteries that are in use and in storage on site - means of monitoring / receiving notification of manufacturers recalls - means of ensuring action is taken to address the recall requirements - means of tracking that action has been taken to address the recall requirements	**Battery management** **To include:** - means of tracking or registering batteries that are in use and in storage on site - means of monitoring / receiving notification of manufacturers recalls - means of ensuring action is taken to address the recall requirements - means of tracking that action has been taken to address the recall requirements
Internal procedure for identification of suspect or damaged batteries ***To include consideration of:*** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation	**Internal procedure for identification of suspect or damaged batteries** **To include consideration of:** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation
Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site ***To include consideration of:*** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site
Trained and competent personnel ***To include consideration:*** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries	**Trained and competent personnel** **To include consideration:** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries



Removal of a known damaged battery

Battery has been damaged during operation and is being removed from the BEV

Barriers & Escalation Factors	
Adhere to manufacturers recommendations	**Adhere to manufacturers recommendations**
Battery fleet management ***To include:*** - risk based inspection program for maintenance and monitoring requirements and frequency - means of tracking or registering batteries that are in use and in storage on site - means of managing and monitoring preventive and corrective maintenance associated with the batteries - means of knowing storage locations - means of monitoring / receiving notification of manufacturers recalls - means of ensuring action is taken to address the recall requirements - means of tracking that action has been taken to address the recall requirements	**Battery fleet management** **To include:** - risk based inspection program for maintenance and monitoring requirements and frequency - means of tracking or registering batteries that are in use and in storage on site - means of managing and monitoring preventive and corrective maintenance associated with the batteries - means of knowing storage locations - means of monitoring / receiving notification of manufacturers recalls - means of ensuring action is taken to address the recall requirements - means of tracking that action has been taken to address the recall requirements



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Internal procedure for identification of suspect or damaged batteries ***To include consideration of:*** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation	**Internal procedure for identification of suspect or damaged batteries** **To include consideration of:** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation
Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site ***To include consideration of:*** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site
Trained and competent personnel ***To include consideration:*** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries	**Trained and competent personnel** **To include consideration:** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries

Charging the battery at the battery charging station

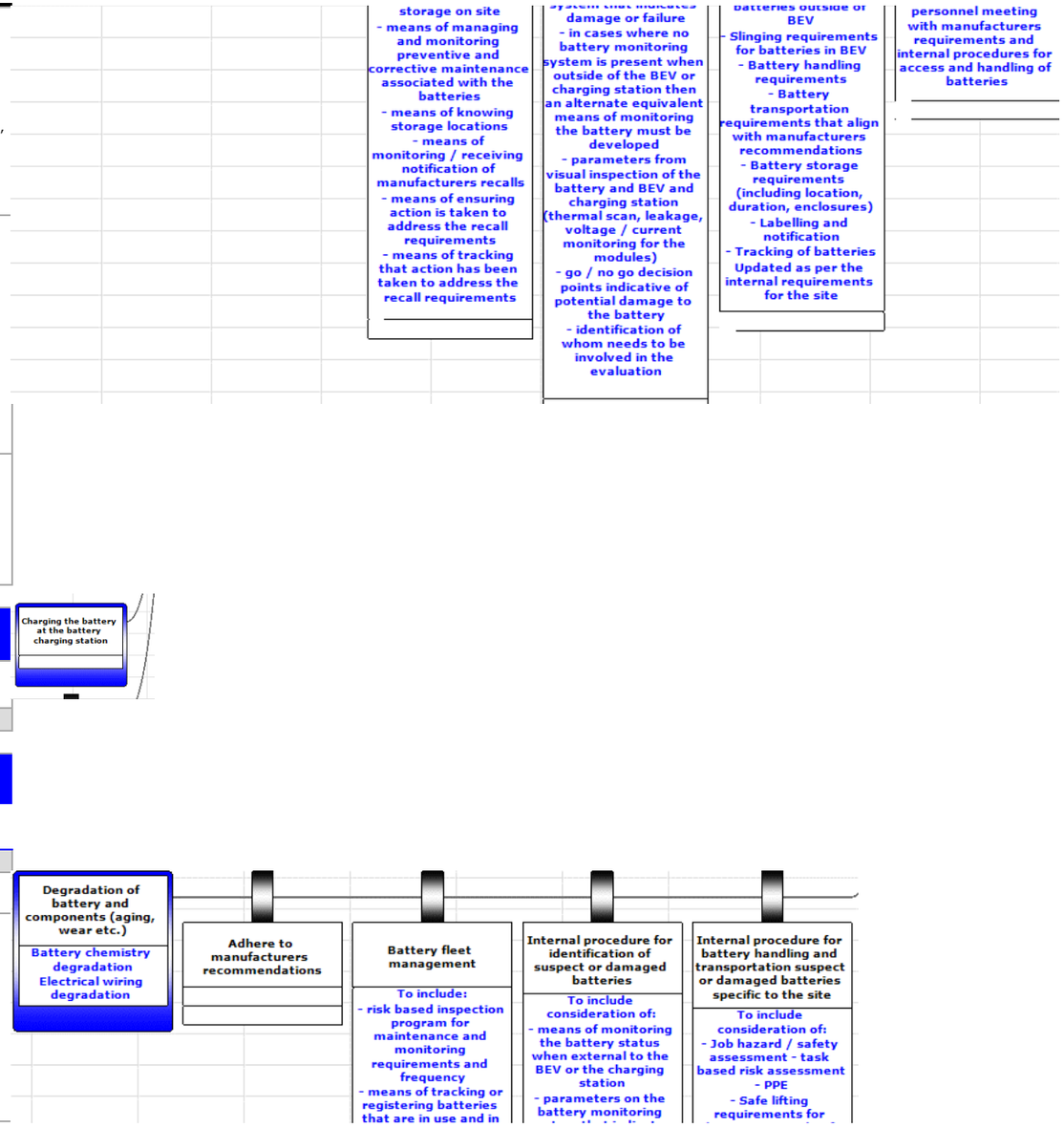
Need technical content

Barriers & Escalation Factors	

Degradation of battery and components (aging, wear etc.)

Battery chemistry degradation
Electrical wiring degradation

Barriers & Escalation Factors	Barriers & Escalation Factors
Adhere to manufacturers recommendations	Adhere to manufacturers recommendations
Battery fleet management ***To include:*** - risk based inspection program for maintenance and monitoring requirements and frequency - means of tracking or registering batteries that are in use and in storage on site - means of managing and monitoring preventive and corrective maintenance associated with the batteries - means of knowing storage locations - means of monitoring / receiving notification of manufacturers recalls - means of ensuring action is taken to address the recall requirements - means of tracking that action has been taken to address the recall requirements	**Battery fleet management** **To include:** - risk based inspection program for maintenance and monitoring requirements and frequency - means of tracking or registering batteries that are in use and in storage on site - means of managing and monitoring preventive and corrective maintenance associated with the batteries - means of knowing storage locations - means of monitoring / receiving notification of manufacturers recalls - means of ensuring action is taken to address the recall requirements - means of tracking that action has been taken to address the recall requirements



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

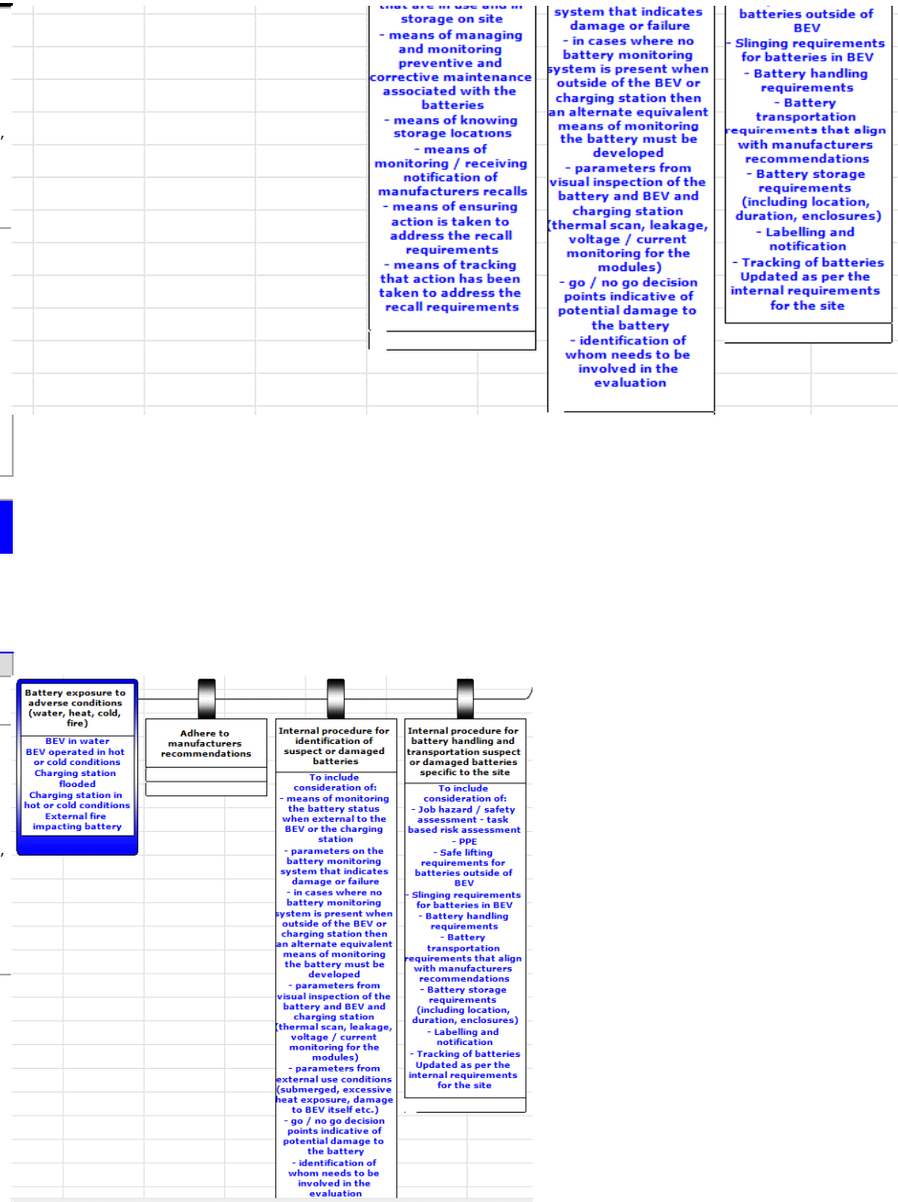
Internal procedure for identification of suspect or damaged batteries ***To include consideration of:*** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation	**Internal procedure for identification of suspect or damaged batteries** **To include consideration of:** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation
Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site ***To include consideration of:*** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery handling ~~and transportation~~ suspect or damaged batteries specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site

Battery exposure to adverse conditions (water, heat, cold, fire)

BEV in water
BEV operated in hot or cold conditions
Charging station flooded
Charging station in hot or cold conditions
External fire impacting battery

Barriers & Escalation Factors	Barriers & Escalation Factors
Adhere to manufacturers recommendations	Adhere to manufacturers recommendations
Internal procedure for identification of suspect or damaged batteries To include consideration of: - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - parameters from external use conditions (submerged, excessive heat exposure, damage to BEV itself etc.) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation	**Internal procedure for identification of suspect or damaged batteries** **To include consideration of:** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - parameters from external use conditions (submerged, excessive heat exposure, damage to BEV itself etc.) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation
Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site To include consideration of: - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site

Damage during maintenance / improper maintenance activities

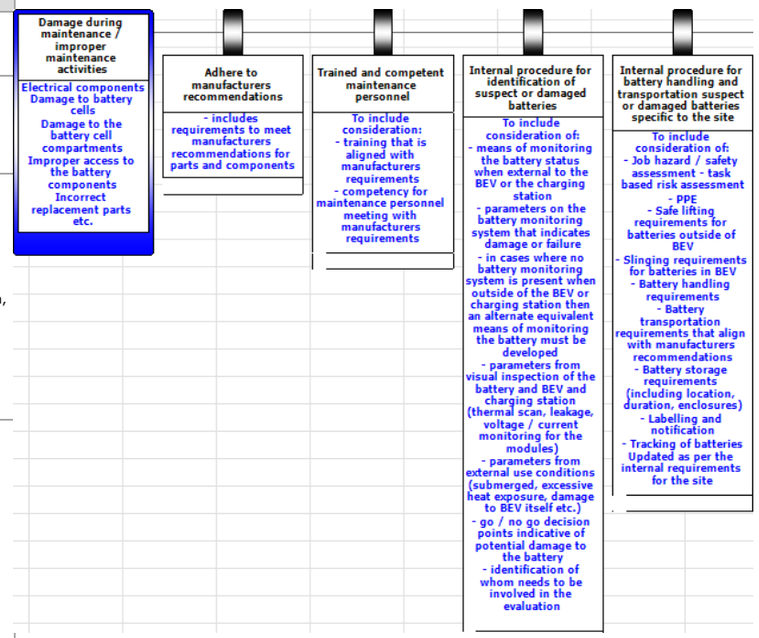


BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

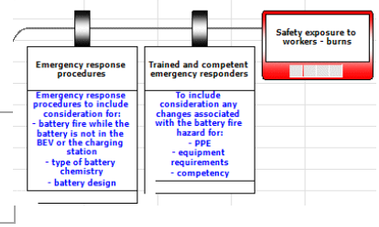
Electrical components
Damage to battery cells
Damage to the battery cell compartments
Improper access to the battery components
Incorrect replacement parts etc.

Barriers & Escalation Factors	Barriers & Escalation Factors
Adhere to manufacturers recommendations - includes requirements to meet manufacturers recommendations for parts and components	Adhere to manufacturers recommendations - includes requirements to meet manufacturers recommendations for parts and components
Trained and competent maintenance personnel ***To include consideration:*** - training that is aligned with manufacturers requirements - competency for maintenance personnel meeting with manufacturers requirements	**Trained and competent maintenance personnel** **To include consideration:** - training that is aligned with manufacturers requirements - competency for maintenance personnel meeting with manufacturers requirements
Internal procedure for identification of suspect or damaged batteries ***To include consideration of:*** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - parameters from external use conditions (submerged, excessive heat exposure, damage to BEV itself etc.) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation	**Internal procedure for identification of suspect or damaged batteries** **To include consideration of:** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - parameters from external use conditions (submerged, excessive heat exposure, damage to BEV itself etc.) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation
Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site ***To include consideration of:*** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery handling ~~and transportation~~ suspect or damaged batteries specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site



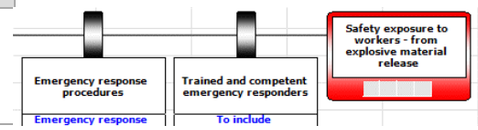
Safety exposure to workers - burns

Barriers & Escalation Factors	
Emergency response procedures ***Emergency response procedures to include consideration for:*** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design	**Emergency response procedures** **Emergency response procedures to include consideration for:** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design
Trained and competent emergency responders ***To include consideration any changes associated with the battery fire hazard for:*** - PPE - equipment requirements - competency	**Trained and competent emergency responders** **To include consideration any changes associated with the battery fire hazard for:** - PPE - equipment requirements - competency



Safety exposure to workers - from explosive material release

Barriers & Escalation Factors	
Emergency response procedures ***Emergency response procedures to include consideration for:*** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design	**Emergency response procedures** **Emergency response procedures to include consideration for:** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design



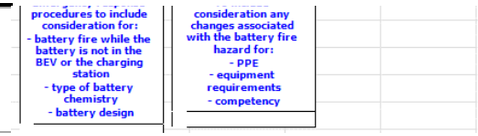
BowTie Group: New BowTie Group

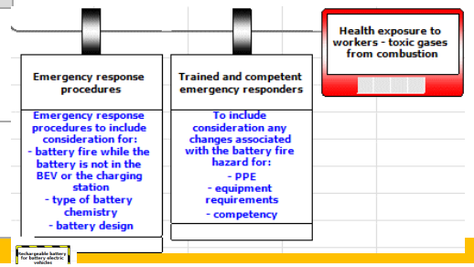
Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Trained and competent emergency responders ***To include consideration any changes associated with the battery fire hazard for:*** - PPE - equipment requirements - competency	**Trained and competent emergency responders** **To include consideration any changes associated with the battery fire hazard for:** - PPE - equipment requirements - competency

Health exposure to workers - toxic gases from combustion

Barriers & Escalation Factors	Barriers & Escalation Factors
Emergency response procedures ***Emergency response procedures to include consideration for:*** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design	**Emergency response procedures** **Emergency response procedures to include consideration for:** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design
Trained and competent emergency responders ***To include consideration any changes associated with the battery fire hazard for:*** - PPE - equipment requirements - competency	**Trained and competent emergency responders** **To include consideration any changes associated with the battery fire hazard for:** - PPE - equipment requirements - competency





BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**
Hazard	**Rechargeable battery for battery electric vehicles**
Top event	**Battery fire during transportation (from the portal or the collar into the underground)**

Transportation of a known damaged battery

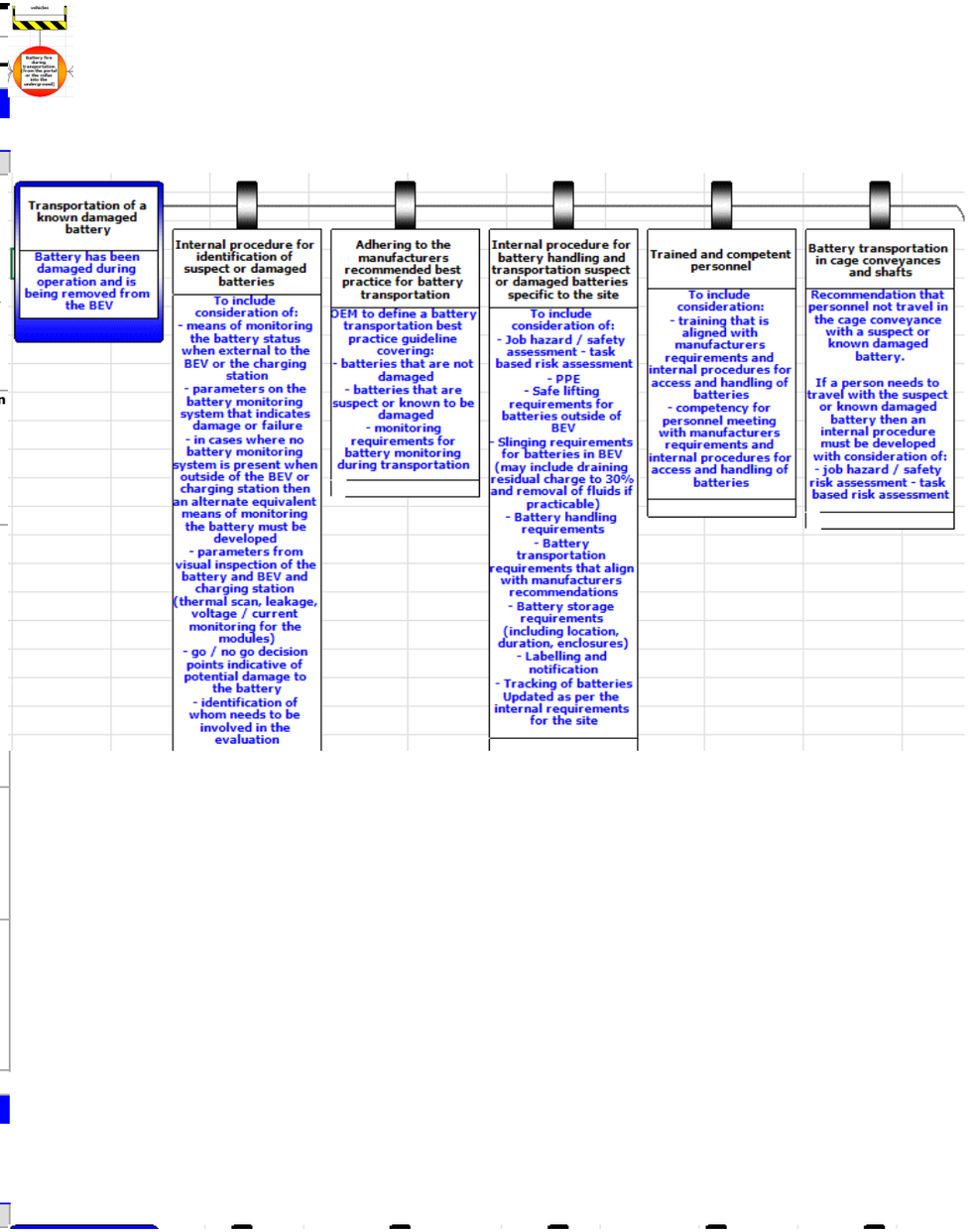
Battery has been damaged during operation and is being removed from the BEV

Barriers & Escalation Factors	Barriers & Escalation Factors
Internal procedure for identification of suspect or damaged batteries ***To include consideration of:*** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation	**Internal procedure for identification of suspect or damaged batteries** **To include consideration of:** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation
Adhering to the manufacturers recommended best practice for battery transportation ***OEM to define a battery transportation best practice guideline covering:*** - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during transportation	**Adhering to the manufacturers recommended best practice for battery transportation** **OEM to define a battery transportation best practice guideline covering:** - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during transportation
Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site ***To include consideration of:*** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV (may include draining residual charge to 30% and removal of fluids if practicable) - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery ~~handling and~~ transportation suspect or damaged batteries specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV (may include draining residual charge to 30% and removal of fluids if practicable) - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site
Trained and competent personnel ***To include consideration:*** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries	**Trained and competent personnel** **To include consideration:** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries
Battery transportation in cage conveyances and shafts Recommendation that personnel not travel in the cage conveyance with a suspect or known damaged battery. If a person needs to travel with the suspect or known damaged battery then an internal procedure must be developed with consideration of: - job hazard / safety risk assessment - task based risk assessment	**Battery transportation in cage conveyances and shafts** Recommendation that personnel not travel in the cage conveyance with a suspect or known damaged battery. If a person needs to travel with the suspect or known damaged battery then an internal procedure must be developed with consideration of: - job hazard / safety risk assessment - task based risk assessment

Transportation of a suspect damaged battery

Known damage to the BEV but no confirmation of damage to the battery itself
Collision with other equipment
Collision with rock / walls
Dropped object on battery

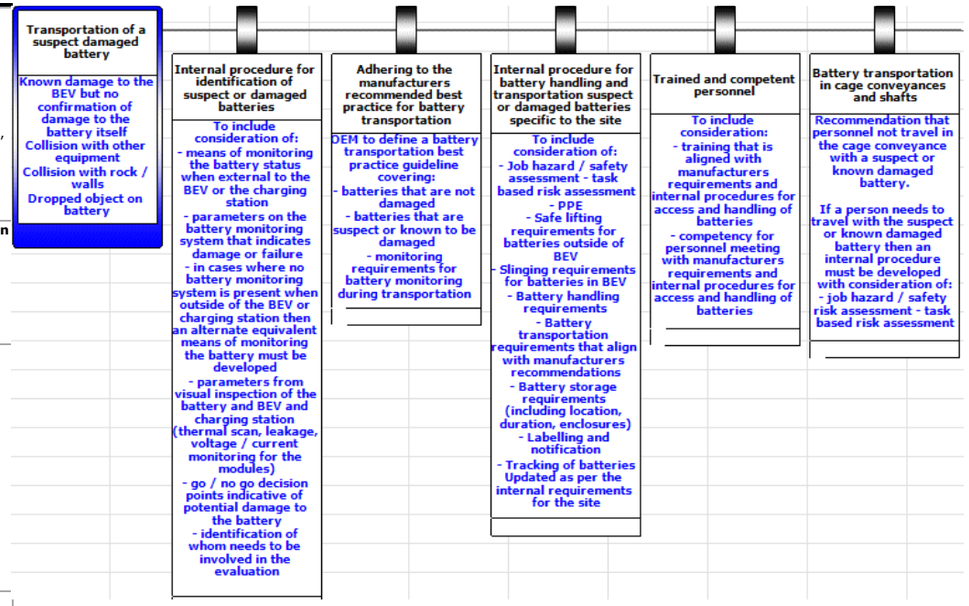
Barriers & Escalation Factors	Barriers & Escalation Factors



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

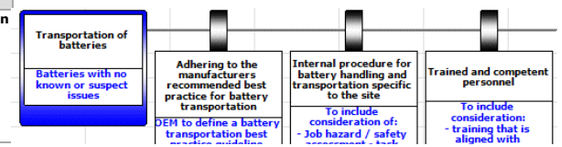
Internal procedure for identification of suspect or damaged batteries ***To include consideration of:*** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation	**Internal procedure for identification of suspect or damaged batteries** **To include consideration of:** - means of monitoring the battery status when external to the BEV or the charging station - parameters on the battery monitoring system that indicates damage or failure - in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed - parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules) - go / no go decision points indicative of potential damage to the battery - identification of whom needs to be involved in the evaluation
Adhering to the manufacturers recommended best practice for battery transportation ***OEM to define a battery transportation best practice guideline covering:*** - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during transportation	**Adhering to the manufacturers recommended best practice for battery transportation** **OEM to define a battery transportation best practice guideline covering:** - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during transportation
Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site ***To include consideration of:*** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging requirements for batteries in BEV - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site
Trained and competent personnel ***To include consideration:*** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries	**Trained and competent personnel** **To include consideration:** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries
Battery transportation in cage conveyances and shafts Recommendation that personnel not travel in the cage conveyance with a suspect or known damaged battery. If a person needs to travel with the suspect or known damaged battery then an internal procedure must be developed with consideration of: - job hazard / safety risk assessment - task based risk assessment	**Battery transportation in cage conveyances and shafts** Recommendation that personnel not travel in the cage conveyance with a suspect or known damaged battery. If a person needs to travel with the suspect or known damaged battery then an internal procedure must be developed with consideration of: - job hazard / safety risk assessment - task based risk assessment



Transportation of batteries

Batteries with no known or suspect issues

Barriers & Escalation Factors	Barriers & Escalation Factors
Adhering to the manufacturers recommended best practice for battery transportation ***OEM to define a battery transportation best practice guideline covering:*** - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during transportation	**Adhering to the manufacturers recommended best practice for battery transportation** **OEM to define a battery transportation best practice guideline covering:** - batteries that are not damaged - batteries that are suspect or known to be damaged - monitoring requirements for battery monitoring during transportation



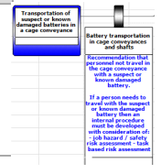
BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Internal procedure for battery handling and transportation specific to the site ***To include consideration of:*** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging of BEV with batteries - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations (to include consideration of draining to 30% power and removing fluids as practicable) - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site	**Internal procedure for battery handling and transportation specific to the site** **To include consideration of:** - Job hazard / safety assessment - task based risk assessment - PPE - Safe lifting requirements for batteries outside of BEV - Slinging of BEV with batteries - Battery handling requirements - Battery transportation requirements that align with manufacturers recommendations (to include consideration of draining to 30% power and removing fluids as practicable) - Battery storage requirements (including location, duration, enclosures) - Labelling and notification - Tracking of batteries Updated as per the internal requirements for the site
Trained and competent personnel ***To include consideration:*** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries	**Trained and competent personnel** **To include consideration:** - training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries - competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries

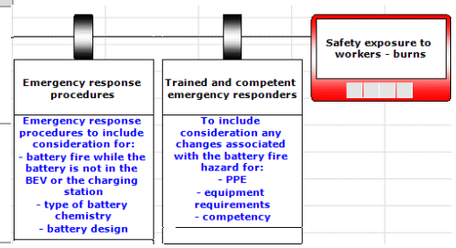
Transportation of suspect or known damaged batteries in a cage conveyance

Barriers & Escalation Factors	Barriers & Escalation Factors
Battery transportation in cage conveyances and shafts Recommendation that personnel not travel in the cage conveyance with a suspect or known damaged battery. If a person needs to travel with the suspect or known damaged battery then an internal procedure must be developed with consideration of: - job hazard / safety risk assessment - task based risk assessment	Battery transportation in cage conveyances and shafts Recommendation that personnel not travel in the cage conveyance with a suspect or known damaged battery. If a person needs to travel with the suspect or known damaged battery then an internal procedure must be developed with consideration of: - job hazard / safety risk assessment - task based risk assessment



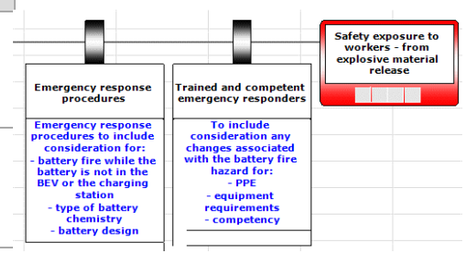
Safety exposure to workers - burns

Barriers & Escalation Factors	Barriers & Escalation Factors
Emergency response procedures ***Emergency response procedures to include consideration for:*** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design	Emergency response procedures Emergency response procedures to include consideration for: - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design
Trained and competent emergency responders ***To include consideration any changes associated with the battery fire hazard for:*** - PPE - equipment requirements - competency	Trained and competent emergency responders To include consideration any changes associated with the battery fire hazard for: - PPE - equipment requirements - competency



Safety exposure to workers - from explosive material release

Barriers & Escalation Factors	Barriers & Escalation Factors
Emergency response procedures ***Emergency response procedures to include consideration for:*** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design	**Emergency response procedures** **Emergency response procedures to include consideration for:** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design
Trained and competent emergency responders ***To include consideration any changes associated with the battery fire hazard for:*** - PPE - equipment requirements - competency	**Trained and competent emergency responders** **To include consideration any changes associated with the battery fire hazard for:** - PPE - equipment requirements - competency

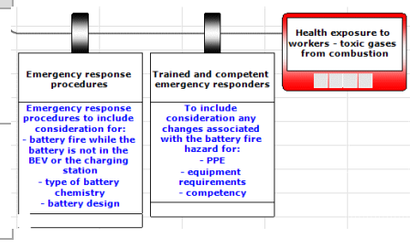


Health exposure to workers - toxic gases from combustion

BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Barriers & Escalation Factors	Barriers & Escalation Factors
Emergency response procedures ***Emergency response procedures to include consideration for:*** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design	**Emergency response procedures** **Emergency response procedures to include consideration for:** - battery fire while the battery is not in the BEV or the charging station - type of battery chemistry - battery design
Trained and competent emergency responders ***To include consideration any changes associated with the battery fire hazard for:*** - PPE - equipment requirements - competency	**Trained and competent emergency responders** **To include consideration any changes associated with the battery fire hazard for:** - PPE - equipment requirements - competency



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Battery in storage or being charged

Barriers & Escalation Factors (Original)

Storage Location in the Underground for known or suspect damaged batteries

Recommendation for the following:
- store at proper proximity distance from explosive storage or flammable / combustible material storage for safe installation, operation, maintenance and accessing in emergency situations. Also keep proper distance to minimize flame propagation to the next battery package
- store in the return air system that directly flows to surface (i.e. does not flow across a drift, or level)
- in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors, equipped with man door and fire monitoring system.
- ensure storage location far away from ref. station or emergency egress
- area to be remotely monitored (e.g. tied to remotely monitored system and camera)
- in an area or through means that is protected from damage (blast, ground fall, etc.)
- with a maximum quantity (tool to assess the max. quantity?) stored in storage/shop? location underground to be defined in the standard (consult ANSI standards and define for example based on ventilation capacity or ventilation risk assessment or something similar)

Adhering to the manufacturers recommended best practice for battery storage or in charging underground

OEM to define a battery storage best practice guideline covering:
- batteries that are not damaged
- batteries that are suspect or known to be damaged
- monitoring requirements for battery monitoring during storage

Internal procedure for battery storage or in charging specific to the site

To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- Battery storage requirements (including location, duration, enclosures)
- Battery monitoring requirements (e.g. thermal cameras during monitoring etc.)
- Labelling and notification
- Tracking of batteries

Updated as per the internal requirements for the site

Monitoring capabability

Recommendation to have:
- means of remotely monitoring the status of the batteries from surface
- means of remotely diagnosing issues associated with the batteries
- means of monitoring the status of the batteries locally
- find way to monitor the battery malfunction status if wireless communication is not available

Battery in storage with known damage

Barriers & Escalation Factors

BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Storage Location in the Underground for known damaged batteries

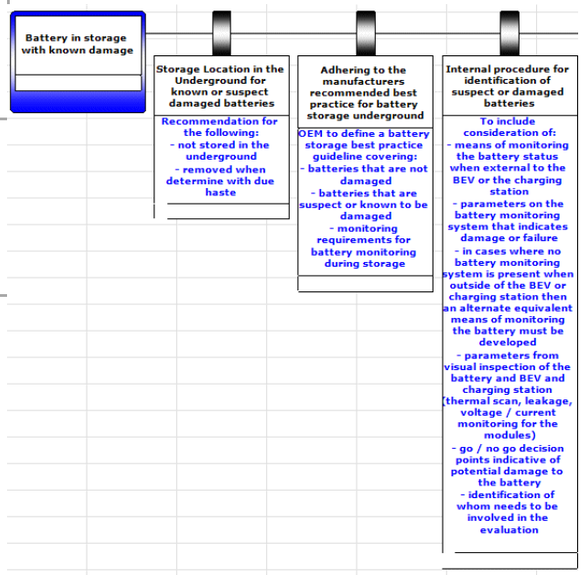
Recommendation for the following:
- not stored in the underground
- removed when determine with due haste

Adhering to the manufacturers recommended best practice for battery storage underground

OEM to define a battery storage best practice guideline covering:
- batteries that are not damaged
- batteries that are suspect or known to be damaged
- monitoring requirements for battery monitoring during storage

Internal procedure for identification damaged batteries

To include consideration of:
- means of monitoring the battery status when external to the BEV or the charging station
- parameters on the battery monitoring system that indicates damage or failure
- in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed
- parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules)
- go / no go decision points indicative of potential damage to the battery
- identification of whom needs to be involved in the evaluation



Battery in storage with suspect damage

Barriers & Escalation Factors

Monitoring capabability

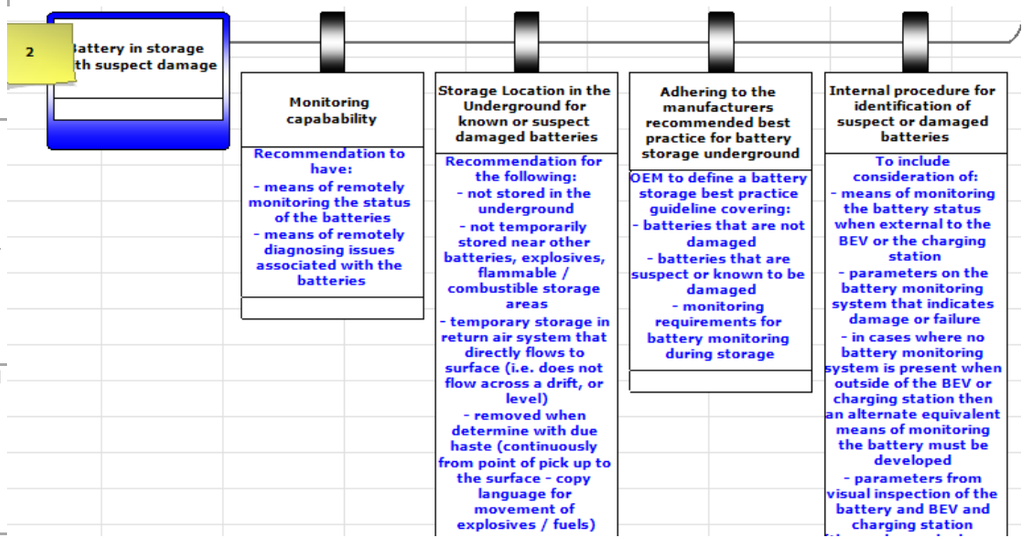
Recommendation to have:
- means of remotely monitoring the status of the batteries
- means of remotely diagnosing issues associated with the batteries

Storage Location in the Underground for suspect damaged batteries

Recommendation for the following:
- not stored in the underground
- not temporarily stored near other batteries, explosives, flammable / combustible storage areas
- temporary storage in return air system that directly flows to surface (i.e. does not flow across a drift, or level)
- removed when determine with due haste (continuously from point of pick up to the surface - copy language for movement of explosives / fuels)

Adhering to the manufacturers recommended best practice for battery storage underground

OEM to define a battery storage best practice guideline covering:
- batteries that are not damaged
- batteries that are suspect or known to be damaged
- monitoring requirements for battery monitoring during storage

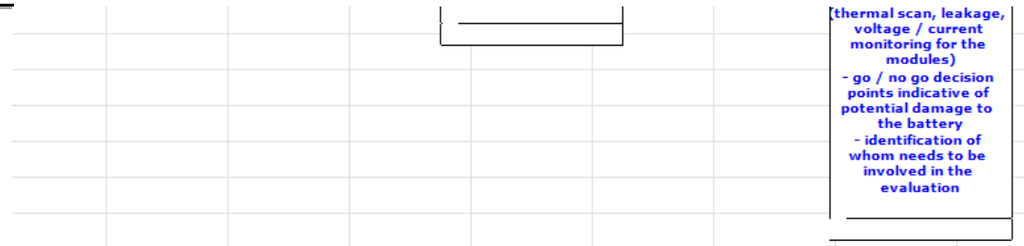


BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Internal procedure for identification of suspect damaged batteries

To include consideration of:
- means of monitoring the battery status when external to the BEV or the charging station
- parameters on the battery monitoring system that indicates damage or failure
- in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed
- parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules)
- go / no go decision points indicative of potential damage to the battery
- identification of whom needs to be involved in the evaluation



Safety exposure to workers - from explosive material release

Barriers & Escalation Factors

Fire suppression system for the storage location to prevent spreading of the fire to other batteries

Recommendations for:
- in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors
- area to be remotely monitored (e.g. tied to remotely monitored system and camera)
- in an area or through means that is protected from damage (blast, ground fall, etc.)

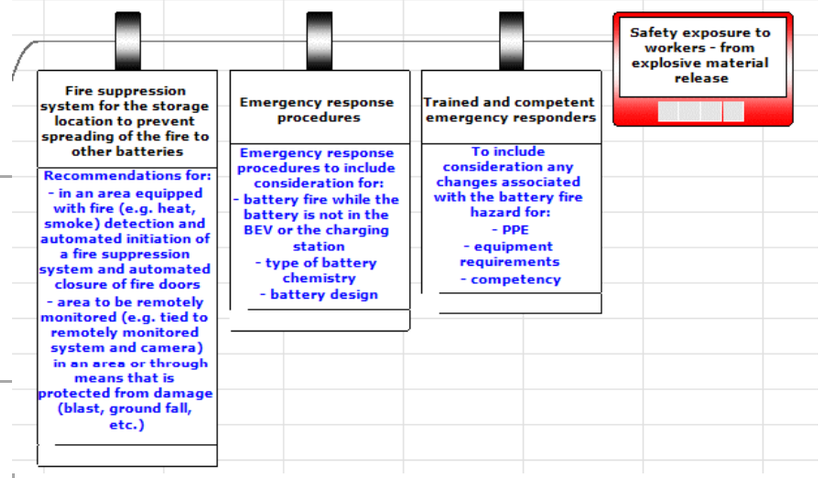
Emergency response procedures

Emergency response procedures to include consideration for:
- battery fire while the battery in the BEV, charging station and storage location
- during tranporting the damaged battery to surface
- type of battery chemistry
- battery design

Trained and competent emergency responders

To include consideration any changes associated with the battery fire hazard for:
- PPE based on SDS
- equipment requirements
- competency

_SDS

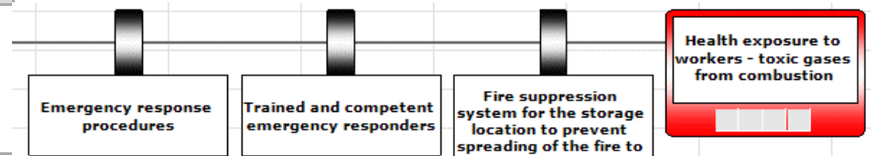


Health exposure to workers - toxic gases from combustion

Barriers & Escalation Factors

Emergency response procedures

Emergency response procedures to include consideration for:
- battery fire while the battery is not in the BEV or the charging station
- type of battery chemistry
- battery design



BowTie Group: New BowTie Group

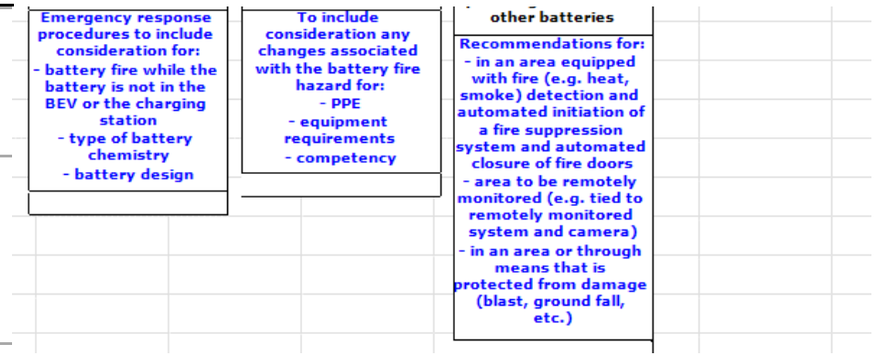
Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Trained and competent emergency responders

To include consideration any changes associated with the battery fire hazard for:
- PPE
- equipment requirements
- competency

Fire suppression system for the storage location to prevent spreading of the fire to other batteries

Recommendations for:
- in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors
- area to be remotely monitored (e.g. tied to remotely monitored system and camera)
- in an area or through means that is protected from damage (blast, ground fall, etc.)



Safety exposure to workers - burns

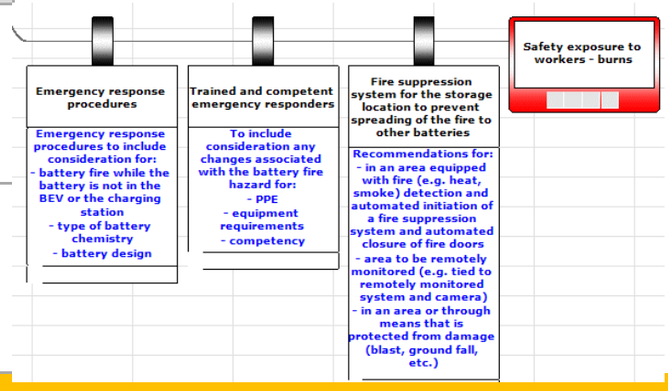
Barriers & Escalation Factors

Emergency response procedures

Emergency response procedures to include consideration for:
- battery fire while the battery is not in the BEV or the charging station
- type of battery chemistry
- battery design

Fire suppression system for the storage location to prevent spreading of the fire to other batteries

Recommendations for:
- in an area equipped with fire (e.g. heat, smoke) detection and automated initiation of a fire suppression system and automated closure of fire doors
- area to be remotely monitored (e.g. tied to remotely monitored system and camera)
- in an area or through means that is protected from damage (blast, ground fall, etc.)



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**
Hazard	**Rechargeable battery for battery electric vehicles**
Top event	**Battery fire during access and handling in the underground**

Damage to battery during handling

Battery is dropped
Battery is damaged through collision with other equipment

Barriers & Escalation Factors

Adhere to manufacturers recommendations

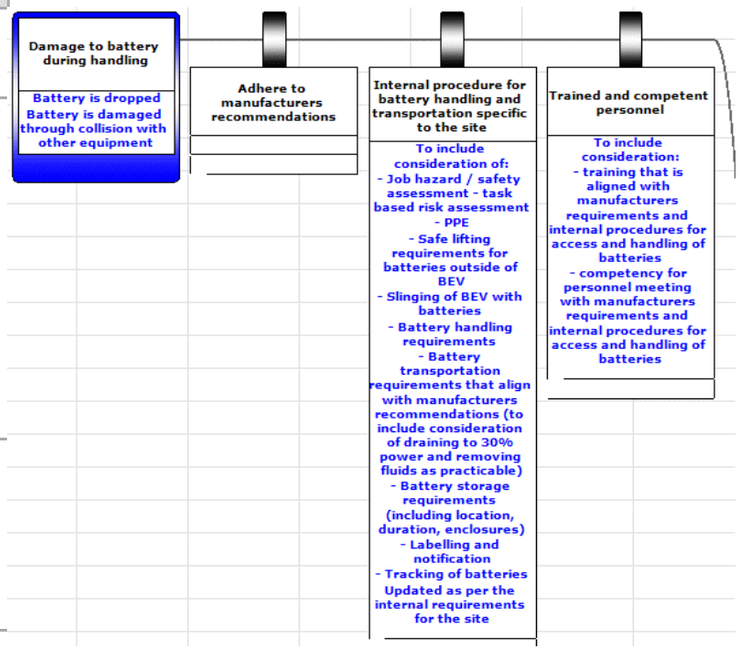
Internal procedure for battery handling and transportation specific to the site

To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- PPE
- Safe lifting requirements for batteries outside of BEV
- Slinging of BEV with batteries
- Battery handling requirements
- Battery transportation requirements that align with manufacturers recommendations (to include consideration of draining to 30% power and removing fluids as practicable)
- Battery storage requirements (including location, duration, enclosures)
- Labelling and notification
- Tracking of batteries

Updated as per the internal requirements for the site

Trained and competent personnel

To include consideration:
- training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries
- competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries

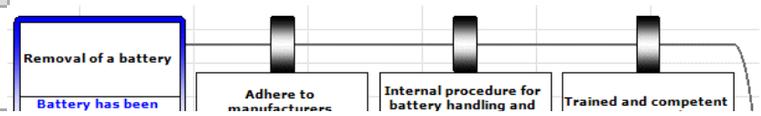


Removal of a battery

Battery has been damaged but there are no ready indications of the failure
Hidden damage in the battery system upon removal

Barriers & Escalation Factors

Adhere to manufacturers recommendations



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Internal procedure for battery handling and transportation specific to the site

To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- PPE
- Safe lifting requirements for batteries outside of BEV
- Slinging of BEV with batteries
- Battery handling requirements
- Battery transportation requirements that align with manufacturers recommendations (to include consideration of draining to 30% power and removing fluids as practicable)
- Battery storage requirements (including location, duration, enclosures)
- Labelling and notification
- Tracking of batteries

Updated as per the internal requirements for the site

Trained and competent personnel

To include consideration:
- training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries
- competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries

Removal of a suspect damaged battery

Known damage to the BEV but no confirmation of damage to the battery itself
Collision with other equipment
Collision with rock / walls
Dropped object on battery

Barriers & Escalation Factors

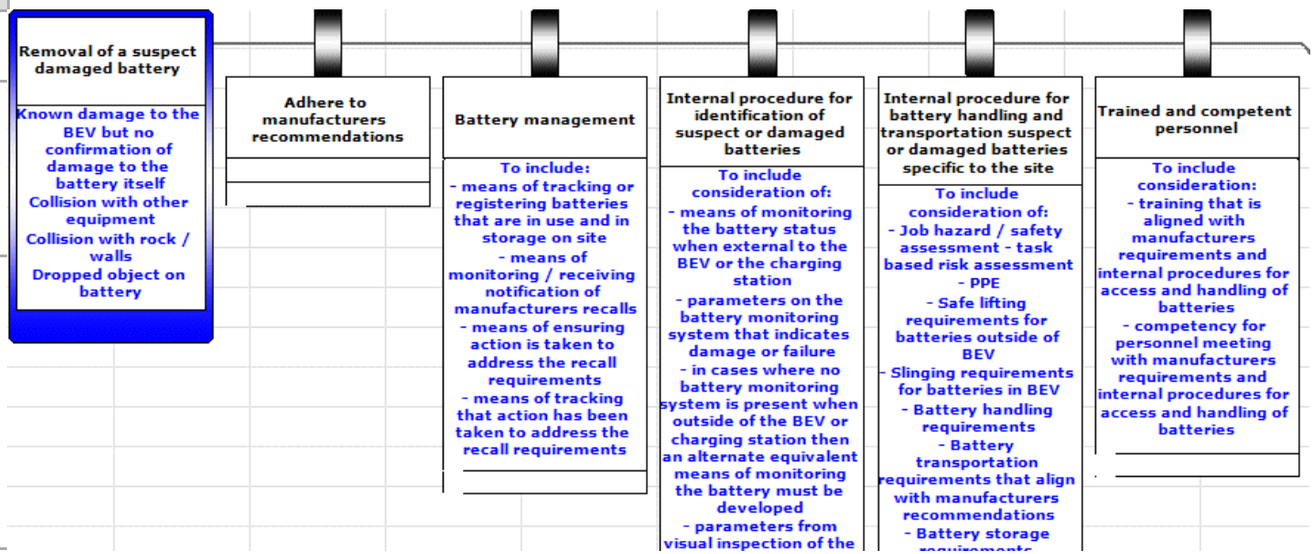
Adhere to manufacturers recommendations

Battery management

To include:
- means of tracking or registering batteries that are in use and in storage on site
- means of monitoring / receiving notification of manufacturers recalls
- means of ensuring action is taken to address the recall requirements
- means of tracking that action has been taken to address the recall requirements

Internal procedure for identification of suspect or damaged batteries

To include consideration of:
- means of monitoring the battery status when external to the BEV or the charging station
- parameters on the battery monitoring system that indicates damage or failure
- in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed
- parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules)
- go / no go decision points indicative of potential damage to the battery
- identification of whom needs to be involved in the evaluation



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site

To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- PPE
- Safe lifting requirements for batteries outside of BEV
- Slinging requirements for batteries in BEV
- Battery handling requirements
- Battery transportation requirements that align with manufacturers recommendations
- Battery storage requirements (including location, duration, enclosures)
- Labelling and notification
- Tracking of batteries

Updated as per the internal requirements for the site

Trained and competent personnel

To include consideration:
- training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries
- competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries

Removal of a suspect damaged battery

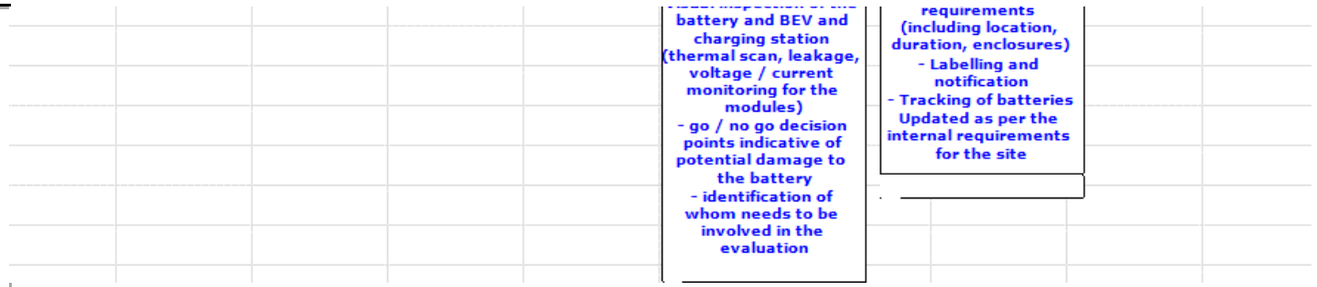
Known damage to the BEV but no confirmation of damage to the battery itself
Collision with other equipment

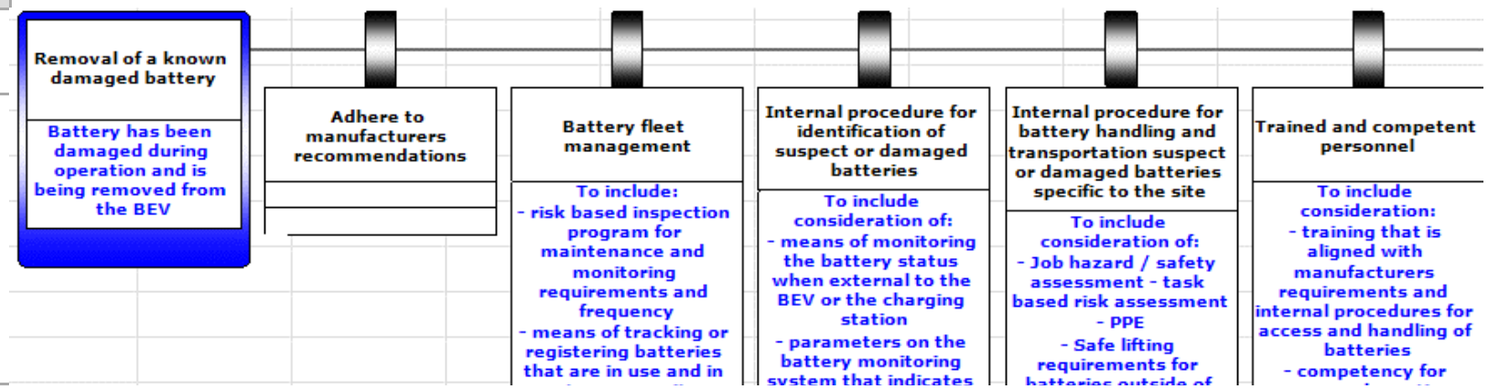
Barriers & Escalation Factors

Adhere to manufacturers recommendations

Battery management

To include:
- means of tracking or registering batteries that are in use and in storage on site
- means of monitoring / receiving notification of manufacturers recalls
- means of ensuring action is taken to address the recall requirements
- means of tracking that action has been taken to address the recall requirements





BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Internal procedure for identification of suspect or damaged batteries

To include consideration of:
- means of monitoring the battery status when external to the BEV or the charging station
- parameters on the battery monitoring system that indicates damage or failure
- in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed
- parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules)
- go / no go decision points indicative of potential damage to the battery
- identification of whom needs to be involved in the evaluation

Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site

To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- PPE
- Safe lifting requirements for batteries outside of BEV
- Slinging requirements for batteries in BEV
- Battery handling requirements
- Battery transportation requirements that align with manufacturers recommendations
- Battery storage requirements (including location, duration, enclosures)
- Labelling and notification
- Tracking of batteries

Updated as per the internal requirements for the site

Trained and competent personnel

To include consideration:
- training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries
- competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries

Charging the battery at the battery charging station

Need technical content

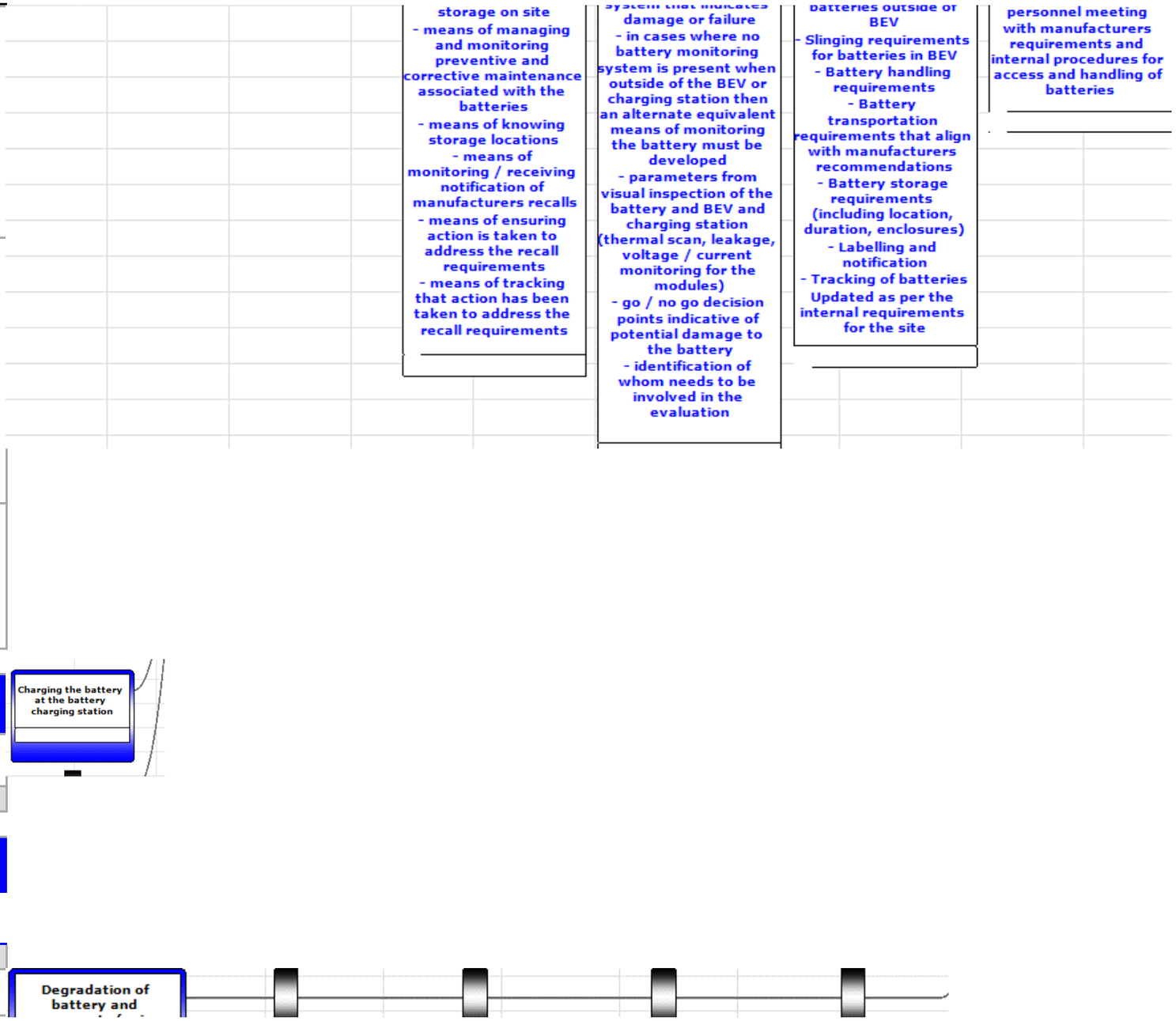
Barriers & Escalation Factors

Degradation of battery and components (aging, wear etc.)

Battery chemistry degradation
Electrical wiring degradation

Barriers & Escalation Factors

Adhere to manufacturers recommendations



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Battery fleet management

To include:
- risk based inspection program for maintenance and monitoring requirements and frequency
- means of tracking or registering batteries that are in use and in storage on site
- means of managing and monitoring preventive and corrective maintenance associated with the batteries
- means of knowing storage locations
- means of monitoring / receiving notification of manufacturers recalls
- means of ensuring action is taken to address the recall requirements
- means of tracking that action has been taken to address the recall requirements

Internal procedure for identification of suspect or damaged batteries

To include consideration of:
- means of monitoring the battery status when external to the BEV or the charging station
- parameters on the battery monitoring system that indicates damage or failure
- in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed
- parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules)
- go / no go decision points indicative of potential damage to the battery
- identification of whom needs to be involved in the evaluation

Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site

To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- PPE
- Safe lifting requirements for batteries outside of BEV
- Slinging requirements for batteries in BEV
- Battery handling requirements
- Battery transportation requirements that align with manufacturers recommendations
- Battery storage requirements (including location, duration, enclosures)
- Labelling and notification
- Tracking of batteries

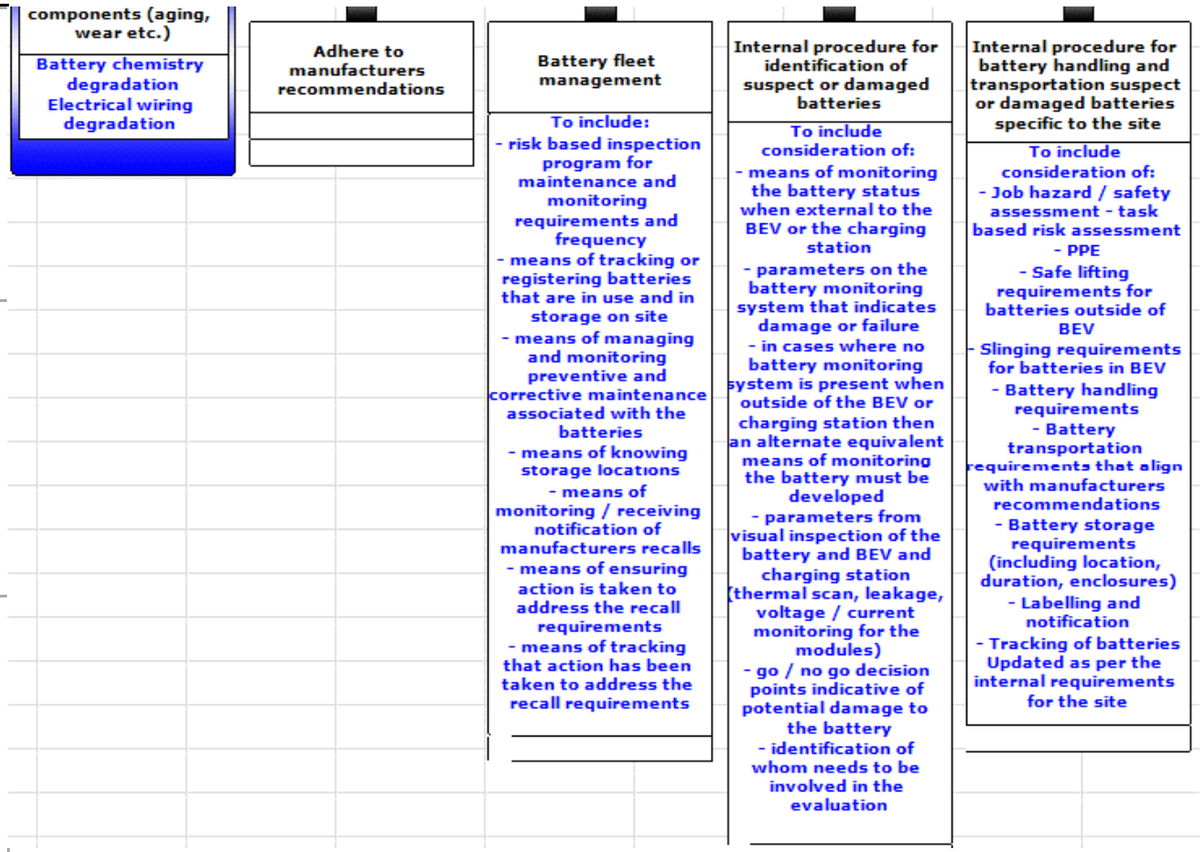
Updated as per the internal requirements for the site

Degradation of battery and components (aging, wear etc.)

Battery chemistry degradation
Electrical wiring degradation

Barriers & Escalation Factors

Adhere to manufacturers recommendations



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Battery fleet management

To include:
- risk based inspection program for maintenance and monitoring requirements and frequency
- means of tracking or registering batteries that are in use and in storage on site
- means of managing and monitoring preventive and corrective maintenance associated with the batteries
- means of knowing storage locations
- means of monitoring / receiving notification of manufacturers recalls
- means of ensuring action is taken to address the recall requirements
- means of tracking that action has been taken to address the recall requirements

Internal procedure for identification of suspect or damaged batteries

To include consideration of:
- means of monitoring the battery status when external to the BEV or the charging station
- parameters on the battery monitoring system that indicates damage or failure
- in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed
- parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules)
- go / no go decision points indicative of potential damage to the battery
- identification of whom needs to be involved in the evaluation

Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site

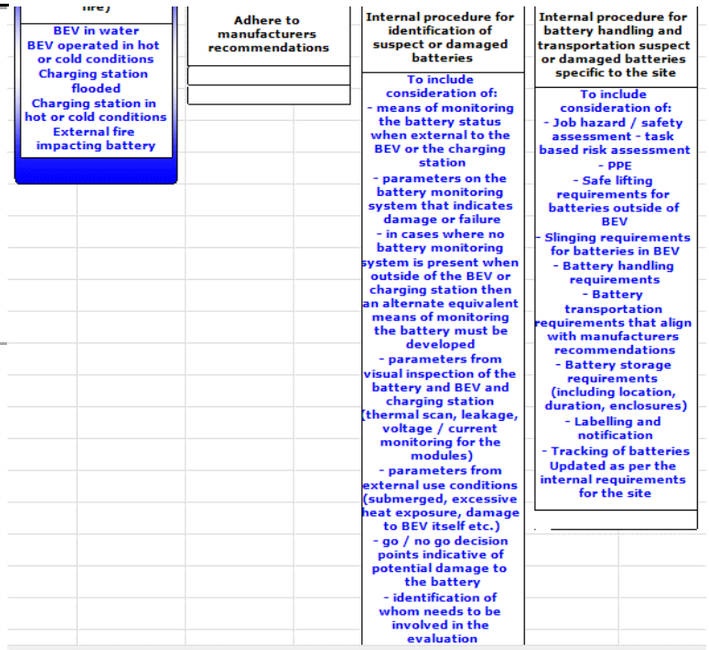
To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- PPE
- Safe lifting requirements for batteries outside of BEV
- Slinging requirements for batteries in BEV
- Battery handling requirements
- Battery transportation requirements that align with manufacturers recommendations
- Battery storage requirements (including location, duration, enclosures)
- Labelling and notification
- Tracking of batteries

Updated as per the internal requirements for the site

Damage during maintenance / improper maintenance activities

Electrical components
Damage to battery cells
Damage to the battery cell compartments
Improper access to the battery components
Incorrect replacement parts etc.

Barriers & Escalation Factors



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Adhere to manufacturers recommendations

- includes requirements to meet manufacturers recommendations for parts and components

Trained and competent maintenance personnel

To include consideration:
- training that is aligned with manufacturers requirements
- competency for maintenance personnel meeting with manufacturers requirements

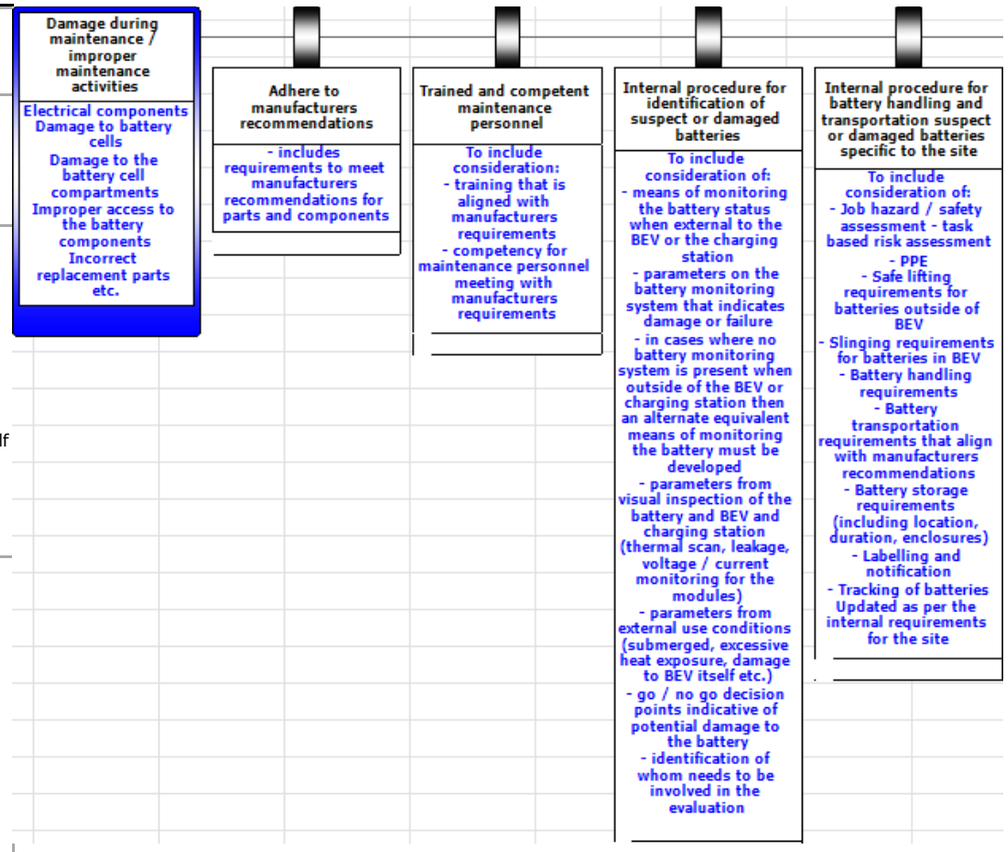
Internal procedure for identification of suspect or damaged batteries

To include consideration of:
- means of monitoring the battery status when external to the BEV or the charging station
- parameters on the battery monitoring system that indicates damage or failure
- in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed
- parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules)
- parameters from external use conditions (submerged, excessive heat exposure, damage to BEV itself etc.)
- go / no go decision points indicative of potential damage to the battery
- identification of whom needs to be involved in the evaluation

Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site

To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- PPE
- Safe lifting requirements for batteries outside of BEV
- Slinging requirements for batteries in BEV
- Battery handling requirements
- Battery transportation requirements that align with manufacturers recommendations
- Battery storage requirements (including location, duration, enclosures)
- Labelling and notification
- Tracking of batteries

Updated as per the internal requirements for the site

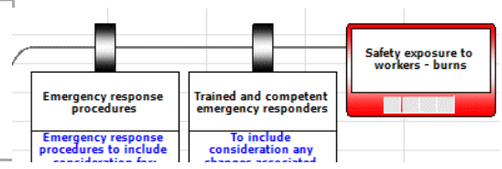


Safety exposure to workers - burns

Barriers & Escalation Factors

Emergency response procedures

Emergency response procedures to include consideration for:
- battery fire while the battery is not in the BEV or the charging station
- type of battery chemistry
- battery design

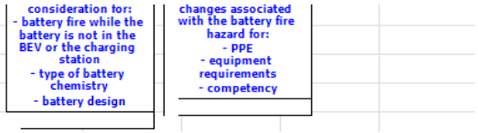


BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Trained and competent emergency responders

To include consideration any changes associated with the battery fire hazard for:
- PPE
- equipment requirements
- competency



Safety exposure to workers - from explosive material release

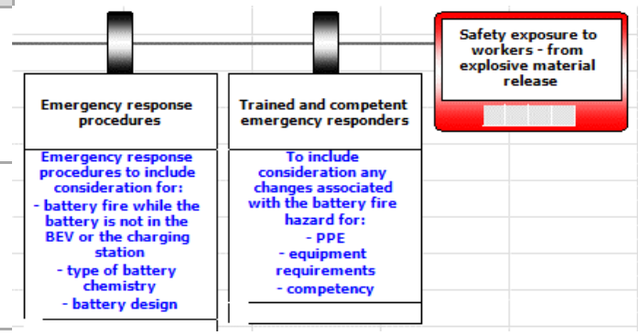
Barriers & Escalation Factors

Emergency response procedures

Emergency response procedures to include consideration for:
- battery fire while the battery is not in the BEV or the charging station
- type of battery chemistry
- battery design

Trained and competent emergency responders

To include consideration any changes associated with the battery fire hazard for:
- PPE
- equipment requirements
- competency



Health exposure to workers - toxic gases from combustion

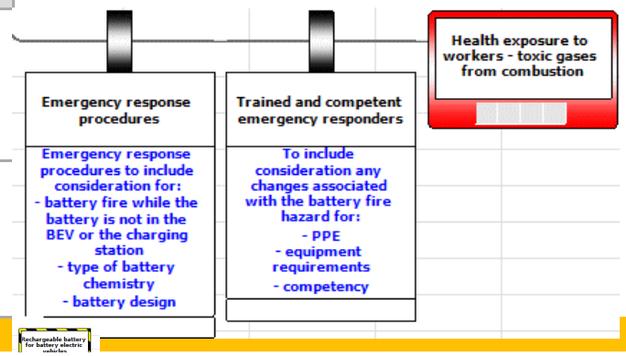
Barriers & Escalation Factors

Emergency response procedures

Emergency response procedures to include consideration for:
- battery fire while the battery is not in the BEV or the charging station
- type of battery chemistry
- battery design

Trained and competent emergency responders

To include consideration any changes associated with the battery fire hazard for:
- PPE
- equipment requirements
- competency



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**
Hazard	**Rechargeable battery for battery electric vehicles**
Top event	**Battery fire during transportation (from the portal or the collar into the underground)**

Transportation of a known damaged battery

Battery has been damaged during operation and is being removed from the BEV

Barriers & Escalation Factors

Internal procedure for identification of suspect or damaged batteries

To include consideration of:
- means of monitoring the battery status when external to the BEV or the charging station
- parameters on the battery monitoring system that indicates damage or failure
- in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed
- parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules)
- go / no go decision points indicative of potential damage to the battery
- identification of whom needs to be involved in the evaluation

Adhering to the manufacturers recommended best practice for battery transportation

OEM to define a battery transportation best practice guideline covering:
- batteries that are not damaged
- batteries that are suspect or known to be damaged
- monitoring requirements for battery monitoring during transportation

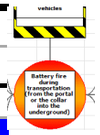
Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site

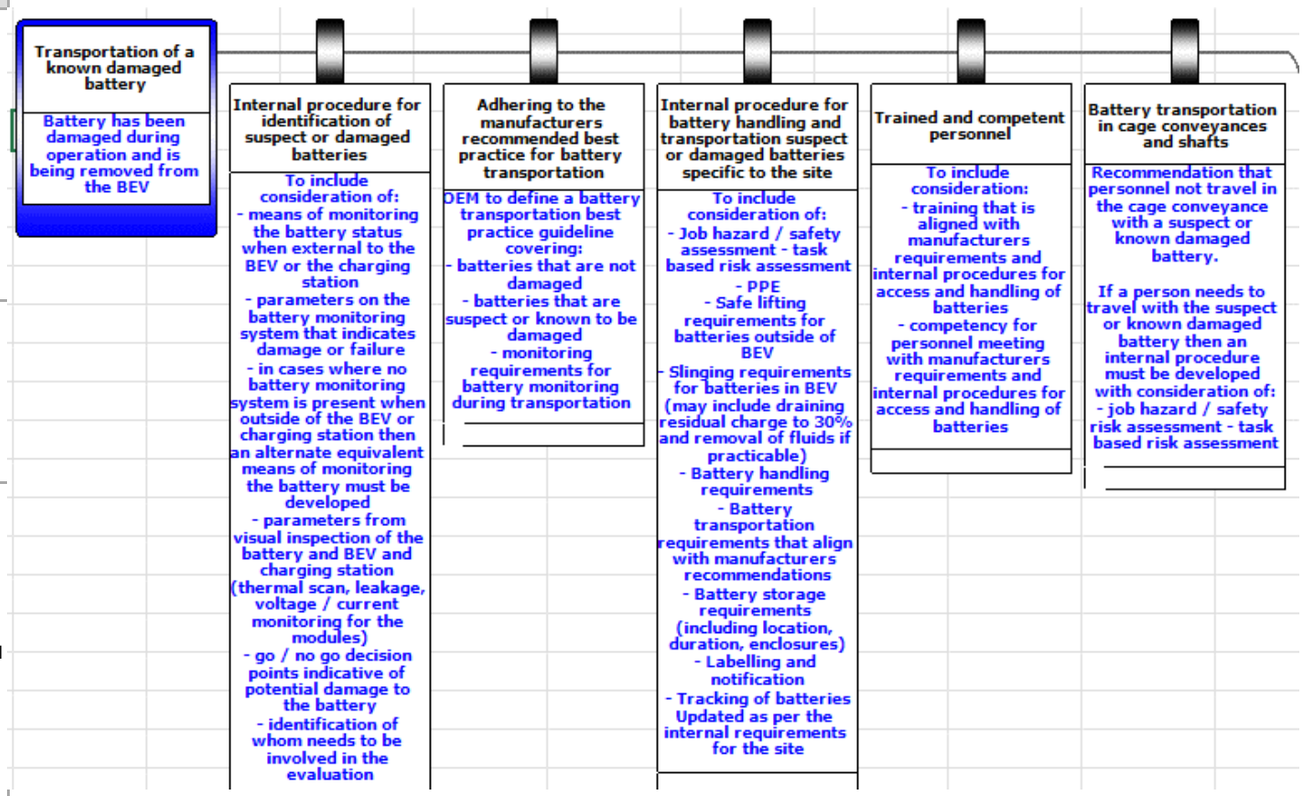
To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- PPE
- Safe lifting requirements for batteries outside of BEV
- Slinging requirements for batteries in BEV (may include draining residual charge to 30% and removal of fluids if practicable)
- Battery handling requirements
- Battery transportation requirements that align with manufacturers recommendations
- Battery storage requirements (including location, duration, enclosures)
- Labelling and notification
- Tracking of batteries

Updated as per the internal requirements for the site

Trained and competent personnel

To include consideration:
- training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries
- competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries





BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Battery transportation in cage conveyances and shafts

Recommendation that personnel not travel in the cage conveyance with a suspect or known damaged battery.

If a person needs to travel with the suspect or known damaged battery then an internal procedure must be developed with consideration of:
- job hazard / safety risk assessment - task based risk assessment

Transportation of a suspect damaged battery

Known damage to the BEV but no confirmation of damage to the battery itself
Collision with other equipment
Collision with rock / walls
Dropped object on battery

Barriers & Escalation Factors

Internal procedure for identification of suspect or damaged batteries

To include consideration of:
- means of monitoring the battery status when external to the BEV or the charging station
- parameters on the battery monitoring system that indicates damage or failure
- in cases where no battery monitoring system is present when outside of the BEV or charging station then an alternate equivalent means of monitoring the battery must be developed
- parameters from visual inspection of the battery and BEV and charging station (thermal scan, leakage, voltage / current monitoring for the modules)
- go / no go decision points indicative of potential damage to the battery
- identification of whom needs to be involved in the evaluation

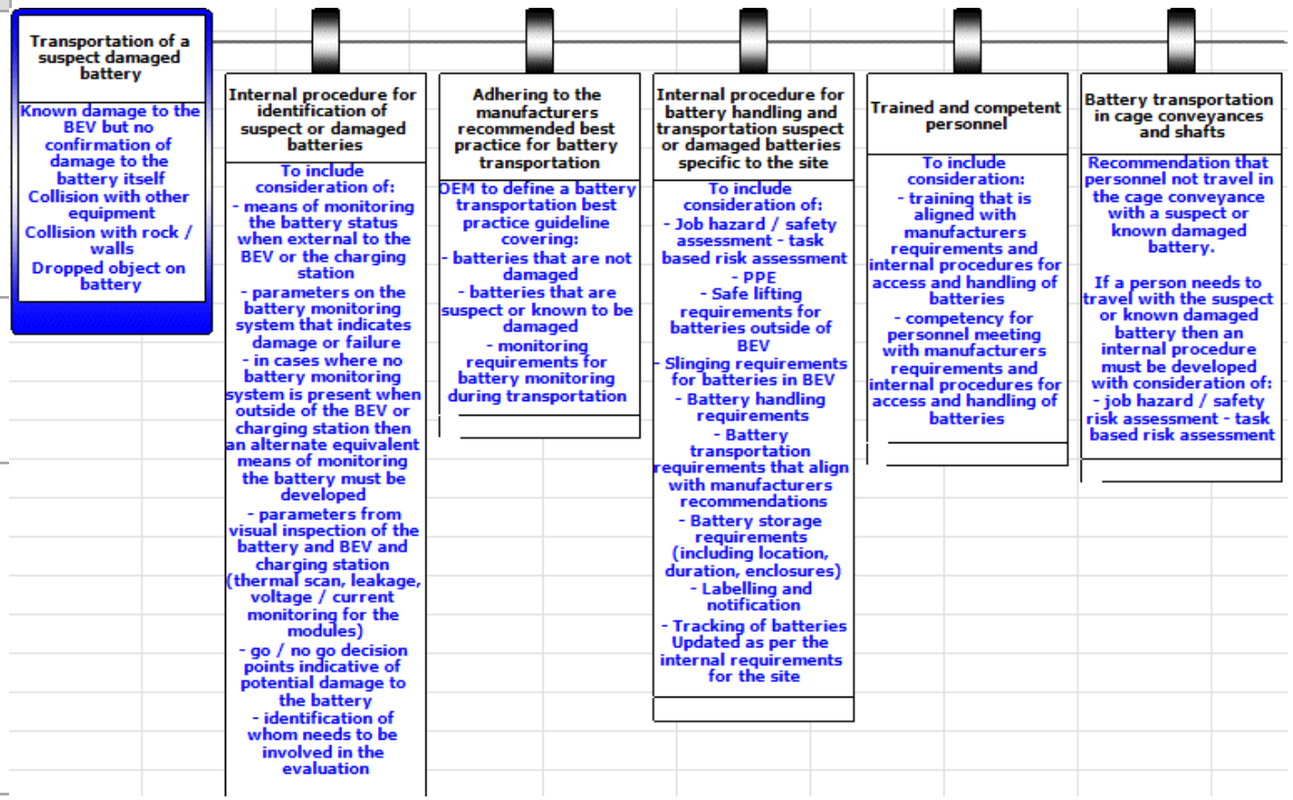
Adhering to the manufacturers recommended best practice for battery transportation

OEM to define a battery transportation best practice guideline covering:
- batteries that are not damaged
- batteries that are suspect or known to be damaged
- monitoring requirements for battery monitoring during transportation

Internal procedure for battery handling and transportation suspect or damaged batteries specific to the site

To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- PPE
- Safe lifting requirements for batteries outside of BEV
- Slinging requirements for batteries in BEV
- Battery handling requirements
- Battery transportation requirements that align with manufacturers recommendations
- Battery storage requirements (including location, duration, enclosures)
- Labelling and notification
- Tracking of batteries

Updated as per the internal requirements for the site



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Trained and competent personnel

To include consideration:
- training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries
- competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries

Battery transportation in cage conveyances and shafts

Recommendation that personnel not travel in the cage conveyance with a suspect or known damaged battery.

If a person needs to travel with the suspect or known damaged battery then an internal procedure must be developed with consideration of:
- job hazard / safety risk assessment - task based risk assessment

Transportation of batteries

Batteries with no known or suspect issues

Barriers & Escalation Factors

Adhering to the manufacturers recommended best practice for battery transportation

OEM to define a battery transportation best practice guideline covering:
- batteries that are not damaged
- batteries that are suspect or known to be damaged
- monitoring requirements for battery monitoring during transportation

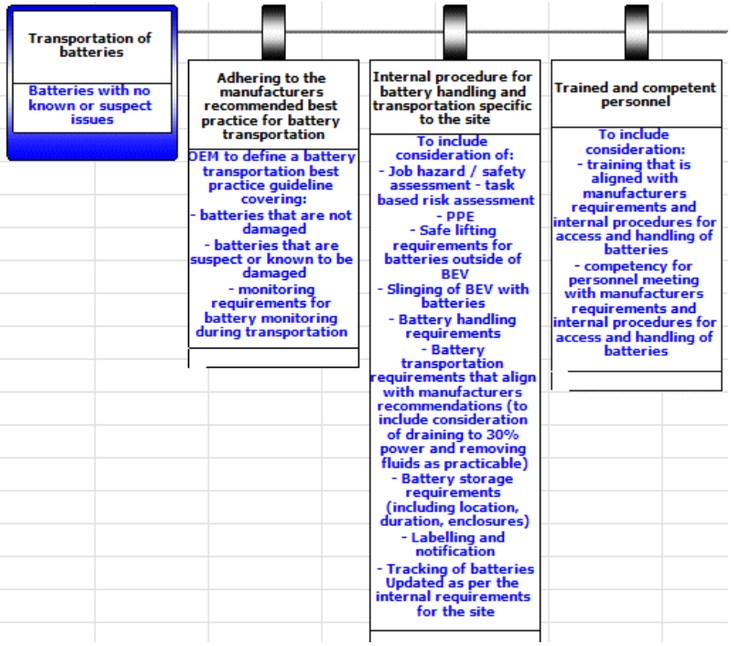
Internal procedure for battery handling and transportation specific to the site

To include consideration of:
- Job hazard / safety assessment - task based risk assessment
- PPE
- Safe lifting requirements for batteries outside of BEV
- Slinging of BEV with batteries
- Battery handling requirements
- Battery transportation requirements that align with manufacturers recommendations (to include consideration of draining to 30% power and removing fluids as practicable)
- Battery storage requirements (including location, duration, enclosures)
- Labelling and notification
- Tracking of batteries

Updated as per the internal requirements for the site

Trained and competent personnel

To include consideration:
- training that is aligned with manufacturers requirements and internal procedures for access and handling of batteries
- competency for personnel meeting with manufacturers requirements and internal procedures for access and handling of batteries



BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

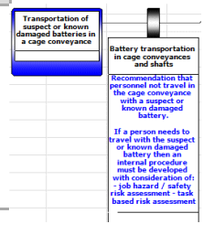
Transportation of suspect or known damaged batteries in a cage conveyance

Barriers & Escalation Factors

Battery transportation in cage conveyances and shafts

Recommendation that personnel not travel in the cage conveyance with a suspect or known damaged battery.

If a person needs to travel with the suspect or known damaged battery then an internal procedure must be developed with consideration of:
- job hazard / safety risk assessment - task based risk assessment



Safety exposure to workers - burns

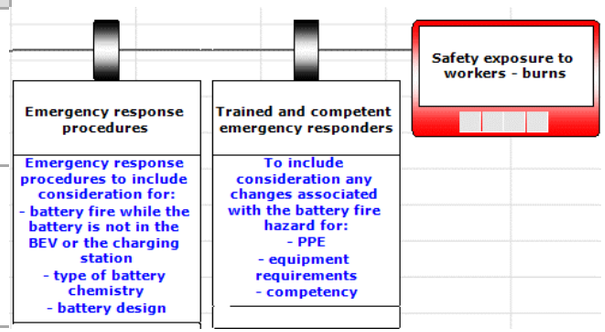
Barriers & Escalation Factors

Emergency response procedures

Emergency response procedures to include consideration for:
- battery fire while the battery is not in the BEV or the charging station
- type of battery chemistry
- battery design

Trained and competent emergency responders

To include consideration any changes associated with the battery fire hazard for:
- PPE
- equipment requirements
- competency



Safety exposure to workers - from explosive material release

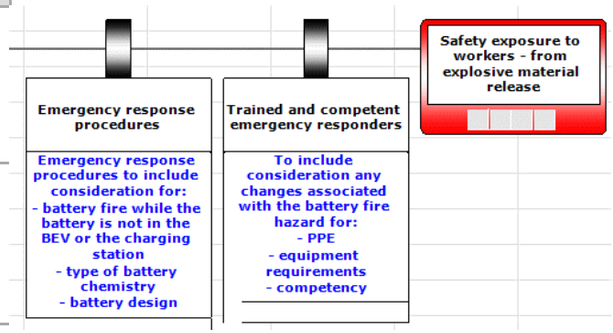
Barriers & Escalation Factors

Emergency response procedures

Emergency response procedures to include consideration for:
- battery fire while the battery is not in the BEV or the charging station
- type of battery chemistry
- battery design

Trained and competent emergency responders

To include consideration any changes associated with the battery fire hazard for:
- PPE
- equipment requirements
- competency



Health exposure to workers - toxic gases from combustion

BowTie Group: New BowTie Group

Hazard	**Rechargable batters for Battery Electric Vehicles**
Top event	**Battery fire while in storage or charging while in the underground**

Barriers & Escalation Factors

Emergency response procedures

Emergency response procedures to include consideration for:
- battery fire while the battery is not in the BEV or the charging station
- type of battery chemistry
- battery design

Trained and competent emergency responders

To include consideration any changes associated with the battery fire hazard for:
- PPE
- equipment requirements
- competency