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DISCLAIMER – *The HyResponse project provides emergency response strategies and tactics for Fuel Cell Hydrogen (FCH) vehicles and applications. The strategies and tactics presented in this document are for the purpose of sharing information about responding to incidents/accidents involving FCH cars, buses and applications. This document is made available on an “as is” basis for “informational purposes” only. The information contained herein may change without notice. The HyResponse project and its partners, collectively and individually, disclaim any liability for injuries resulting from actions expressed or implied in this document.*

1 DIFFERENCES BETWEEN STRATEGY AND TACTICS

1.1 STRATEGY

1.1.1 Strategy Definition

Build an incident settlement strategy is answering the question:

“Which goal does the organization want to reach?”

Answering this question define the general goal of the fire and rescue services.

Their three main goals are always the same all over the world:

N°1: Protect human life

N°2: Protect Property

N°3: Protect environment

Inside a society, Strategy is a stable notion decided at a political level, according to the risk sociological acceptance. Choosing a strategy to deal with a type of incident is tightly linked with the “Stakes assessment” notion.

1.1.2 Stakes assessment

The three mains goals (protection of life, property and environment) must be pursued in the safest manner allowed by each unique incident situation stakes assessment. The authority in charge must take only the appropriate risks considering the salvable lives, salvable possessions and environmental situation balanced out with the available rescue forces at the moment he takes his operational decisions.

Nevertheless, the rescue of human lives overrides all other considerations.

So strategies can be divided in two main orientations:

High stake level situations: If nothing is done the incident will lead in a short time to the certain death of human(s), major infrastructure destructions and/or irreversible environmental effects.

Low stake level situations: The incidental situation will lead within a longer amount of time to minor effects on humans, infrastructures and/or reversible effects on environment.

1.2 TACTICS

1.2.1 Tactic definition

Using a defined tactic is the direct consequence of the chosen strategy. As the strategy is the answer to the question “Which goal do I want to reach?” a tactic is the answer to the question:

“How will I reach this goal (in the safest manner)?”

Tactic is a variable concept decided at an operational level, according to the situation available at the present moment and in a near future.

For a defined situation type, it is possible to plan as a tactic a step by step procedure that describes the actions of a first responders team. However, from the general rules, the incident commander has always the opportunity and the duty to use the appropriate behavior for each incident because each incident is unique.

1.2.2 The danger process theory

The danger process theory (Perilhon, 2003) was developed to describe the ways a danger source affects a target through a danger flux.

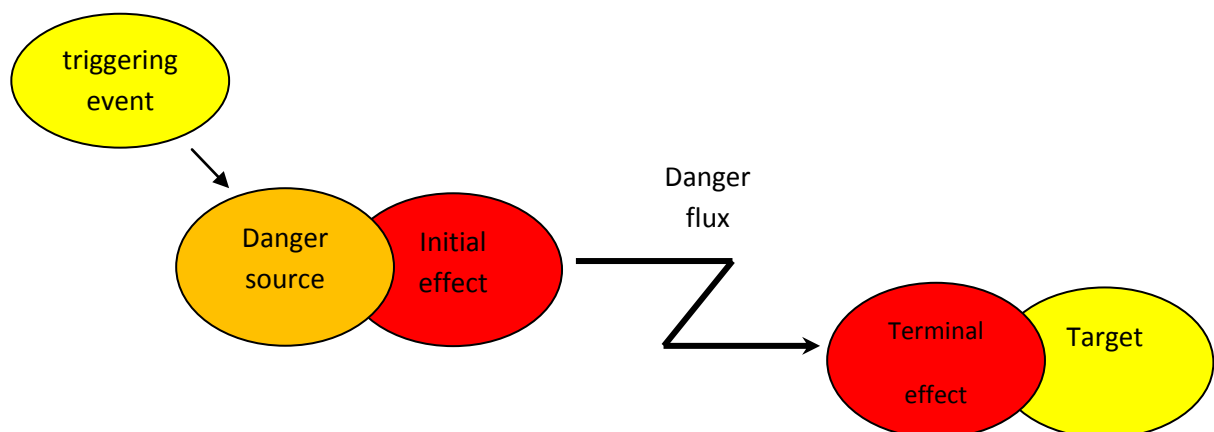


Figure 1 danger process

During an incident and when the fire service is called, the triggering event has already occurred. So, to suppress the effect on targets, fire services can act:

- on danger sources, thus preventing the initial effects to happen
- on danger flux, preventing the terminal effects to exist

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- on targets, preventing the effects to reach the targets.

1.2.3 Offensive and defensive tactic

Two main types of tactics are usually in use: Offensive or defensive.

Offensive tactic: (or acting on danger sources)

Those tactics aims to act very quickly on the origin of the incident to prevent it to produce its effects.

Advantages: rapid settlement of the incident, a little area is concerned, the required amount of personnel and appliances is limited

Drawbacks: risky for firefighters, one shot available

Defensive tactic: (or acting on danger flux and targets)

Those tactics aim to act on the closest area of the incident preventing those effects from reaching an area which was not concerned beforehand

Advantages : safer for crews

Drawbacks: it needs more preparedness, the settlement of the incident takes a long time, the area finally concerned by the incident is wider.

2 HYDROGEN SPECIFICITIES IN EMERGENCY SITUATIONS

2.1 Hydrogen dangers

Hydrogen is an odourless, colourless, tasteless, non toxic, non corrosive, but highly flammable gas. It can be stored in a gaseous phase at ambient temperature by high pressure compression or in liquid phase by cryogenical liquefaction. Its dangers are associated to its chemical and physical properties.

2.1.1 Asphyxiation

Hydrogen can replace oxygen in the atmosphere and then cause asphyxiation by anoxia. The effects begin if oxygen rate is under 18% in the air.(normal oxygen rate in the air is 20-21%)

2.1.2 Pressure

Gaseous hydrogen is stored in tanks, pressurised up to 700 bar. The rupture of tanks or flexible tubes under pressure may cause major injuries.

The liquid to gas phase change causes the occupied volume to increase from 1 to 845. Consequently the pressure in a confined space will increase extremely quickly.

2.1.3 Noise

Due to the high pressure needed for storage (350-700b), a gaseous hydrogen leak produces a noise that can reach 130-140dB.(first ear damages occur above 90dB and pain limit starts at 120 dB)

2.1.4 Embrittlement

Hydrogen is the smallest molecule of all. The permeation of hydrogen through containment material lattice can cause a loss of structural strength and lead to tanks and pipes embrittlement causing their eventual rupture.

2.1.5 Cryogeny

At ambient pressure, liquid hydrogen must be kept at 20.3°K (-252.85°C/-423.13°F)

Direct skin contact with liquid or cold gaseous hydrogen causes instantaneous cold burns.

2.1.6 Combustion

Hydrogen is highly flammable and explosive. Ignition range in air is 4-75% [% v/v] and the minimum ignition energy is 0.02 mJ.

In the air, the Hydrogen flame is only visible on 30% of its length.

2.2 Specific tools

2.2.1 Thermal Imaging Equipment

The first responders can use a thermal imaging device to make the hydrogen flame in the air visible as shown on picture



Figure 2 H2 tank fire (700b) ensosp 2014

A Laser thermometer can also be used to find safely high or low temperature items

2.2.2 Single-gas monitor

single-gas or multi gas monitor continuously displays gas concentrations in the atmosphere. It can be used to monitor O₂ rate and H₂ rate. Such an equipment is useful for First responders to assess the threat zone and create or refine the danger area.

3 INCIDENT GENERAL TACTICS

3.1 The emergency call management

The incident begins when the emergency call arrives at the control room. People who call the emergency services are usually over excited or terrorised. Despite this, essential informations must be gathered :

- Type of incident (electrical malfunction, gas leak, explosion, fire...)
- Location of the incident
- are any persons killed, injured or threatened by the incident?

With that information, the emergency answering service can select the nearest available emergency appliance and provide usefull advice to the person who called :

As an example, if the emergency call concerns a Fuel Cell vehicle catching fire in the street:

- Make sure all the passengers escape from the vehicle
- Shut down the contact key
- Provide first aid to the casualties in a safe area
- Try to get rid of fire with a fire extinguisher if the fire is little
- Keep anybody from approaching the vehicle before the fire services arrive
- ...

Before leaving the fire station, the incident commander must choose a safe way to arrive at the incident ground, preventing the fire appliances to cross a flammable gaz cloud, and make sure to arrive upwind.

3.2 Fire and Rescue operational sequence

Every fire and rescue operation follows the same “step by step” sequence on the incident field. Notice that those steps can be realised simultaneously, according to the real situation.

1. RECOGNITION
2. RESCUE
3. PREPAREDNESS
4. INCIDENT SETTLEMENT
5. PROTECTION
6. CLEAR OUT
7. OVERHAUL

3.2.1 RECOGNITION :

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This step aims at collecting every available information on the incident field in order to size up the scene.

The incident commander will search for information such as :

What happened and what is happening?

Are there casualties or people threatened by the situation?

Was a fire dart seen? Was a loud hissing sound heard?

What are the resources of the place?

To do so, he will undertake a large circle around the scene. If the scene takes place in a building, the recognition also includes the floors under and above the incident place.

During the recognition a danger area is defined, taking into account the reality of the known risks. The incident commander is at this moment able to decide the safest way to deal with the situation, enounce the objectives and choose the angles of attack.

3.2.2 RESCUE

If a casualty is identified and located, rescue operations are launched immediately even if recognition is not complete. Casualties are taken out of the danger area and led to the first aid paramedics teams. As said before: rescue of human lives overrides all other considerations.

3.2.3 PREPAREDNESS

During this step, the crew will prepare the needed tools and accessories required to deal with the situation (hoselines, hydrants, thermal imaging devices, gas detectors...). The tools and accessories used are function of the incident situation.

3.2.4 INCIDENT SETTLEMENT

Considering the available information, The incident commander will at this step decide to use an offensive or a defensive tactic.

1st example :

a FCH Car is burning on a little road in the countryside.

The driver is safe and out of the danger area.

A large flame is visible with the thermal imaging device and a loud hissing sound is heard.

Analysis : the TPRD of H2 tank is open, in a very short time the ignited leak will blowdown. Nothing is threatened by the flame.

Tactical choice :

Use a defensive tactic : close the road on both directions, wait for the blowdown of the tank while preparing the hoselines and then extinguish the car fire, using the electrical car fire procedures.

2nd example :

A FCH car is burning in a crowded street, close to a 10 floor building, no sound is heard, the fire began 2 minutes ago.

Tactical choice :

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Use an offensive tactic : close the road on both directions, prevent anybody from approaching less than 100 meters from the car, stretch two hoselines and attack immediately the car fire simultaneously with two teams, from safe angles (see below) before TPRD opens. Keep cooling the tanks, after the fire is put out.

3.2.5 PROTECTION

The “protection” step aims to avoid destructions caused by the incident (the fire) or by what was used to extinguish it (the water).

As an example, if the fire occurs in a bus parking lot, the busses closest to the fire are protected using water jet curtains, and those which are a little bit further can simply be driven away from the incident area.

In the buildings and the industrial plants, the effects of the water or foam sprays can also be destructive. The Incident commander must use the only necessary amount of water or foam. During this step, shoring-up can also be necessary.

3.2.6 CLEAR OUT

At the end of a fire, it's important to clear out the incident scene, remove and sprinkle all burnt pieces of material to be sure that no ignited materials remain underneath.

3.2.7 OVERHAUL

After the end of extinguishing operations and the incident settlement, the first responders must not leave the fire ground too early.

The temperature decrease of the burnt tank must regularly be checked.

An overhaul of the fire ground must be steadily done, until any risk still exists.

4 INCIDENT TACTICS FOR FCH APPLICATIONS

4.1 French guidelines

The “French Ministry of Interior” provided in 2013 an operational guideline notice for incidents involving H₂ and its applications. It deals with 5 main situations:

RESCUE on a FCH application

IGNITED HYDROGEN LEAK

UNIGNITED HYDROGEN LEAK

FIRE on a FCH application

FIRE THREATENING FCH application

The 5 following tables (extracted and translated from the French guidelines) explain the sequences to deal with the related situations .

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4.1.1 RESCUE

Situations covered by this sequence are :

- Injured person in a nearby FCH.
- Asphyxiation caused by an H2 leak in a confined space.
- Electrocutation
- Burns caused by a H2 leak

The indicative step by step sequence are listed below.

Table 1 Operational sequence for RESCUE on a FCH application

steps	actions	Goals
RECOGNITION	Identify	- Contact the safety manager of the installation for the details of the incident; - Take into account the risk of explosion of hydrogen in confined spaces; - Take into account the risk of anoxia in confined spaces.
	Prohibit	- Prohibit the progress downwind . It is imperative to establish an exclusion zone of 50 m; - Prohibit the use of electrical or electronic devices in the non ATEX exclusion zone (cell phones, radios, etc.).
	Inspect	- Operate the external power cuts of the building
RESCUE	act Isolate	<u>-In case of hydrogen leak in confined spaces:</u> Wear a self-contained breathing apparatus Remove the affected casualty outside the exclusion zone <u>- If risk of electrified or electrocuted victim</u> Use the electro-rescue equipment to remove the victim Avoid contact of the first responders with electrical elements;

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PREPAREDNESS/ INCIDENT SETTLEMENT		<p>Confirm or refine exclusion zone (50 m)</p> <p>Conduct surveys using an explosimeter (from top to bottom of the installation or storage facility)</p>
PROTECTION		<p><u>- Actions to prevent a risk of anoxia:</u></p> <ul style="list-style-type: none"> • Close the hydrogen supply valves • Ventilate the area by promoting the natural drawing (do not use electrical and thermal fans) <p><u>Action on the electrical risk:</u></p> <p>Press the emergency stop button of the installation (delay of 20 minutes with the presence of residual current)</p>
CLEAR OUT OVERHAUL		<p>- The monitoring phase ceases as soon as: the oxygen level in the room is normal (about 20 vol. %)</p> <p>Repeatedly check H2 presence in the atmosphere</p> <ul style="list-style-type: none"> • the electrical system is secure and supported by a technician

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4.1.2 Electrical Fire

Situation covered by this sequence is a Fire on the electrical components of a FCH application.

Table 2 Operational sequence for FIRE on the electrical components of a FCH application

steps	actions	goals
RECOGNITION	Identify	<ul style="list-style-type: none"> - Contact the safety manager of the installation for the details of the incident ; - Take into account the “low voltage” hazards
	Prohibit	<ul style="list-style-type: none"> - Prohibit downwind progression and imperatively establish an exclusion zone of 50 m; - Prohibit the use of non ATEX electrical or electronic devices in the exclusion zone (cell phones, radios, etc.).
	Inspect	<ul style="list-style-type: none"> - Operate the external power cuts of the building;
RESCUE	act Isolate	<ul style="list-style-type: none"> - In case of hydrogen in confined spaces: <ul style="list-style-type: none"> • Wear a breathing apparatus • Remove the affected person outside the exclusion zone - If risk of electrified or electrocuted victim <ul style="list-style-type: none"> • Use the electro-rescue equipment to remove the victim • Avoid contact of the first responders with electrical elements
PREPAREDNESS/INCIDENT SETTLEMENT		<p>Confirm or refine exclusion zone (50 m) (based on the sound of a leak under pressure, readings of explosimetry, etc.);</p> <ul style="list-style-type: none"> - Proceed to the extinction of the flame based on its virulence: <ul style="list-style-type: none"> • With a powder or CO2 fire extinguisher at a distance more than > 1m • with variable flow-rate nozzles in, spray attack pulse at a distance of more than 3m
PROTECTION		<p>Operate the emergency stop punch installation (20 minutes from time with the presence of a residual current);</p> <ul style="list-style-type: none"> - Take into account the flow of water during the timeout shutdown phase of the installation (electrical hazard); - Close hydrogen supply valves; - Ventilate premises facilitating natural drawing (opening existing outlets).
CLEAR OUT OVERHAUL		<p>Look for high temperature points on hydrogen storage using thermal imaging device on Hydrogen storage ;</p> <ul style="list-style-type: none"> - The monitoring phase ends when it is found that the actions aimed at extinguishing measures proved effective.

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4.1.3 External Fire

The situation covered by this sequence is a Fire threatening a FCH application or a H2 storage

Table 3 Operational sequence for a FIRE THREATENING FCH application or H2 storage

steps	actions	Goals
RECOGNITION	Identify	Contact the safety manager of the installation for the details of the incident ; - Take into account the risk of explosion of a hydrogen tanks under fire, with projections (several tens of meters for bottles to several hundreds for trailers).
	Prohibit	- Prohibit the progress downwind and imperative to establish an exclusion zone of 50 m; - Prohibit the use of non ATEX electrical or electronic devices in the exclusion zone (cell phones, radios, etc.).
	Inspect	- Operate the external power cuts of the building;
RESCUE	act Isolate	- In case of hydrogen in confined spaces: <ul style="list-style-type: none"> • Wear a breathing apparatus • Remove the affected person/victim outside the exclusion zone - If risk of electrified or electrocuted victim <ul style="list-style-type: none"> • Use the electro-rescue equipment to remove the victim • Avoid contact with electrical stakeholder bodies
PREPAREDNESS/INCIDENT SETTLEMENT		- Confirm or refine the exclusion zone (tanks or Installation directly threatened by the flames); - Proceed with the extinction of fires - Provide preventive cooling of the facilities and hydrogen storage in the following ways: <ul style="list-style-type: none"> • Establishment of a "peacock tail "type nozzle • Direct attack spread water jet on the hydrogen tanks using variable flow-rate nozzles spear 250l/min minimum (avoid directing the jets on pipes) • establishment of spread water jet for the protection of sensitive point (power Bay)
PROTECTION		Operate the emergency stop punch installation (20 minutes from time with the presence of a residual current); - Close hydrogen supply valves; - Ventilate premises facilitating natural drawing (opening existing outlets).
CLEAR OUT OVERHAUL		- Look for high temperature points on hydrogen storage using thermal imaging device on hydrogen storage ; ; -The monitoring phase ends when it is found that <ul style="list-style-type: none"> • the actions aimed at extinguishing proved effective. • the water spread on the hydrogen tanks do not

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		evaporate on contact with surfaces
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4.1.4 Ignited H2 leak

The situation covered by this sequence is an ignited H₂ leak

Table 4 Operational sequence for an IGNITED HYDROGEN LEAK

steps	actions	Goals
RECOGNITION	Identify	<ul style="list-style-type: none"> - Contact the safety manager of the installation for the details of the incident ; - Take into account the dispersion of H₂ in premises before the ignition (possibility of UVCE unconfined vapour cloud explosion).
	Prohibit	<ul style="list-style-type: none"> - Prohibit downwind progression and imperatively establish an exclusion zone of 50 m; - Prohibit the use of non ATEX electrical or electronic devices in the exclusion zone (cell phones, radios, etc.). - Prohibit the extinguishment of the hydrogen flames. - Prohibit the actions on the electrical system of the facility in case of hydrogen leak.
	Inspect	<ul style="list-style-type: none"> - Operate the external power cuts of the building - Confirm the presence of an ignited leak and its length using thermal camera (hardly visible flame in its entirety, in the day light); - Pay attention to the significant sound of an ignited gas leak.
RESCUE	act Isolate	<p><u>- In case of hydrogen in confined spaces:</u></p> <ul style="list-style-type: none"> • Wear a breathing apparatus • Remove the affected person(s) outside the exclusion zone <p><u>- If risk of electrified or electrocuted victim</u></p> <ul style="list-style-type: none"> • Use the electro-rescue equipment to remove the victim • Avoid contact with electrical stakeholder bodies
PREPAREDNESS/INCIDENT SETTLEMENT		<ul style="list-style-type: none"> - Refine the exclusion area (explosimeter measurements, information on the nature of the incident ...); - Set up water curtains to prevent a fire spread; - If necessary, provide preventive cooling on hydrogen storage and facilities nearby.
PROTECTION		<ul style="list-style-type: none"> - Close hydrogen supply valves; - Ventilate premises facilitating natural drawing (opening existing outlets).

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CLEAR OUT OVERHAUL		<ul style="list-style-type: none">- Look for high temperature points on hydrogen storage using thermal imaging device on Hydrogen storage ;;- Conduct surveys of explosimeter in confined spaces prioritizing high points;- Press the emergency stop mushroom of the installation (delay of 20 minutes with the presence of a residual current).
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4.1.5 Unignited H2 leak

The situation covered by this sequence is an unignited H2 leak

Table 5 Operational sequence for an unignited Hydrogen leak

steps	actions	Goals
RECOGNITION	Identify	<ul style="list-style-type: none"> - Contact the safety manager of the installation for the details on the incident ; - Take into account the risk of explosion
	Prohibit	<ul style="list-style-type: none"> - Prohibit downwind progression and imperatively establish an exclusion zone of 50 m; - Prohibit the use of non ATEX electrical or electronic devices in the exclusion zone (cell phones, radios, etc.). - Prohibit the actions on the electrical system of the facility in case of hydrogen leak.
	Inspect	<ul style="list-style-type: none"> - Operate the external power cuts of the building
RESCUE	act Isolate	<ul style="list-style-type: none"> - In case of hydrogen in confined spaces: <ul style="list-style-type: none"> • Wear a breathing apparatus • Remove the affected person (s) outside the exclusion zone - If risk of electrified or electrocuted victim <ul style="list-style-type: none"> • Use the electro-rescue equipment to remove the victim • Avoid contact with electrical stakeholder bodies
PREPAREDNESS/INCIDENT SETTLEMENT		<ul style="list-style-type: none"> - Refine the security area based explosimeter measurements (from top to bottom of the installation); - Close hydrogen supply valves; - Ventilate premises facilitating natural drawing (opening existing outlets).
PROTECTION		
CLEAR OUT OVERHAUL		<ul style="list-style-type: none"> - The monitoring phase ends when there is no risk of explosion in a secure area (complete emptying of the tank or draining in open air in a secure area monitored by the operator, efficient ventilation of the premises.) - Press the electrical emergency shutdown device of the installation (delay of 20 minutes with the presence of a residual current)

Note: the action on the emergency stop punch during the overhaul phase, clears electric ignition sources, intrinsic with the installation.

4.2 HYresponse First responders Team and appliance

All the fire fighting equipments used in Hyresponse program must be in accordance with the following document :

“Catalogue des Normes Applicables aux Sapeurs Pompiers et à la Sécurité civile Direction Générale de la Sécurité Civile et de la Gestion des Crises Sous-direction des ressources, des compétences et de la doctrine d'emploi Bureau de la Formation, des Techniques et des Équipements, Version Éditée le 27 août 2014 » and following ones.

4.2.1 The team

The typical fire appliance used in HyResponse training has the following crew :

- appliance Chief (first incident commander)
- driver/pump operator
- Team leader 1
- First responder 1
- Team leader 2
- First responder 2

Each first responder must wear a complete fire gear composed in particular of the following elements:

helmet with face shield, hood, turnout coat, turnout, pants, and fire fighter boots and gloves. All protective clothing must be worn as a complete set.

Use of self contained breathing apparatus is also mandatory.

4.2.2 The fire appliance

The vehicle used in Hyresponse is the French Pump (fourgon pompe tonne). It has the characteristics specified in the European standard EN 1846-1/2/3 and to the french standard NFS 61-515

For the purpose of the specific H2 fires, additional tools are required :

- Polyvalent flammable gas detector
- H2 dectector
- Thermal camera

4.3 Specific tactics sheets proposed for selected applications

Taking into account the existing knowledge about Hydrogen application fires, Hyresponse project propose the following “Tactical sheets”.

For each selected application (Car, bus , forklift, trailer, reffuelling station, Stationary power generation unit (SPGS), Hydrogen-based energy storage system (H2ESS)), we propose a tactical approach for 4 incidents:


- No leak no fire,
- H2 leak,
- Fire,
- External fire threatening the application

For each situation we propose a step by step sequence, informations about safety points and indicative safety distances **in case of a failure of the pressure release devices and to prevent the public from the effects of the explosion of the tanks.**

Important Notice: Mind that those distances are INDICATIVE. The Incident commander must enlarge or reduce the safety perimeter taking into account the reality of the situation and especially the capacity of the involved H2 (or O2) tank.

4.3.1 FC Cars, Busses and Forklifts

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	FC CAR FC FORKLIFT FC BUS	
Tactic n° 1	NO LEAK NO FIRE (technical alarm, work accident, road traffic accident)	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none"> • assure the precise incident location • are there any person involved in the incident? • type of vehicle concerned • what happend? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none"> • wind direction • wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none"> • do not cross an eventual explosive gas cloud • do not reach scene from bellow • anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none"> • Gaseous hydrocarbons dectector, • H2 detector • O2 detector • Thermal imaging camera 		
ARRIVAL ON SCENE		
<p>ARRIVAL :</p> <ul style="list-style-type: none"> • Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind. • Stop the fire appliance 50 meters (55 yd) before the incident • away from a possible ignited flammable liquid leak progression. 		

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- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

- Set up a safety area for the public beyond a radius of 50 meters (55 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

- BY QUESTIONNING THE WITNESSES AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS :

- o Which Type is the involved vehicle?
- o what has happened?
- o Is someone injured? Threatened?
- o Has a leak occurred? Is a leak still occurring?
- o Is a part of the vehicle damaged?

Check energies present in the involved vehicle (tank type, refueling hole type, vehicle registration papers...)

Vehicle identification:

H2 car may be identified by FCHV Fuel Cell Hybrid Vehicle badges (figure 3)

operate H2 detector

RESCUE

engage rescue as a conventional accident
Rescue of humans override all other considerations.

EXPOSURE PROTECTION

- Use only necessary personnel
 - open the doors and hoods (if present)
 - set parking brake
 - wedge the vehicle.
 - Turn off the ignition key
 - press the fuel cell emergency shutdown device (busses and forklift)
- For Busses, an Emergency shutdown device is generally located near the driver seat on left side and another is on fuel cell in "engine" compartment, located at the back of the bus.
- If it's not possible to reach Ignition key, remove all the fuses in the fuse boxes and then, cut the negative low voltage battery cable (12 or 24V).

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- Repeatedly check H2 presence in the atmosphere. If H2 is detected apply H2 leak tactic.
- Check if high temperature points exist on the vehicle (more than 150°C/302°F)
- stretch a fire hoseline to protect the action of teams

INCIDENT TREATMENT

If no H2 leak and no sign of fire is detected :

- engage incident settlement following manufacturers Emergency Response Guides.


DO NOT:

- cut or crush H2 lines
- cut or crush High Voltage Lines (orange)
- damage H2 tank
- damage traction Battery Stack

If a H2 leak is detected, apply tactic n°2 "H2 LEAK WITHOUT FIRE"

OVERHAUL

- after a last H2 atmospheric control, Make sure that the vehicle or the wreckage is evacuated by authorized personnels (idealy manufacturer)

	FC CAR FC FORKLIFT FC BUS	
Tactic n° 2	H2 LEAK WITHOUT FIRE	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none">• assure the precise incident location• type of vehicle concerned• what happend <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none">• wind direction• wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none">• do not cross an eventual explosive gas cloud• do not reach scene from bellow• anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none">• Gaseous hydrocarbons dectector,• H2 detector• O2 detector• Thermal imaging camera		

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ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind.
- Stop the fire appliance 50 meters (55 yd) before the incident
- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

- CAR and FORKLIFT Set up a safety area for the public beyond a radius of 100 meters (110 yd)
- BUS : Set up a safety area for the public beyond a radius of 200 meters (220 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

IF A PERSON IS INSIDE THE HAZARDOUS AREA :

ENGAGE RESCUE OPERATIONS

IF NO ONE IS INSIDE THE HAZARDOUS AREA:

- answer the following questions:
 - o Which Type is the involved vehicle?
 - o what happened?
 - o Has a loud hissing sound been eared before the FR arrive?

Vehicle identification:

H2 car may be identified by FCHV Fuel Cell Hybrid Vehicle badges (figure 3)

Confirm the safety area with the H2 detector .

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If H₂ is detected, refine the safety area

Check if high temperature points exist on the vehicle (more than 150°C/302°F)

RESCUE

Rescue of humans override all other considerations.

If a human is threatened or concerned by the gas leak :

- Team 1 : extract the victim(s) from the danger zone by any possible means
- Team 2 : stretch a fire hoseline to protect the action of the Team 1 in case of an ignition of the cloud

evacuate the passengers in the opposite direction of the wind

EXPOSURE PROTECTION

- Use only necessary personnel
- evacuate adjacent buildings
- if the vehicle is in a building, prevent H₂ accumulation by operating wide ventilation of the building
- open the doors and hoods (if present)
- set parking brake
- wedge the vehicle.
- Turn off the ignition key
- press the fuel cell emergency shutdown device (busses and forklift)


For Busses, an Emergency shutdown device is generally located near the driver seat on left side and another is on fuel cell in "engine" compartment, located at the back of the bus

- Do not operate any other electrical breaker to avoid creation of electrical spark.
- Repeatedly check H₂ presence in the atmosphere.
- Refine safety area.
- Check if high temperature points exist on the vehicle (more than 150°C/302°F)

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INCIDENT TREATMENT
<ul style="list-style-type: none">• if H2 Leak still exist after "exposure protection step "anf if it exists, close H2 valve as close as possible of the H2 tank.• If it is not possible to reach a H2 valve, allow H2 to leak safely until the tank is empty
OVERHAUL
<ul style="list-style-type: none">• after a last H2 atmospheric control, Make sure that the vehicle or the wreckage is evacuated by authorized personnels (idealy manufacturer)

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	FC CAR FC FORKLIFT FC BUS	
Tactic n° 3	FIRE	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none">• assure the precise incident location• type of vehicle concerned• what happend? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none">• wind direction• wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none">• do not cross an eventual explosive gas cloud• do not reach scene from bellow• anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none">• Gaseous hydrocarbons dectector,• H2 detector• O2 detector• Thermal imaging camera		
ARRIVAL ON SCENE		
<p>ARRIVAL :</p> <ul style="list-style-type: none">• Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind.• Stop the fire appliance 50 meters (55 yd) before the incident• away from a possible ignited flammable liquid leak progression.• Engage the pump and connect the fire appliance to a hydrant. <p>SAFETY AREA</p>		

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- CAR and FORKLIFT Set up a safety area for the public beyond a radius of 100 meters (110 yd)
- BUS :Set up a safety area for the public beyond a radius of 200 meters (220 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

IF A PERSON IS INSIDE THE HAZARDOUS AREA :
ENGAGE RESCUE OPERATIONS

- answer the following questions:
 - o Is someone threatened by the fire? Where?
 - o How many vehicles are involved in the fire?
 - o How many of these vehicles are powered by H2 or another compressed flammable Gaz?
 - o Has a loud hissing sound been eared before the FR arrive?

Vehicle identification:

H2 car may be identified by FCHV Fuel Cell Hybrid Vehicle badges (figure 3)

RESCUE

Rescue of humans override all other considerations.

If a human is threatened or concerned by the Fire :

- Team 1 : extract the victim(s) from the danger zone by any possible means (figure 10)
 - Team 2 : stretch a fire hoseline to protect the action of the Team 1
- evacuate the passengers in the opposite direction of the wind

EXPOSURE PROTECTION

- Use only necessary personnel
 - evacuate adjacent buildings
 - Prevent the fire from spreading to a uninvolved vehicle(s) or building(s)
 - move adjacent non involved vehicles by any way possible (driving, towing, pushing...)
 - if the vehicle is in a building, prevent combustion gases and H2 accumulation by operating wide ventilation of the building
- if possible:
- open the doors and hoods (if present)
 - set parking brake
 - wedge the vehicle.
 - Turn off the ignition key
 - press the fuel cell emergency shutdown device (busses and forklift)

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For Busses, an Emergency shutdown device is generally located near the driver seat on left side and another is on fuel cell in "engine" compartment, located at the back of the bus

- Repeatedly check H2 presence in the atmosphere.
- Refine safety area.
- Repeatedly check H2 tanks temperature with thermal imaging device.

INCIDENT TREATMENT

In case of High stake level situation :

Operate an offensive Fire attack: (figures 8-9)

each Team prepare 80 m of hoselines directly connected to the fire appliance pump (figure 4)

- Team 1: aims to cool the H2 tank and so doing prevent Thermal Pressure Release Device to operate
- Team 2: aims to extinguish the vehicle fire

The teams avoid passing through danger angles. (figures 5-6-7)

Mind that violent reactions are possible between water and burning materials as soon as possible, wedge the vehicle.


Mind that water will be polluted during extinction (especially if battery is damaged.) operate its containment.

In there is no identified stake:

evaluate the opportunity to let the vehicle burn safely.

OVERHAUL

- Cool the wreckage as soon as no heat point is detected by the thermal imaging device.
- after a last H2 atmospheric control, Make sure that the vehicle or the wreckage is evacuated by authorized personnels (idealy manufacturer)

	FC CAR FC FORKLIFT FC BUS	
Tactic n° 4	EXTERNAL FIRE THREATENING THE APPLICATION	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none"> • assure the precise incident location • are there any person involved in the incident? • type of vehicle concerned • what happend? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none"> • wind direction • wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none"> • do not cross an eventual explosive gas cloud • do not reach scene from bellow • anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none"> • Gaseous hydrocarbons dectector, • H2 detector • O2 detector • Thermal imaging camera 		
ARRIVAL ON SCENE		
<p>ARRIVAL :</p> <ul style="list-style-type: none"> • Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind. • Stop the fire appliance 50 meters (55 yd) before the incident • away from a possible ignited flammable liquid leak progression. • Engage the pump and connect the fire appliance to a hydrant. 		

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<p>SAFETY AREA</p> <ul style="list-style-type: none">• CAR and FORKLIFT Set up a safety area for the public beyond a radius of 100 meters (110 yd)• BUS : Set up a safety area for the public beyond a radius of 200 meters (220 yd)• Ensure that unauthorized/untrained personnel do not enter the hazardous area
SIZE UP THE SCENE
<ul style="list-style-type: none">• answer the following questions:• What is burning?• What's the fire Strength?• What's the distance between the Fire and the FCH Vehicle?o Is someone injured? Threatened?o Has a leak occurred? Is a leak still occurring?
RESCUE
<p>Rescue of humans override all other considerations.</p> <p>If a human is threatened or concerned by the Fire :</p> <ul style="list-style-type: none">• Team 1 : extract the victim(s) from the danger zone by any possible means• Team 2 : stretch a fire hoseline to protect the action of the Team 1 <p>evacuate the passengers in the opposite direction of the wind</p>
EXPOSURE PROTECTION
<ul style="list-style-type: none">• Team 1: Attenuate the radiant heat by providing a water spray curtain between the fire and the FCH vehicle.
INCIDENT TREATMENT
<p>Operate an defensive Fire attack:</p> <p>each Team prepare 80 m of hoselines directly connected to the fire appliance pump</p> <ul style="list-style-type: none">• Team 1: Attenuate the radiant heat by providing a water spray curtain between the fire and the FCH vehicle.• Team 2 : Put out the fire with water, foam or powder depending what is burning. <p>If putting fire out is not possible, or if enough personnel is available, move the FCH vehicle by</p>

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any way possible (driving, towing, pushing...) away from the radiant effect of the fire
OVERHAUL
<ul style="list-style-type: none">• Check temperature on the FCH vehicle with thermal imaging device.

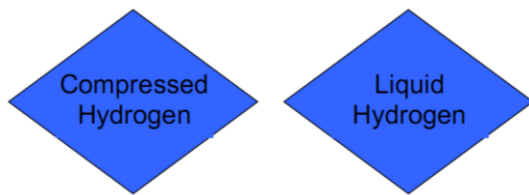


Figure 3 Examples of labels for FCH vehicles



Figure 4 Offensive fire attack preparedness (connected to hydrant if available) ©crise-2015



Figure 5 (In red) forbidden angles for reaching a FCH car in fire on wheels. ©crise-2015

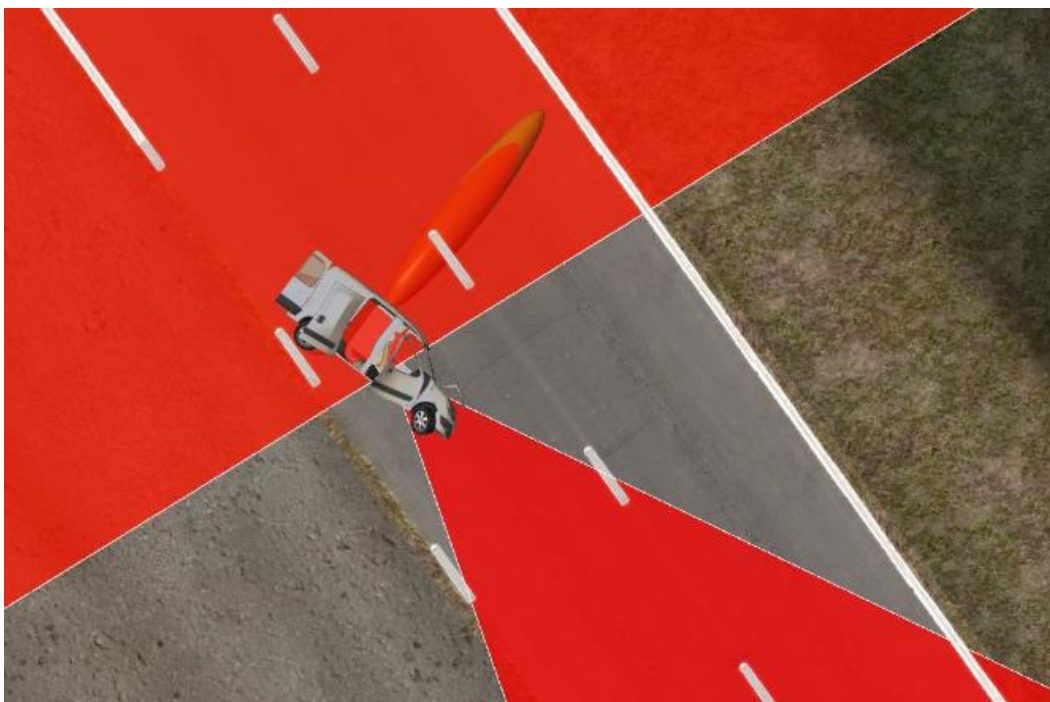


Figure 6 (In red) forbidden angles for reaching a FCH car in fire on the side (TPRD located in the roof) ©crise-2015

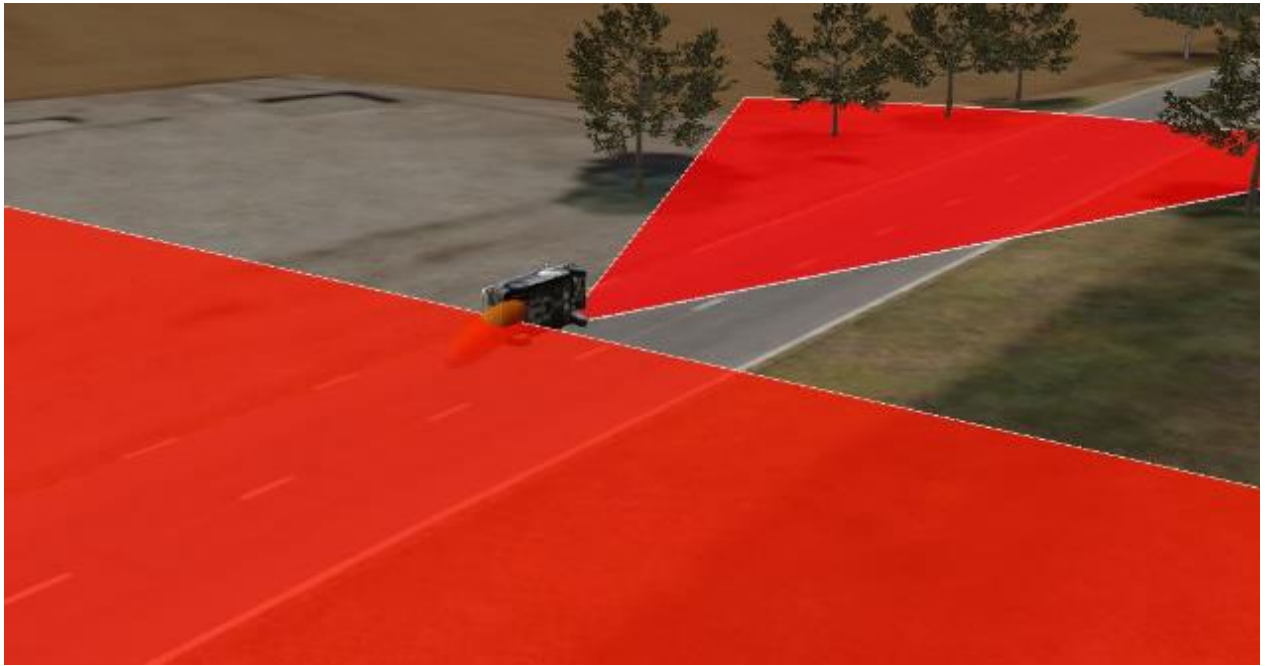


Figure 7 (In red) forbidden angles for reaching a FCH car in fire on the side (TPRD located between the rear wheels with an angle of 45°) ©crise-2015

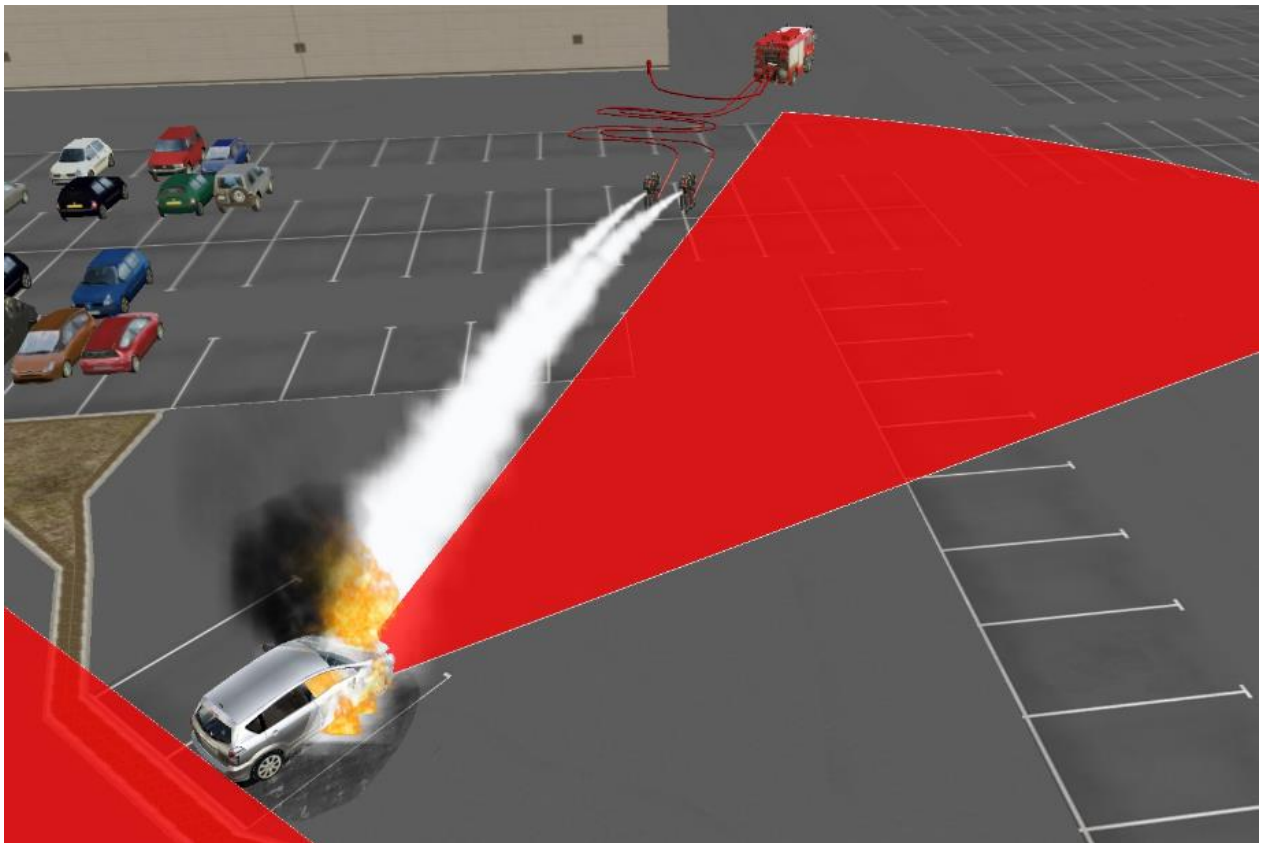


Figure 8 Offensive fire attack with two teams (1st phase) ©crise-2015



Figure 9 Offensive fire attack with two teams (2nd phase) ©crise-2015



Figure 10 Rescue near a FCH car on fire. ©crise-2015

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Figure 11 Forklift H₂ release vent (on each side) ©Air Liquide-2014

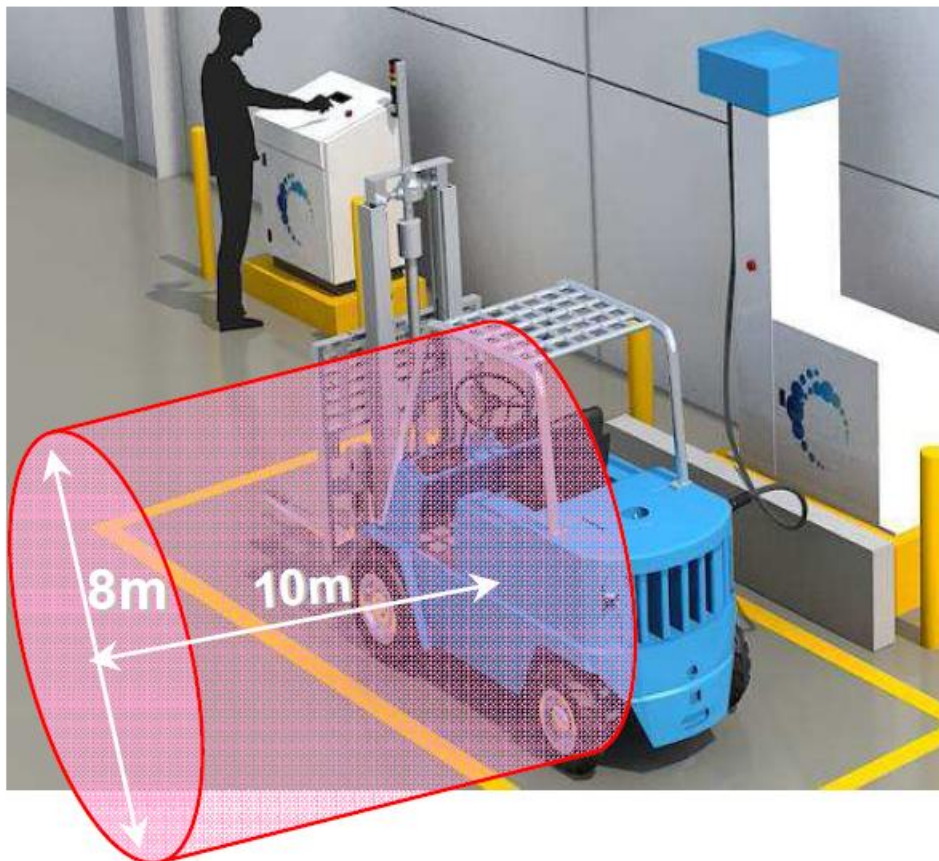


Figure 12 gaseous Danger zone for a forklift during a TPRD H₂ release (on each side during 1 minute) ©Air Liquide-2014

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Figure 13 Indoor refuelling station for forklifts (dispenser) ©Air Liquide-2014



Figure 14 Fire threatening the forklifts©crise-2015

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Table 6 concentrations of hydrogen in air depending on distance to the leak (m)

Pressure in hydrogen storage tank, MPa	TPRD orifice diameter, mm	Distances to 4 vol %, m	Distance to 8 vol %, m
35	2	15	7
35	3	23	11
35	4	31	15
35	5	38	18
35	6	46	22
70	2	20	10
70	3	30	14
70	4	40	19
70	5	50	24
70	6	60	29

Table 7 Flame lengths and separation distances for jet fires from on-board hydrogen tanks

Pressure in storage tank, MPa	TPRD orifice, mm	Flame length, m	SD (no harm), m	SD (pain threshold), m	SD (3 rd degree burn), m
35	2	5	18	16	10
35	3	8	27	23	16
35	4	10	36	26	18
35	5	13	46	39	26
35	6	16	55	47	31
70	2	7	23	20	13
70	3	10	35	30	20
70	4	13	46	40	27
70	5	17	58	50	33
70	6	20	70	60	40

4.3.2 H2 trailer

	H2 trailer	
Tactic n° 5	NO LEAK NO FIRE (technical alarm, work accident, road traffic accident)	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none"> • assure the precise incident location • are there any person involved in the incident? • type of trailer concerned? Size, cargo? is it full or empty? • is the cargo dismantled? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none"> • wind direction • wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none"> • do not cross an eventual explosive gas cloud • do not reach scene from below • anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none"> • Gaseous hydrocarbons detector, • H2 detector • O2 detector • Thermal imaging camera 		
ARRIVAL ON SCENE		
<p>ARRIVAL :</p> <ul style="list-style-type: none"> • Choose a safe way to get to the incident ground, preventing the fire appliance to cross a 		

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flammable gas cloud, and make sure to arrive upwind.

- Stop the fire appliance 50 meters (55 yd) before the incident
- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

- Set up a safety area for the public beyond a radius of 50 meters (55 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

• BY QUESTIONING THE WITNESSES AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS :

- o Which Type is the involved vehicle?
- o what has happened?
- o Is someone injured? Threatened?
- o Has a leak occurred? Is a leak still occurring?
- o Is a part of the truck damaged?
- o Is the trailer dismantled?
- Check energies present in the involved vehicle (tank type, refueling hole type, vehicle registration papers...)
- does a flammable liquid leak exists?
- operate H2 detector

RESCUE


engage rescue as a conventional accident
Rescue of humans override all other considerations.

EXPOSURE PROTECTION

- Use only necessary personnel
- set parking brake
- wedge the vehicle.
- Turn off the ignition key
- Repeatedly check H2 presence in the atmosphere. If H2 is detected apply H2 leak tactic.
- Check if high temperature points exist on the vehicle (more than 150°C/302°F)
- stretch a fire hoseline to protect the action of other teams

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INCIDENT TREATMENT
<ul style="list-style-type: none">• check and close every H2 valve on the trailer.• If no H2 leak and no sign of fire is detected : engage incident settlement following usual road traffic accident and extrication guidelines. <p>DO NOT:</p> <ul style="list-style-type: none">• cut or crush H2 lines• damage H2 tanks <p>If the trailer is dismantled, inspect individually each cylinder contact the transport company hotline to evacuate safely the cylinders</p>
OVERHAUL
<ul style="list-style-type: none">• after a last H2 atmospheric control, Make sure that the vehicle or the wreckage and the cargo is evacuated by authorized personnels (idealy transport company)

	H2 trailer	
Tactic n° 6	H2 LEAK WITHOUT FIRE	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none"> • assure the precise incident location • what happend? • are there any person involved in the incident? • type of trailer concerned? Size, cargo?is if full or empty? •is the cargo dismanteled? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none"> • wind direction • wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none"> • do not cross an eventual explosive gas cloud • do not reach scene from bellow • anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none"> • Gaseous hydrocarbons dectector, • H2 detector 		

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- O2 detector
- Thermal imaging camera

ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind.
- Stop the fire appliance 50 meters (55 yd) before the incident (figure 15)
- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

- Set up a safety area for the public beyond a radius of 100 meters (110 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

IF A PERSON IS INSIDE THE HAZARDOUS AREA :

ENGAGE RESCUE OPERATIONS

IF NO ONE IS INSIDE THE HAZARDOUS AREA:

BY QUESTIONNING THE WITNESSES (DRIVER) AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS:

- o Which Type is the involved vehicle? (Figure 22)
- o what happened?
- o Is the trailer dismanteled?
- o Has a loud hissing sound been eared before the FR arrive?

Confirm the safety area with the H2 detector . If H2 is detected, refine the safety area


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Check if high temperature points exist on the vehicle (more than 150°C/302°F)
RESCUE
<p>Rescue of humans override all other considerations.</p> <p>If a human is threatened or concerned by the gas leak :</p> <ul style="list-style-type: none">• Team 1 : extract the victim(s) from the danger zone by any possible means• Team 2 : stretch a fire hoseline to protect the action of the Team 1 in case of an ignition of the cloud
EXPOSURE PROTECTION
<ul style="list-style-type: none">• Use only necessary personnel• set parking brake• wedge the vehicle.• Turn off the ignition key <ul style="list-style-type: none">• Check if high temperature points exist on the vehicle (more than 150°C/302°F)• stretch a fire hoseline to protect the action of other teams
INCIDENT TREATMENT
<ul style="list-style-type: none">• listen to abnormal noises• Repeatedly check H2 presence in the atmosphere.• check and close every H2 valve on the trailer.(figures 16-17-18-19-20) <p>If there is no means for preventing H2 leak, and no identified stake</p> <p>evaluate the opportunity to let the vehicle leak safely.</p>

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OVERHAUL

- after a last H2 atmospheric control, Make sure that the vehicle or the wreckage and the cargo is evacuated by authorized personnels (idealy transport company)

	H2 trailer	
Tactic n° 7	FIRE	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none">• assure the precise incident location• are there any person involved in the incident?• what happend?• type of trailer concerned? Size, cargo?is if full or empty?•is the cargo dismanteled? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none">• wind direction• wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none">• do not cross an eventual explosive gas cloud• do not reach scene from bellow• anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none">• Gaseous hydrocarbons dectector,• H2 detector		

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- O2 detector
- Thermal imaging camera

ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind.
- Stop the fire appliance 50 meters (55 yd) before the incident
- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

- Set up a safety area for the public beyond a radius of 500 meters (550 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

IF A PERSON IS INSIDE THE HAZARDOUS AREA :

ENGAGE RESCUE OPERATIONS

IF NO ONE IS INSIDE THE HAZARDOUS AREA:

BY QUESTIONNING THE WITNESSES (DRIVER) AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS:

- Which Type is the involved vehicle?
- what happened?
- Is the trailer dismanteled?
- is a cylinder involved in fire?

check the fire scene with the thermal imaging camera:

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- is a cylinder provide a ignited H2 leak?
- is a cylinder impinged by a flame dart?
-

RESCUE

Rescue of humans override all other considerations.

If a human is threatened or concerned by the gas leak :

- Team 1 : extract the victim(s) from the danger zone by any possible means
- Team 2 : stretch a fire hoseline to protect the action of the Team 1

EXPOSURE PROTECTION

- evacuate adjacent buildings
- Prevent the fire from spreading to a uninvolved vehicle(s) or building(s)
- move adjacent non involved vehicles by any way possible (driving, towing, pushing...)

INCIDENT TREATMENT

In case of High stake level situation :

operate an offensive Fire attack:

each Team prepare 80 m of hoselines directly connected to the fire appliance pump

- Team 1: aims to cool the H2 tank to prevent pressure increase in the tanks
- Team 2: aims to extinguish the vehicle fire. Mind that foam can be used to extinguish the truck (tractor) while water is used to cool the trailer tanks. Make sure not to flush foam with water.

THE INCIDENT COMMANDER WILL EVALUATE THE OPORTUNITY AND THE SEQUENCE ORDER TO CLOSE LEAKING TANKS AS SOON THEY ARE NO MORE SUBMITTED TO A PRESSURE

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INCREASE;

if the fire concerns an ignited H₂ leak, the only safe way to put out the fire is to close the appropriate valve.

Previously, the incident commander must have taken appropriate actions to prevent pressure increase in the tanks and checked the efficiency.

Mind that violent reactions are possible between water and burning materials

as soon as possible, wedge the vehicle.

Mind that water will be polluted during extinction

operate its containment.


In there is no identified stake:

evaluate the opportunity to let the vehicle burn safely.

Mind that a cylinder or a bottle is not equipped with pressure release device and will explode if submitted to a pressure increase.

OVERHAUL

- Cool the wreckage as soon as no heat point is detected by the thermal imaging device.
- after a last H₂ atmospheric control, Make sure that the vehicle or the wreckage is evacuated by authorized personnel ideally transport company)

	H2 trailer	
Tactic n° 8	EXTERNAL FIRE THREATENING THE APPLICATION	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none"> • assure the precise incident location • are there any person involved in the incident? • what happend? • type of trailer concerned? Size, cargo?is if full or empty? •is the cargo dismanteled? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none"> • wind direction • wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none"> • do not cross an eventual explosive gas cloud • do not reach scene from bellow • anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none"> • Gaseous hydrocarbons dectector, 		

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- H2 detector
- O2 detector
- Thermal imaging camera

ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind.
- Stop the fire appliance 50 meters (55 yd) before the incident
- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

- Set up a safety area for the public beyond a radius of 500 meters (550 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

- answer the following questions:
 - What is burning?
 - What's the fire Strength?
 - What's the distance between the Fire and the H2 trailer?
- o Is someone injured? Threatened?
- o Has a leak occurred? Is a leak still occurring?

RESCUE

Rescue of humans override all other considerations.

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If a human is threatened or concerned by the Fire :

- Team 1 : extract the victim(s) from the danger zone by any possible means
- Team 2 : stretch a fire hoseline to protect the action of the Team 1

evacuate the passengers in the opposite direction of the wind

EXPOSURE PROTECTION

- Team 1: Attenuate the radiant heat by providing a water spray curtain between the fire and the H2 trailer.

INCIDENT TREATMENT

Operate an defensive Fire attack:

each Team prepare 80 m of hoselines directly connected to the fire appliance pump

- Team 1: Attenuate the radiant heat by providing a water spray curtain between the fire and the H2 trailer.
- Team 2 : Put out the fire with water, foam or powder depending what is burning.

If putting fire out is not possible, move the H2 trailer by any way possible (driving, towing, ...) away from the radiant effect of the fire

Mind that a cylinder or a bottle is not equiped with pressure release device and will explode if submitted to a pressure increase.

OVERHAUL

- Check temperature on the H2 trailer with thermal imaging device.
- after a last H2 atmospheric control, Make sure that the vehicle or the wreckage is evacuated by authorized personnels ideally transport company)



Figure 15 H2 Trailer©Air Liquide-2014



Figure 16 Individual cylinder valve on a H2 trailer. ©Air Liquide-2014



Figure 17 H2 trailer with vertical bottles racks. © Areva/ENSOSP 2015



Figure 18 H2 bottles rack © Areva/ENSOSP 2015



Figure 19 Valves on a H2 bottles Rack © Areva/ENSOSP 2015



Figure 20 Trailer Main H2 valve (outside view) © Areva/ENSOSP 2015




Figure 21 Trailer Main H2 valve (inside view) © Areva/ENSOSP 2015



Figure 22 ADR orange placard on a H2 trailer © Areva/ENSOSP 2015

4.3.3 Refuelling station

	REFUELLING STATION	
Tactic n° 9	NO LEAK NO FIRE (technical alarm, work accident, road traffic accident)	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none"> • assure the precise incident location • are there any person involved in the incident? • are there any vehicle involved in the incident? • what happened? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none"> • wind direction • wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none"> • do not cross an eventual explosive gas cloud • do not reach scene from below • anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p>		

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- Gaseous hydrocarbons detector,
- H2 detector
- O2 detector
- Thermal imaging camera

ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gas cloud, and make sure to arrive upwind.
- Stop the fire appliance 50 meters (55 yd) before the incident
- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

Set up a safety area for the public beyond a radius of 50 meters (55 yd)

- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

• BY QUESTIONING THE WITNESSES, TECHNICAL STAFF OF THE REFUELLING STATION AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS :

o what has happened?

o Is someone injured? Threatened?

o Has a leak occurred? Is a leak still occurring?

o Is a vehicle connected to the refueling station? (if yes, apply FCH vehicle related tactic)

Check energies present in the involved vehicle (tank type, refueling hole type, vehicle registration papers...)


operate H2 detector

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where emergency shutdown devices of the refuelling station activated?
RESCUE
<p>engage rescue as a conventional accident</p> <p>Rescue of humans override all other considerations.</p>
EXPOSURE PROTECTION
<ul style="list-style-type: none">• Use only necessary personnel• Repeatedly check H2 presence in the atmosphere. If H2 is detected apply H2 leak tactic.• stretch a fire hoseline to protect the action of teams <p>push Emergency shutdown devices</p> <p>if the dispenser is physically damaged, close the valves between the storage area and the dispenser.</p>
INCIDENT TREATMENT
<p>If no H2 leak and no sign of fire is detected :</p> <ul style="list-style-type: none">• engage incident settlement with conventional techniques. <p>If a FCH vehicle is connected to the refueling station, disconnect it and move it away.</p> <p>if a H2 trailer is connected to the refueling station storage, close the valves between the trailer and the storage and apply simultaneously the tactic related to trailers</p> <p>DO NOT:</p> <ul style="list-style-type: none">• cut or crush H2 lines• cut or crush High Voltage Lines (orange)• damage H2 tank

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OVERHAUL
<ul style="list-style-type: none">• after a last H2 atmospheric control, <p>Make sure that the refuelling station will be checked be authorized personnels before restart.</p>

	REFUELLING STATION	
Tactic n° 10	H2 LEAK WITHOUT FIRE	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none">• assure the precise incident location• are there any person involved in the incident?• are there any vehicle involved in the incident?• what happened? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none">• wind direction• wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none">• do not cross an eventual explosive gas cloud• do not reach scene from bellow• anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none">• Gaseous hydrocarbons dectector,• H2 detector• O2 detector		

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- Thermal imaging camera

ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind.
- Stop the fire appliance 50 meters (55 yd) before the incident
- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

- Set up a safety area for the public beyond a radius of 100 meters (110 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

IF A PERSON IS INSIDE THE HAZARDOUS AREA :

ENGAGE RESCUE OPERATIONS

IF NO ONE IS INSIDE THE HAZARDOUS AREA:

• BY QUESTIONNING THE WITNESSES, TECHNICAL STAFF OF THE REFUELLING STATION AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS :

o what has happened?

o Is someone injured? Threatened?

o Has a leak occurred? Is a leak still occurring?

Has a loud hissing sound been eared before the FR arrive?

o Is a vehicle connected to the refueling sation? (if yes, apply related tactic)

Check energies present in the involved vehicle (tank type, refueling hole type, vehicle registration papers...)

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<p>operate H2 detector</p> <p>where emergency shutdown devices of the refuelling station activated?</p>
RESCUE
<p>Rescue of humans override all other considerations.</p> <p>If a human is threatened or concerned by the gas leak :</p> <ul style="list-style-type: none">• Team 1 : extract the victim(s) from the danger zone by any possible means• Team 2 : stretch a fire hoseline to protect the action of the Team 1 in case of an ignition of the cloud <p>evacuate the persons in the opposite direction of the wind</p>
EXPOSURE PROTECTION
<ul style="list-style-type: none">• Use only necessary personnel• Repeatedly check H2 presence in the atmosphere. If H2 is detected apply H2 leak tactic.• stretch a fire hoseline to protect the action of teams <p>push Emergency shutdown devices</p> <p>if the dispenser is physically damaged, close the valves between the storage area and the dispenser.</p>
INCIDENT TREATMENT
<p>close the valves between the dispenser and the h2 storage</p> <p>If a FCH vehicle is connected to the refueling station, disconnect it and move it away.</p> <p>if a H2 trailer is connected to the refueling station storage, close the valves between the trailer and the storage and apply simultaneously the tactic related to trailers</p>

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Prevent H2 to accumulate in enclosed premises


DO NOT:

- cut or crush H2 lines
- cut or crush High Voltage Lines
- damage H2 tank

OVERHAUL

- after a last H2 atmospheric control,

Make sure that before restart, the refuelling station will be checked by authorized personnel and the malfunction and damages repaired.

	REFUELLING STATION	
Tactic n° 11	FIRE	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none">• assure the precise incident location• are there any person involved in the incident?• are there any vehicle involved in the incident?• what happened? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none">• wind direction• wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none">• do not cross an eventual explosive gas cloud• do not reach scene from bellow• anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none">• Gaseous hydrocarbons dectector,• H2 detector• O2 detector• Thermal imaging camera		

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ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind.
- Stop the fire appliance 50 meters (55 yd) before the incident
- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

- Set up a safety area for the public beyond a radius of 500 meters (550 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

IF A PERSON IS INSIDE THE HAZARDOUS AREA :

ENGAGE RESCUE OPERATIONS

IF NO ONE IS INSIDE THE HAZARDOUS AREA:

- BY QUESTIONNING THE WITNESSES, TECHNICAL STAFF OF THE REFUELLING STATION AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS :

o what has happened?

o Is someone injured? Threatened?

o Has a leak occurred? Is a leak still occurring?

Has a loud hissing sound been eared before the FR arrive?

o Is a vehicle connected to the refueling sation? (if yes, apply related tactic)

Check energies present in the involved vehicle (tank type, refueling hole type, vehicle registration papers...)

operate H2 detector

where emergency shutdown devices of the refuelling station activated?

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RESCUE
<p>Rescue of humans override all other considerations.</p> <p>If a human is threatened or concerned by the Fire :</p> <ul style="list-style-type: none">• Team 1 : extract the victim(s) from the danger zone by any possible means• Team 2 : stretch a fire hoseline to protect the action of the Team 1 <p>evacuate the passengers in the opposite direction of the wind</p>
EXPOSURE PROTECTION
<ul style="list-style-type: none">• evacuate adjacent buildings• Prevent the fire from spreading to a uninvolved vehicle(s) or building(s)• move adjacent non involved vehicles by any way possible (driving, towing, pushing...) <p>Push Emergency shutdown devices on the dispenser and the storage.</p> <p>close the valves between the storage area and the dispenser.</p>
INCIDENT TREATMENT
<p>two cases are possible:</p> <p>The fire concerns the dispenser area.</p> <p>Push Emergency shutdown devices</p> <p>prevent the fire to spread to a uninvolved part of the refuelling station with water spray curtains.</p> <p>put the fire out.</p> <p>the fire concerns the storage area.(High stake level situation)</p> <p>Push Emergency shutdown devices</p> <p>prevent the fire to spread to a uninvolved part of the refuelling station with water spray</p>

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curtains.

put the fire out.

if the fire concerns an ignited H₂ leak, the only safe way to put out the fire is to close the appropriate valve.

Previously, the incident commander must have taken appropriate actions to prevent pressure increase in the tanks and checked the efficiency.

Operate an offensive Fire attack:

each Team prepare 80 m of hoselines directly connected to the fire appliance pump

- Team 1: aims to cool the H₂ tank to prevent pressure increase in the tanks
- Team 2: aims to extinguish the fire.

Mind that H₂ storages are equipped with Pressure release devices that may open and close several times depending on the pressure inside the tank.

Mind that violent reactions are possible between water and burning materials

Mind that water will be polluted during extinction


operate its containment.

In there is no identified stake:

evaluate the opportunity to let the vehicle burn safely.

OVERHAUL

- Cool the wreckage as soon as no heat point is detected by the thermal imaging device.
- Repeatedly check H₂ presence in the atmosphere.

	REFUELLING STATION	
Tactic n° 12	EXTERNAL FIRE THREATENING THE APPLICATION	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none">• assure the precise incident location• are there any person involved in the incident?• are there any vehicle involved in the incident?• what happened? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none">• wind direction• wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none">• do not cross an eventual explosive gas cloud• do not reach scene from bellow• anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none">• Gaseous hydrocarbons dectector,• H2 detector		

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- O2 detector
- Thermal imaging camera

ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind.
- Stop the fire appliance 50 meters (55 yd) before the incident
- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

- Set up a safety area for the public beyond a radius of 500 meters (550 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

• BY QUESTIONNING THE WITNESSES, TECHNICAL STAFF OF THE STATION AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS :

o what has happened?

o witch part of the application is concerned by the incident? (dispenser, storage, electrical equipment...)

o Is someone injured? Threatened?

o Has a leak occured? Is a leak still occuring?

• What is burning?

• What's the fire Strength?

• What's the distance between the Fire and the refuelling station?


The station manager is able to provide accurate informations

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RESCUE
<p>Rescue of humans override all other considerations.</p> <p>If a human is threatened or concerned by the Fire :</p> <ul style="list-style-type: none">• Team 1 : extract the victim(s) from the danger zone by any possible means• Team 2 : stretch a fire hoseline to protect the action of the Team 1 <p>evacuate people in the opposite direction of the wind</p>
EXPOSURE PROTECTION
<ul style="list-style-type: none">• Team 1: Attenuate the radiant heat by providing a water spray curtain between the fire and the refuelling station.
INCIDENT TREATMENT
<p>Operate an defensive Fire attack:</p> <p>each Team prepare 80 m of hoselines directly connected to the fire appliance pump</p> <ul style="list-style-type: none">• Team 1: Attenuate the radiant heat by providing a water spray curtain between the fire and the refuelling station.• Team 2 : Put out the fire with water, foam or powder depending what is burning. <p>Mind that a refuelling station storage is equipped with pressure release device . A H2 leak may occur if the storage is submitted to a high temperature flux.</p>
OVERHAUL
<ul style="list-style-type: none">• Cool the wreckage as soon as no heat point is detected by the thermal imaging device.• Repeatedly check H2 presence in the atmosphere

4.3.4

4.3.5 Stationnary power generation unit (SPGU)/Hydrogen based energy storage system (H2ESS)

	Stationary power generation unit (SPGU) Hydrogen-based energy storage system (H2ESS)	
Tactic n° 13	NO LEAK NO FIRE (technical alarm)	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none"> • assure the precise incident location and the concerned power • is this stationary power generation unit known by the fire service? • Does a firefighting plan exist? take it in the fire appliance and read it on the road. <p>which part of the application is concerned by the incident? (Fuel cell, H2/O2 storage, photovoltaic panels, wind turbine...)</p> <ul style="list-style-type: none"> • are there any person involved in the incident? • what happened? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none"> • wind direction • wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p>		

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- do not cross an eventual explosive gas cloud
- do not reach scene from below
- anticipate the need of a hydrant

TAKE FOLLOWING TOOLS:

- Gaseous hydrocarbons detector,
- H₂ detector
- O₂ detector
- Thermal imaging camera

ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gas cloud, and make sure to arrive upwind.
- Stop the fire appliance 50 meters (55 yd) before the incident .

If a wind turbine is concerned, stop at a distance of twice the height of the wind turbine

- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

if H₂/O₂ storage is concerned:

- Set up a safety area for the public beyond a radius of 500 meters (550 yd)

if a wind turbine is concerned:

- Set up a safety area for the public beyond a radius of twice the height of the wind turbine ..

if fuel cell or electrical devices is concerned:

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- Set up a safety area for the public beyond a radius of 50 meters (55 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

• BY QUESTIONING THE WITNESSES, TECHNICAL STAFF OF THE SPGU/H2ESS AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS :

o what has happened?

o which part of the application is concerned by the incident? (Fuel cell, H₂/O₂ storage, photovoltaic panels, wind turbine...)

o Is someone injured? Threatened?

o Has a leak occurred? Is a leak still occurring? Which ones?

is the system delivering electricity?

Is a technician present on the plant area?

look for the emergency fire and rescue plan.

locate precisely dangerous areas, Emergency shutdown devices, valves,

evaluate the amount of compressed gases present in the tanks.

RESCUE

engage rescue as a conventional accident

Rescue of humans override all other considerations.

To reach safely a casualty, it is necessary sure that he's not already submitted to an electrical current.

Push Emergency shutdown devices, take fallen cables away with appropriate electrical gloves...(figure 23)

EXPOSURE PROTECTION

Push Emergency shutdown devices of the concerned area

As it is possible:

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Isolate (pressure, gas supply, electricity) energy production unit, fuel cell and storages (each one from the others).

Check and note every ESD or valve turned off on the emergency plan.(figures 24-25-26-27)

- Repeatedly check H2 presence in the atmosphere. If H2 is detected apply H2 leak tactic.

INCIDENT TREATMENT

If no H2 leak and no sign of fire is detected :

- engage incident settlement.

DO NOT:

- cut or crush H2/O2 lines
- cut or crush High Voltage Lines (orange)
- damage H2/O2 tank


If a H2 leak is detected, apply tactic n°2 "H2 LEAK WITHOUT FIRE"

Mind that Photovoltaic panels still produce high voltage electricity when exposed to daylight.

OVERHAUL

- after a last H2 atmospheric control,

Make sure that the application will be checked be authorized personnels before restart.

	Stationary power generation unit (SPGU) Hydrogen-based energy storage system (H2ESS)	
Tactic n° 14	H2 LEAK WITHOUT FIRE	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none"> • assure the precise incident location and the concerned power • is this stationary power generation unit known by the fire service? • Does a firefighting plan exist? take it in the fire appliance and read it on the road. <p>Which part of the application is concerned by the incident? (Fuel cell, H2/O2 storage, photovoltaic panels, wind turbine...)</p> <ul style="list-style-type: none"> • are there any person involved in the incident? • what happened? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none"> • wind direction • wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none"> • do not cross an eventual explosive gas cloud • do not reach scene from below • anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p>		

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- Gaseous hydrocarbons detector,
- H2 detector
- O2 detector
- Thermal imaging camera

ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gas cloud, and make sure to arrive upwind.

- Stop the fire appliance 50 meters (55 yd) before the incident .

If a wind turbine is concerned, stop at a distance of twice the height of the wind turbine

- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

if H2/O2 storage is concerned:

- Set up a safety area for the public beyond a radius of 500 meters (550 yd)

if a wind turbine is concerned:

- Set up a safety area for the public beyond a radius of twice the height of the wind turbine .

if fuel cell or electrical devices is concerned:

- Set up a safety area for the public beyond a radius of 50 meters (55 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

- BY QUESTIONNING THE WITNESSES, TECHNICAL STAFF OF THE SPGU/H2ESS AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS :

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o what has happened?

o witch part of the application is concerned by the incident? (Fuel cell, H2/O2 storage, ...)

o Is someone injured? Threatened?

o Has a leak occured? Is a leak still occuring?

is the system delivering electricity?

Is a technician present on the plant area?

look for the mergency fire and rescue plan.

locate precisely dangerous areas, Emergency shutdown devices, valves,

evaluate the amount of compressed gases present in the tanks.

RESCUE

Rescue of humans override all other considerations.

If a human is threatened or concerned by the Fire :

- Team 1 : extract the victim(s) from the danger zone by any possible means
- Team 2 : stretch a fire hoseline to protect the action of the Team 1

evacuate the passengers in the opposite direction of the wind

EXPOSURE PROTECTION

note that a SPGU is supposed to produce electricity as soon as it is no longer supplied by the electrical network.

So it is necessary to stop the electrical production of the SPGU before any other action by Pushing Emergency shutdown devices.

As it is possible:

Isolate (pressure, gas supply, electricity) energy production unit, fuel cell and storages (each one from the others).

Check and note every ESD or valve turned off on the emergency plan.

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- Repeatedly check H2 presence in the atmosphere.

INCIDENT TREATMENT

If no H2 leak and no sign of fire is detected :

- engage incident settlement.

DO NOT:

- cut or crush H2/O2 lines
- cut or crush High Voltage Lines (orange)
- damage H2/O2 tank

Fire services are not supposed to open the Fuel Cell compartment.

Locate precisely the H2 leak

if located in an building, operate a wide ventilation of all concerned premises.

according to information provided by the emergency plans and the validation of the technicians (if available), close appropriate valves, ESD...

- Repeatedly check H2 presence in the atmosphere.


Mind that Photovoltaic panels still produce high voltage electricity when exposed to daylight.

Mind that H2 and O2 storages are equipped with Pressure release devices that may open and close several times depending the pressure inside the tank.(figures 31-32)

OVERHAUL

- after a last H2 atmospheric control,

Make sure that the application will be checked by authorized personnels before restart.

	<p>Stationary power generation unit (SPGU)</p> <p>Hydrogen-based energy storage system (H2ESS)</p>	
Tactic n° 15	FIRE	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none"> • assure the precise incident location and the concerned power • is this stationary power generation unit known by the fire service? • Does a firefighting plan exist? take it in the fire appliance and read it on the road. <p>Which part of the application is concerned by the incident? (Fuel cell, H2/O2 storage, photovoltaic panels, wind turbine...)</p> <ul style="list-style-type: none"> • are there any person involved in the incident? • what happened? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none"> • wind direction • wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none"> • do not cross an eventual explosive gas cloud • do not reach scene from below • anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p> <ul style="list-style-type: none"> • Gaseous hydrocarbons detector, • H2 detector 		

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- O2 detector
- Thermal imaging camera

ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gaz cloud, and make sure to arrive upwind.

- Stop the fire appliance 50 meters (55 yd) before the incident .

If a wind turbine is concerned, stop at a distance of twice the height of the wind turbine

- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

if H2/O2 storage is concerned:

- Set up a safety area for the public beyond a radius of 500 meters (550 yd)

if a wind turbine is concerned:

- Set up a safety area for the public beyond a radius of twice the height of the wind turbine .

if fuel cell or electrical devices is concerned:

- Set up a safety area for the public beyond a radius of 50 meters (55 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

• BY QUESTIONNING THE WITNESSES, TECHNICAL STAFF OF THE SPGU/H2ESS AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS :

o what has happened?

o witch part of the application is concerned by the incident? (Fuel cell, H2/O2 storage, photovoltaic panels, wind turbine...)

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o Is someone injured? Threatened?

o Has a leak occurred? Is a leak still occurring? Which ones?

is the system delivering electricity?

Is a technician present on the plant area?

look for the emergency fire and rescue plan.

locate precisely dangerous areas, Emergency shutdown devices, valves,

evaluate the amount of compressed gases present in the tanks.

RESCUE

Rescue of humans override all other considerations.

If a human is threatened or concerned by the Fire :

- Team 1 : extract the victim(s) from the danger zone by any possible means
- Team 2 : stretch a fire hoseline to protect the action of the Team 1

evacuate the passengers in the opposite direction of the wind

EXPOSURE PROTECTION

- evacuate adjacent buildings
- Prevent the fire from spreading to uninvolved buildings

note that a SPGU is supposed to produce electricity as soon as it is no longer supplied by the electrical network.

So it is necessary to stop the electrical production of the SPGU before any other action by Pushing Emergency shutdown devices.

As it is possible:

Isolate (pressure, gas supply, electricity) energy production unit, fuel cell and storages (each one from the others).(figure 33)

Check and note every ESD or valve turned off on the emergency plan.

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- Repeatedly check H2 presence in the atmosphere.

INCIDENT TREATMENT

3 cases are possible:

The fire concerns the photovoltaic panels or wind turbine area.

Push Emergency shutdown devices

prevent the fire to spread to a uninvolved part of the plant with water spray curtains.

put the fire out.

the fire concerns the Fuel cell Compartment.

Push Emergency shutdown devices

prevent the fire to spread to a uninvolved part of the plant with water spray curtains.

do not open the FC compartment.

the fire concerns the storage area.(High stake level situation)

Push Emergency shutdown devices

prevent the fire to spread to a uninvolved part of the plant with water spray curtains.

put the fire out with an offensive Fire attack:

each Team prepare 80 m of hoses directly connected to the fire appliance pump

- Team 1: aims to cool the H2 tank to prevent pressure increase in the tanks
- Team 2: aims to extinguish the fire.

if the fire concerns an ignited H2 leak, the only safe way to put out the fire is to close the appropriate valve.

Previously, the incident commander must have taken appropriate actions to prevent pressure increase in the tanks and checked the efficiency.

Mind that H2 storages are equipped with Pressure release devices that may open and close

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several times depending the pressure inside the tank.

Mind that violent reactions are possible between water and burning materials

Mind that water will be polluted during extinction


operate its containment.

In there is no identified stake:

evaluate the opportunity to let the fire burn safely.

OVERHAUL

- Cool the wreckage as soon as no heat point is detected by the thermal imaging device.
- Repeatedly check H2 presence in the atmosphere.

	Stationary power generation unit (SPGU) Hydrogen-based energy storage system (H2ESS)	
Tactic n° 16	EXTERNAL FIRE THREATENING THE APPLICATION	
AT THE FIRE STATION		
<p>TAKE USEFUL information ABOUT THE INCIDENT:</p> <ul style="list-style-type: none"> • assure the precise incident location and the concerned power • is this stationary power generation unit known by the fire service? • Does a firefighting plan exist? take it in the fire appliance and read it on the road. <p>Which part of the application is concerned by the incident? (Fuel cell, H₂/O₂ storage, photovoltaic panels, wind turbine...)</p> <ul style="list-style-type: none"> • are there any person involved in the incident? • what happened? <p>TAKE USEFUL INFORMATION ABOUT THE METEOROLOGICAL SITUATION:</p> <ul style="list-style-type: none"> • wind direction • wind speed <p>ITINERARY</p> <p>choose a safe itinerary :</p> <ul style="list-style-type: none"> • do not cross an eventual explosive gas cloud • do not reach scene from below • anticipate the need of a hydrant <p>TAKE FOLLOWING TOOLS:</p>		

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- Gaseous hydrocarbons detector,
- H2 detector
- O2 detector
- Thermal imaging camera

ARRIVAL ON SCENE

ARRIVAL :

- Choose a safe way to get to the incident ground, preventing the fire appliance to cross a flammable gas cloud, and make sure to arrive upwind.
- Stop the fire appliance 50 meters (55 yd) before the incident .

If a wind turbine is concerned, stop at a distance of twice the height of the wind turbine

- away from a possible ignited flammable liquid leak progression.
- Engage the pump and connect the fire appliance to a hydrant.

SAFETY AREA

if H2/O2 storage is concerned:

- Set up a safety area for the public beyond a radius of 500 meters (550 yd)

if a wind turbine is concerned:

- Set up a safety area for the public beyond a radius of twice the height of the wind turbine .

if fuel cell or electrical devices is concerned:

- Set up a safety area for the public beyond a radius of 50 meters (55 yd)
- Ensure that unauthorized/untrained personnel do not enter the hazardous area

SIZE UP THE SCENE

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- BY QUESTIONNING THE WITNESSES, TECHNICAL STAFF OF THE SPGU/H2ESS AND OBSERVATION, ANSWER THE FOLLOWING QUESTIONS :

o what has happened?

o witch part of the application is concerned by the incident? (Fuel cell, H2/O2 storage, photovoltaic panels, wind turbine...)

o Is someone injured? Threatened?

o Has a leak occured? Is a leak still occuring?

is the system delivering electricity?

Is a technician present on the plant area?

look for the mergency fire and rescue plan.

locate precisely dangerous areas, Emergency shutdown devices, valves,

evaluate the amount of compressed gases present in the tanks.

RESCUE

Rescue of humans override all other considerations.

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EXPOSURE PROTECTION

- evacuate adjacent buildings
- Prevent the fire from spreading to uninvolved buildings

note that a SPGU is supposed to produce electricity as soon as it is no longer sullpied by the electrical network.

So it is necessary to stop the electrical production of the SPGU before any other action by Pushing Emergency shutdown devices.

As it is possible:

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Isolate (pressure, gas supply, electricity) energy production unit, fuel cell and storages (each one from the others).

Check and note every ESD or valve turned off on the emergency plan.

- Repeatedly check H2 presence in the atmosphere.

INCIDENT TREATMENT

2 cases are possible:

The fire threatens the Fuel cell Compartment, the photovoltaic panels or wind turbine area.

Push Emergency shutdown devices

prevent the fire to spread to a uninvolved part of the plant with water spray curtains.

put the fire out.

do not open the FC compartment.

the fire concerns the storage area.(High stake level situation)

Push Emergency shutdown devices

prevent the fire to spread to a uninvolved part of the plant with water spray curtains.

put the fire out with an offensive Fire attack:

each Team prepare 80 m of hoselines directly connected to the fire appliance pump

- Team 1: aims to cool the H2 tank to prevent pressure increase in the tanks
- Team 2: aims to extinguish the fire.

if the fire concerns an ignited H2 leak, the only safe way to put out the fire is to close the appropriate valve.

Previously, the incident commander must have took appropriate actions to prevent pressure increase in the tank and checked the efficiency.

Mind that H2 storages are equipped with Pressure release devices that may open and close several times depending the pressure inside the tank.

Mind that violent reactions are possible between water and burning materials

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Mind that water will be polluted during extinction
operate its containment.

In there is no identified stake:
evaluate the opportunity to let the fire burn safely.

OVERHAUL

- Cool the wreckage as soon as no heat point is detected by the thermal imaging device.
- Repeatedly check H₂ presence in the atmosphere.



Figure 23 Main electrical Emergency ShutDown © Areva/ENSOSP 2015

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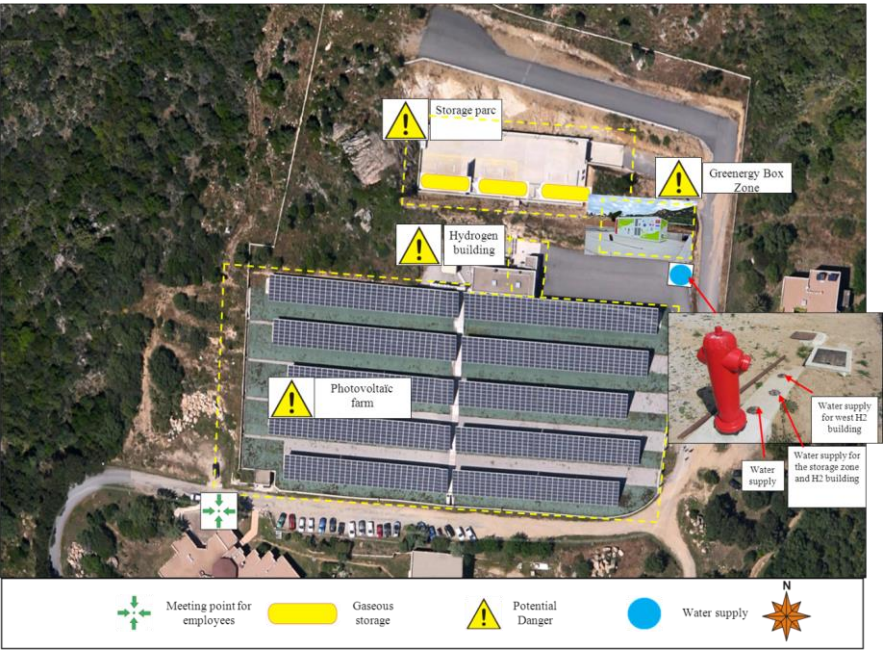


Figure 24 Example of emergency plan (1) ©areva

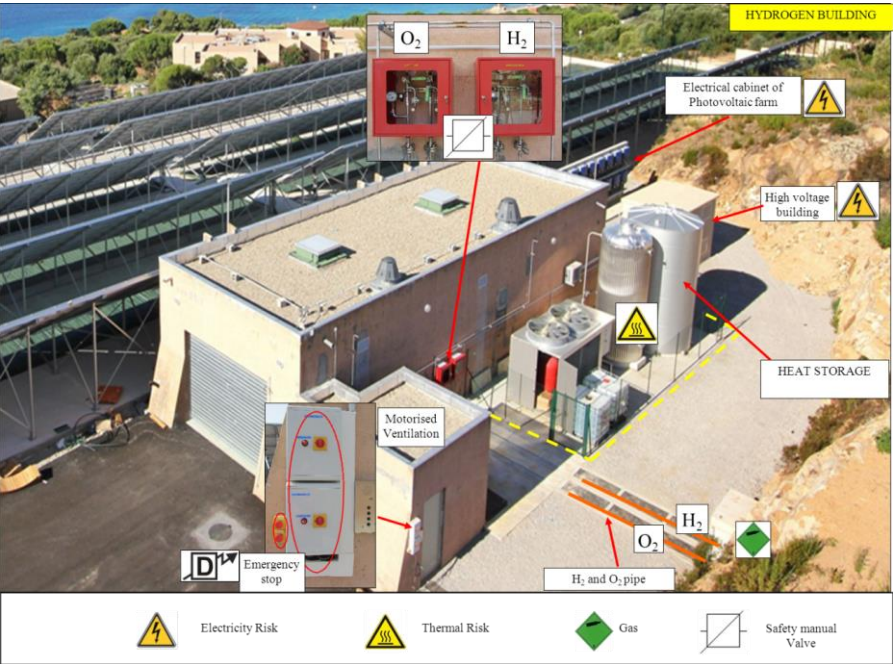


Figure 25 Example of emergency plan (2) ©areva

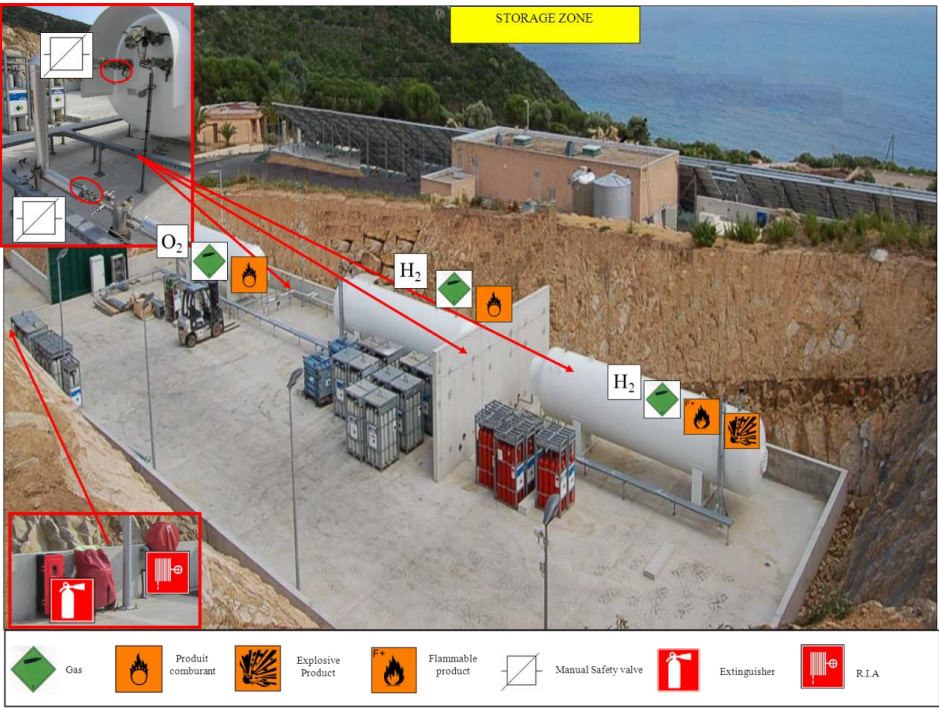


Figure 26 Example of emergency plan (3) ©areva

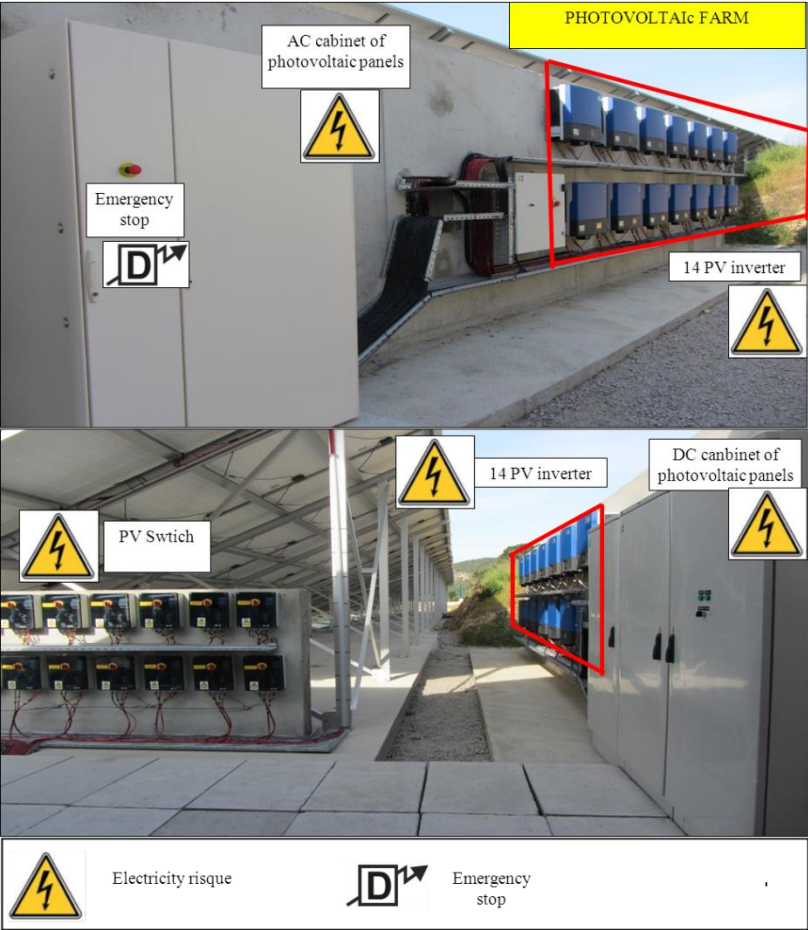


Figure 27 Example of emergency plan (4) ©areva



Figure 28 Areva backup System global view ©Areva/Ensosp 2015



Figure 29 Areva backup System (fuel cell compartment) ©Areva/Ensosp 2015

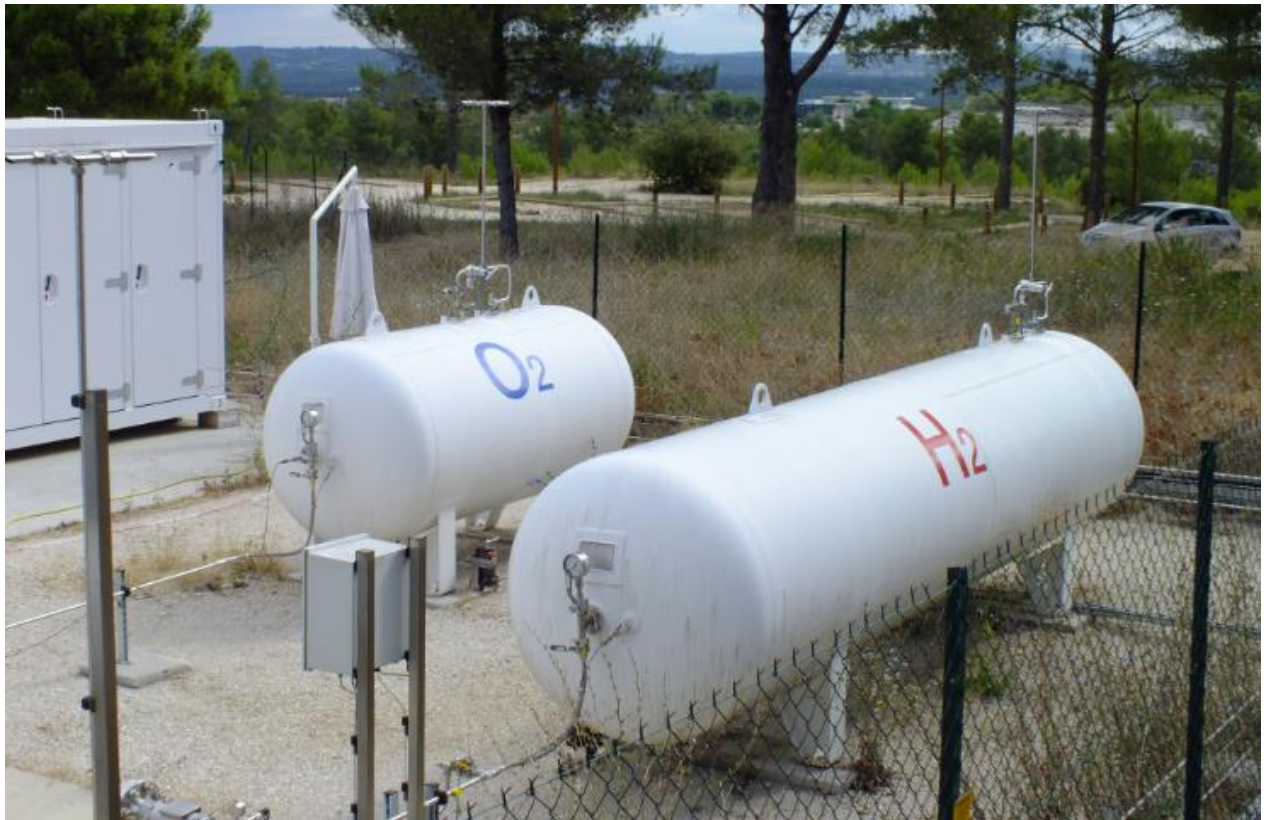


Figure 30 Areva backup System (H2 and O2 storages) ©Areva/Ensosp 2015



Figure 31 Areva backup System (pressure release devices) ©Areva/Ensosp 2015



Figure 32 Areva backup System (pressure release device detail) ©Areva/Ensosp 2015



Figure 33 Areva backup System (H2 and O2 network detail with valves) ©Areva/Ensosp 2015



Figure 34 Emergency shutdown and h₂/o₂ valves on a areva greenbox©Areva/Ensosp 2015



Figure 35 Valve on a H₂ bottle ©Areva/Ensosp 2015

5 CONCLUSION

This document aim to describe strategies and tactics to deal with Hydrogen fires in some specific situation.

As said in this document, every situation is unique and the incident commander must gather all useful informations to assess precisely the incident and take the appropriate decisions.

The safety distances proposed in this document take into account the worst case scenarii : the failure of the pressure release devices. The incident commander can with verified informations enlarge or reduce those distances.

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