

Comparative audio analysis

Title: Result of cigarette and propagation tests

Tests carried out and audio pick-up sources available:

Six tests including a fire break-out in an oxygen box were carried out:

- Three tests were carried out in an oxygen box with glass panel to illustrate the fire damage sequence to the oxygen box and mask assembly.
- Three fire tests using a lateral storage compartment to analyse the propagation of the fire to the elements in the vicinity of the oxygen box.

During these tests, the audio pick-up sources consisted of:

- an oxygen mask microphone,
- a boomset microphone (placed close to oxygen box),
- a cockpit area microphone (CAM),
- one or more Gopro cameras.

Note: the signals from the oxygen mask, boomset and CAM microphones were recorded by a CVR.

All these tests were carried out with a 5-bar oxygen supply.

Description of tests (conditions and short description)

“Cigarette_00” test¹:

An oxygen box with glass panel holding an oxygen mask nose cup equipped with its microphone. An “open” hose replaced the original hose of the oxygen mask (i.e. the oxygen mask regulator was not connected to the oxygen supply. The “open” hose reproduced a leak in the box upstream of the mask). The door was opened and then closed again and the supply of oxygen cut-off by means of the solenoid valve. A cigarette was placed in the oxygen box and the oxygen flow was opened again to create a continuous leak. The combustion of the cigarette - accelerated by the continuous flow of oxygen - quickly caused damage to the nearby elements with the fire spreading to the oxygen box + mask assembly.

“Cigarette_03” and “Cigarette_04” tests:

An oxygen box with glass panel holding an oxygen mask equipped with its microphone. The mask was connected to the outlet of the oxygen box valve. Pressing and holding the “Push To Test” pushbutton of the oxygen box enriched the oxygen box with oxygen. A cigarette was then placed in the oxygen box and its combustion caused an element to catch fire with the fire then spreading to the oxygen box + mask assembly.

“Propagation_01” test:

A lateral storage compartment equipped with two oxygen boxes (each holding its oxygen mask) connected to an oxygen supply controlled by a solenoid valve. One of the two oxygen boxes was modified (put in a “non-reset” configuration) and the mask inside it, set to the EMERGENCY position. The oxygen box was enriched with oxygen by opening the oxygen supply for 5 s. A flame was produced² inside the box and the solenoid valve opened again to allow a continuous flow of oxygen (via the mask EMERGENCY position) into the box. The elements of the box + mask assembly caught fire and the fire spread to their environment (lateral storage compartment).

¹ This test is not mentioned in the study

² Using a remote-controlled system

“Propagation_02” test:

A lateral storage compartment equipped with an oxygen box (holding its oxygen mask) was connected to an oxygen supply controlled by a solenoid valve set to open. The left door of the oxygen box was opened and then closed again without pressing the box’s “Push To Test” button (i.e. no reset). The oxygen box was enriched with oxygen by pressing the oxygen mask knob twice for a total time of 8 s³. A flame was then produced inside the box and the elements of the box + mask assembly successively caught fire. The fire caused an element to rupture resulting in a continuous oxygen leak. The fire spread to the immediate environment. A fire extinguisher was activated and completely emptied to try and put out the fire.

“Propagation_03” test:

A doc storage compartment equipped with two oxygen boxes (each holding its oxygen mask) was connected to an oxygen supply controlled by a solenoid valve set to open. The left door of the oxygen box was opened and then closed again without pressing the box’s “Push To Test” button (i.e. no reset). The oxygen box was enriched with oxygen by pressing the oxygen mask knob for 7 s. A flame was then produced inside the box and the elements of the box + mask assembly successively caught fire. The fire caused an element to rupture resulting in a continuous oxygen leak. The fire spread to the immediate environment. The oxygen supply was cut off and a fire extinguisher activated and completely emptied.

Definition:

Leaking noise: Broadband noise over the entire bandwidth of the microphone picking up the sound.

Sound runaway: Presence of noise bumps - broadband energy bumps - where the frequency increases rapidly to concentrate around 1.2 and 2 kHz (the phenomenon could be described in psychoacoustic terms as a "hissing sound increasing in pitch"). The sound runaway is accompanied by an increase in the overall noise level.

³ 6 s then 2 s

Analysis of data:

The sound sequences picked up during these tests were analysed and compared with the sequence from flight MS804:

- Page #1 shows the waveform of the audio recording (oxygen mask microphone signal and CAM signal) during the "Cigarette_00" test and the associated sequence of images. In the presence of an established oxygen leak, the cigarette introduced into the box immediately ignited, and very quickly set fire to the entire box and its contents (oxygen mask). There was a sound runaway 2.5 s after the cigarette was introduced and the microphone on the oxygen mask stopped working 3.5 s after the mask ignited.
- Page #2 shows the waveform of the audio recording (oxygen mask microphone signal and boomset microphone signal) during the "Cigarette_03" test and the associated sequence of images. The cigarette introduced into the oxygen-enriched box progressively damaged the oxygen mask hose (28 s of crackling noises are present during which the combustion of the braided protection is visible) until the core of the hose was pierced. When the hose was pierced, there was a broadband noise followed 1s later by a sound runaway. The fire that immediately followed the piercing of the hose very quickly engulfed the entire box and its contents (oxygen mask). The oxygen mask microphone stopped working 6 s after the mask caught fire.
- Page #3 shows the waveform of the audio recording (oxygen mask microphone signal and boomset microphone signal) during the "Cigarette_04" test and the associated sequence of images. The cigarette introduced into the oxygen-enriched box progressively damaged the oxygen mask hose (22 s of crackling noises are present during which the combustion of the braided protection is visible) until the core of the hose was pierced. When the hose was pierced, there was a broadband noise followed 0.5 s later by a sound runaway. The fire that followed the piercing of the hose very quickly engulfed the entire box and its contents (oxygen mask). The oxygen supply was cut off 5 s after the mask ignited and before the oxygen mask microphone was damaged.
- Page #4 shows the waveform of the audio recording (GOPRO camera sound band) during the "Propagation_01" test and the associated sequence of images. Smoke and flames could be seen coming out of the oxygen box 5 s after the remote lighting of a cotton pad placed in the bottom of the oxygen box. The mask hose was probably pierced 18 s after the start of the fire. This was shown by a broadband noise followed 1s later by a sound runaway. The fire that followed the piercing of the hose spread rapidly to the surrounding elements. The leaking noise suddenly stopped for 0.5 s - without any action by the test operators - 50 s after the mask hose was probably pierced. This short interruption in the leak preceded a detonation, the resumption of the leak and the enrichment of the fire.
- Page #5 shows the waveform of the audio recording (oxygen mask microphone signal and CAM signal) during the "Propagation_02" test and the associated sequence of images. Smoke and flames could be seen coming out of the oxygen box 6 s after the remote reactivation of the cotton pad fire in the bottom of the oxygen box⁴. The mask hose was probably pierced 13 s after the reactivation of the fire. It was preceded over the same period by cracking noises picked up by the oxygen mask microphone. The probable piercing of the hose produced a broadband noise. The sound runaway described for the previous tests was not perceived. The fire that followed the piercing of the hose spread rapidly to the surrounding elements. The leaking noise was continuous until the oxygen supply of the test set-up was cut off.

⁴ The initial break-out did not last; the fire did not spread in the box.

The oxygen mask microphone stopped working 5 s after the probable piercing of the oxygen mask hose.

- Page #6 shows the waveform of the audio recording (oxygen mask microphone signal and CAM signal) during the "Propagation_03" test and the associated sequence of images. Smoke and flames could be seen coming out of the oxygen box 7 s after the remote lighting of a cotton pad placed in the bottom of the oxygen box. The mask hose was probably pierced 14 s after the start of the fire. It was preceded over the same period by cracking noises picked up by the oxygen mask microphone. The probable piercing of the hose produced a broadband noise followed 0.5 s later, by a sound runaway. The fire that followed the piercing of the hose spread rapidly to the surrounding elements. Cutting off the oxygen supply - which preceded the use of the fire extinguisher - stopped the leaking noise.
- Appendix 7 shows for comparison purposes, the waveform of the CVR audio recording of MS804 (co-pilot's oxygen mask microphone signal and CAM signal).

Results:

It was observed during these tests that:

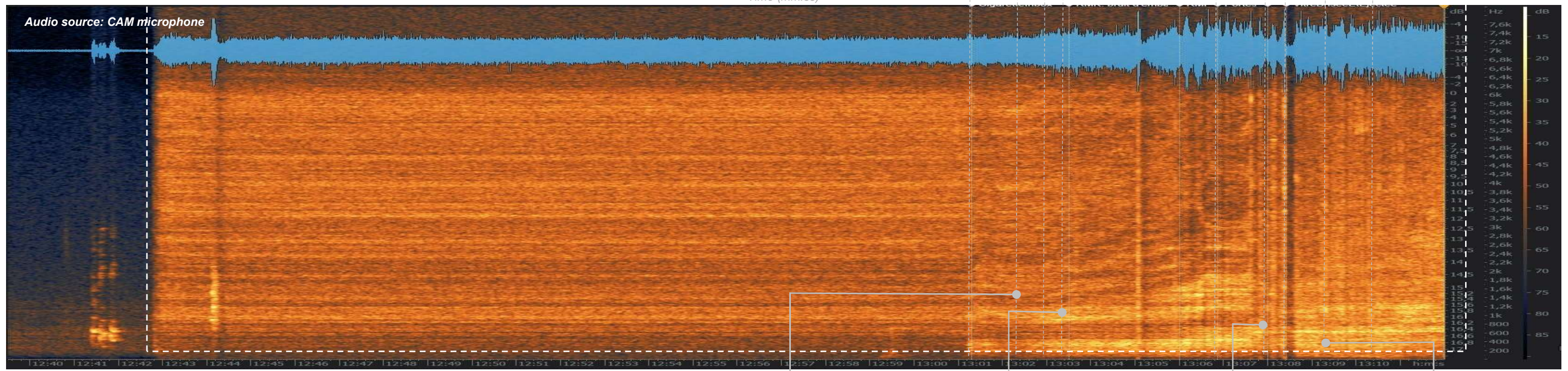
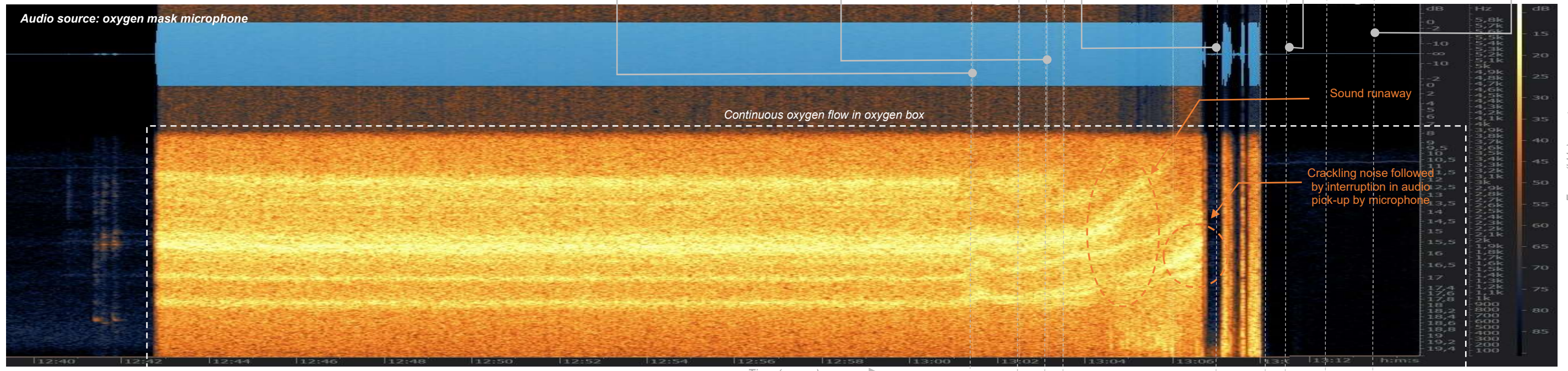
- The introduction of an external, glowing or ignited object into an oxygen box caused slow combustion of the protective elements of the oxygen distribution hoses of the assembly; the hose was pierced between 13 and 28 s after the introduction of an outside element into the crew oxygen assembly (oxygen mask and box). This slow combustion was accompanied by characteristic crackling noises.
- A sound runaway was present when the mask assembly caught fire.
- A screeching noise may precede the loss of signal from the oxygen mask microphone.
- The degradation mechanism produced by the propagation of the fire to the environment of the mask storage boxes (lateral storage compartment) seems to present significant and uncontrolled variations; these variations were shown by differences in the audio phenomena picked up with random variations in the level and timbre of the sound. During these tests there was one case of an unexplained interruption in the leaking noise for 0.5 s, followed by a detonation.

Comparison with the CVR recording of flight MS804:

- No crackling noise can be perceived in the recording from the co-pilot's oxygen mask microphone.
- A sound runaway was present on the co-pilot's oxygen mask microphone and CAM channels at 00:25:31 (EVT6). This noise can probably be attributed to the co-pilot's oxygen mask catching fire.
- The screeching noise that preceded the loss of the microphone signal from the co-pilot's oxygen mask at 00:25:33 (EVT7) was probably produced by the destruction of the mask microphone by the flames.
- The momentary interruption (510 ms) of the oxygen leak at 00:25:42 (EVT8) was probably produced by damage to the oxygen assembly⁵ located in and/or under the lateral storage compartment.

⁵ Oxygen supply T-connections and hoses on the two oxygen boxes (co-pilot and third person)

1 ___ Spectrum and waveform of audio recording of "Cigarette_00" test



2 ___ Spectrum and waveform of audio recording of "Cigarette_01" test

Cigarette falls to bottom of oxygen box



Cigarette seems to extinguish/hose envelope glowing red



Mask catches fire

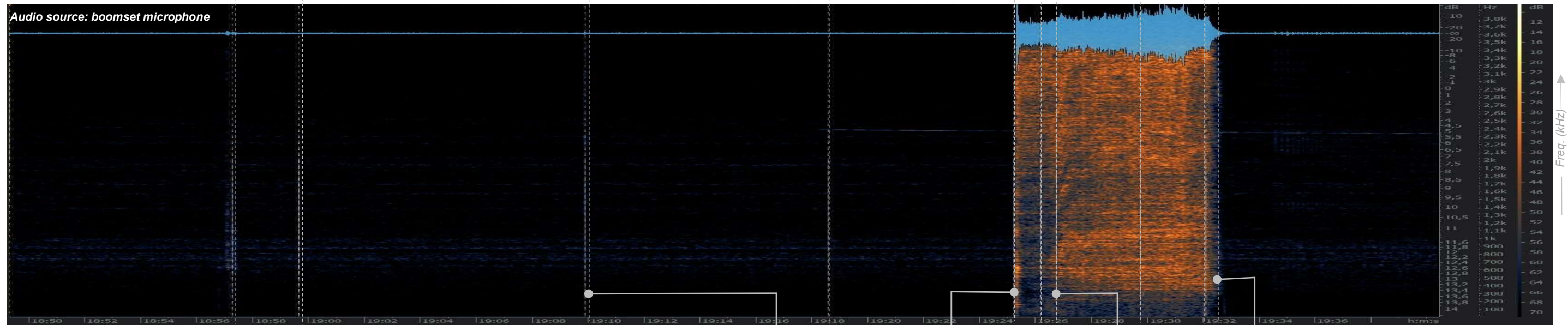
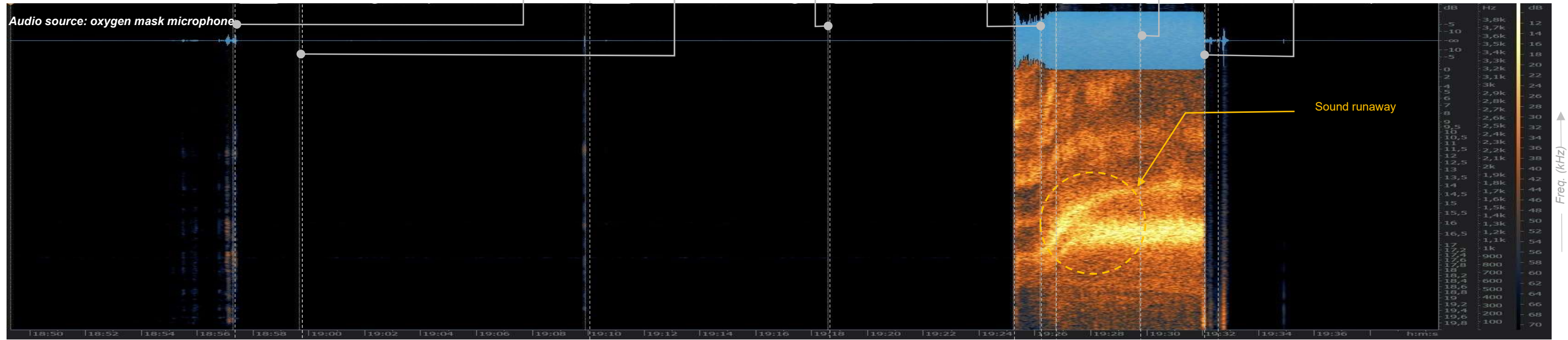


Fire escapes from oxygen box



Slight crackling noises/combustion of envelope of mask oxygen hose

End of audio pick-up by oxygen mask microphone



Cigarette burning at bottom of oxygen box



Oxygen mask hose pierced



Oxygen box assembly catches fire

Oxygen supply to oxygen box cut off

3 ___ Spectrum and waveform of audio recording of "Cigarette_02" test

Cigarette falls to bottom of oxygen box



Fire spreads to harness and Nomex protection of hose



Oxygen mask hose pierced

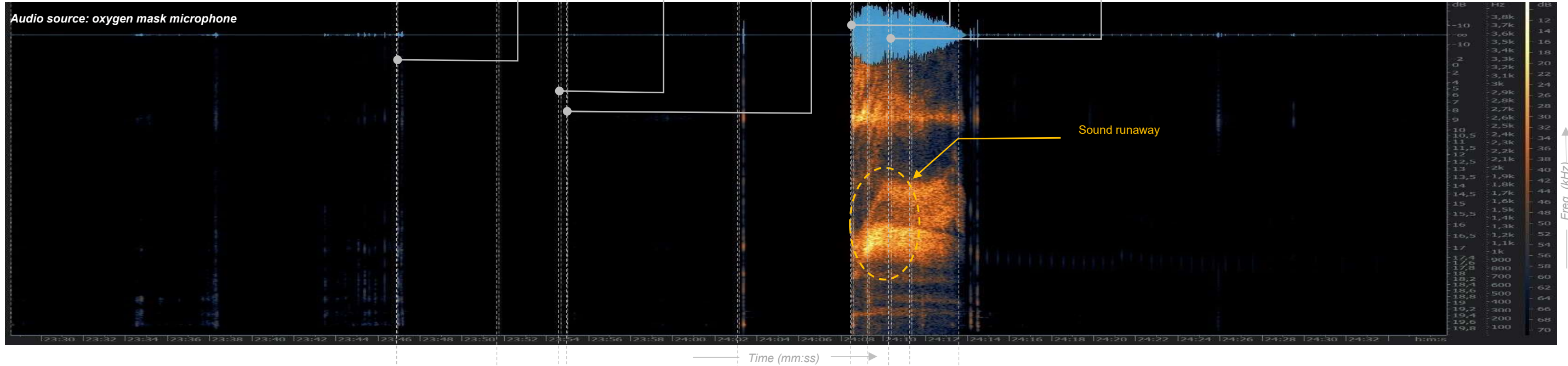


Oxygen box assembly catches fire

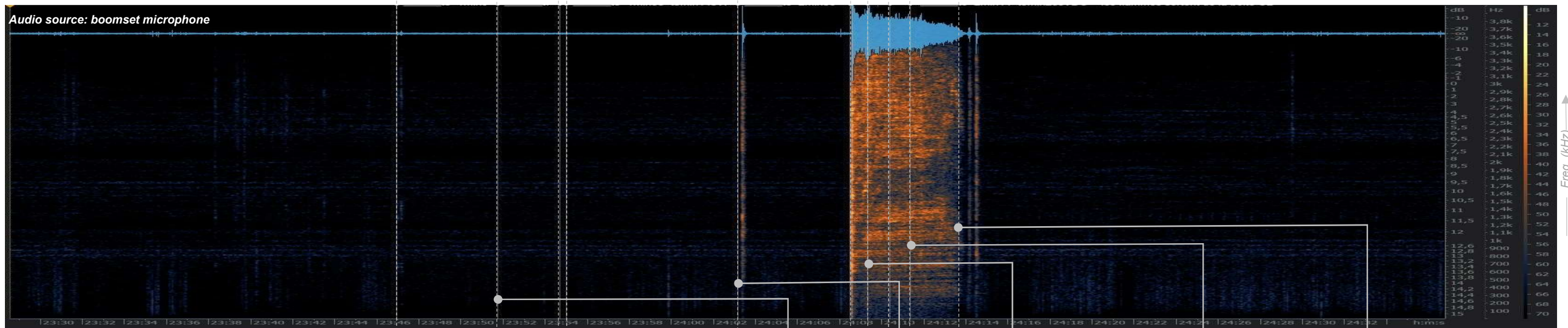


Slight crackling noises/combustion of envelope of mask oxygen hose

Audio source: oxygen mask microphone



Audio source: boomset microphone



Cigarette burning at bottom of oxygen box

Window cracks



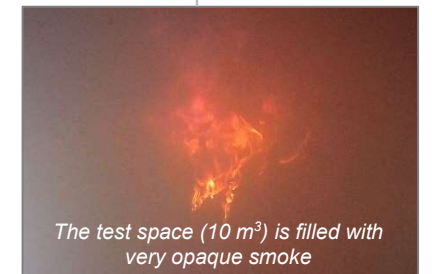
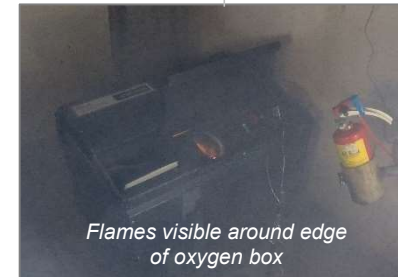
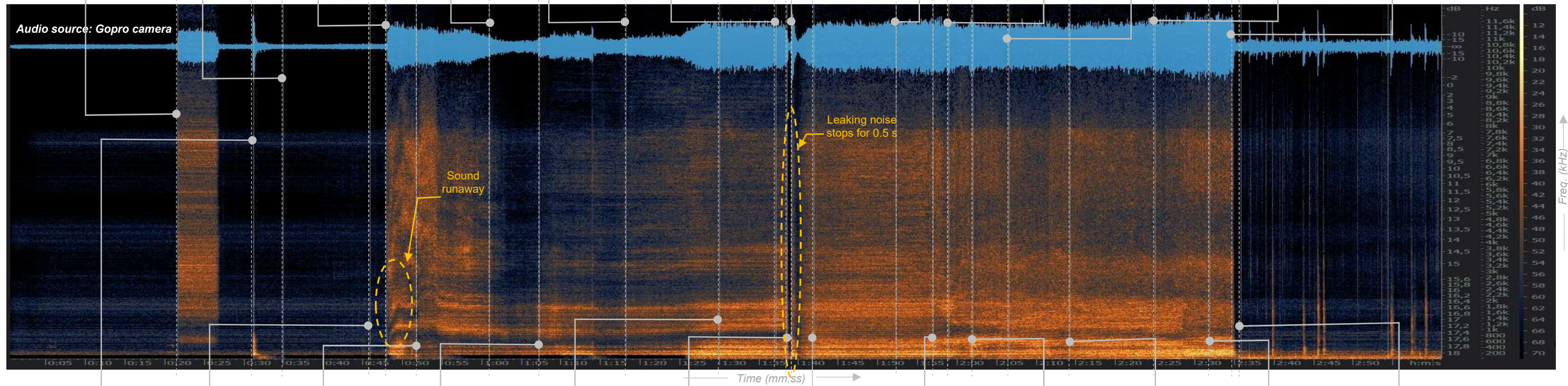
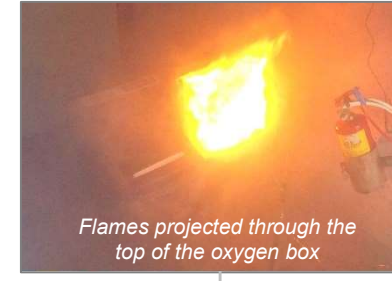
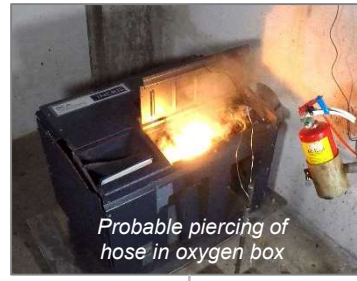
Mask catches fire



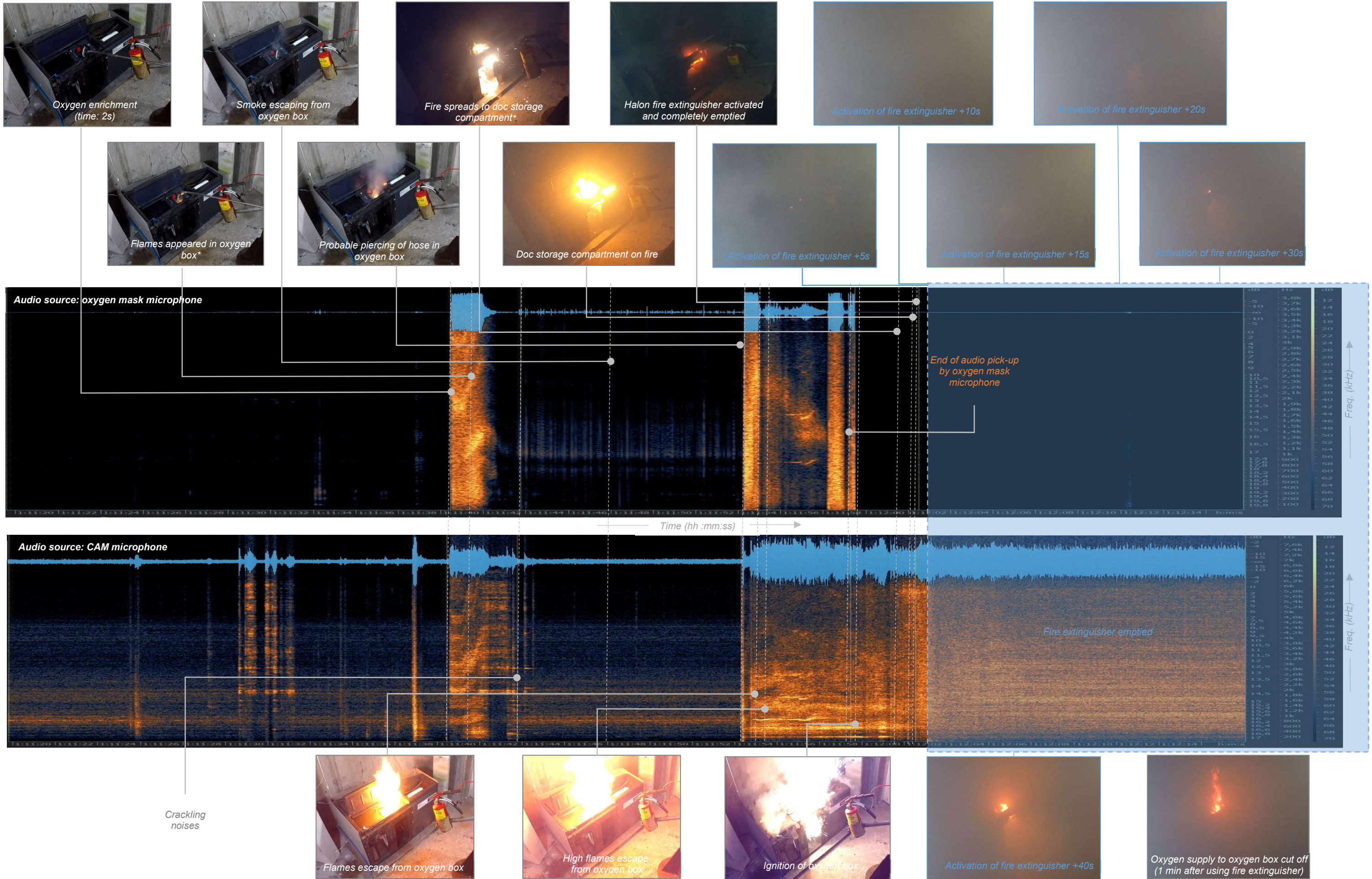
Fire escapes from oxygen box

Oxygen supply to oxygen box cut off

4 ___ Spectrum and waveform of audio recording of "Propagation_01" test



5 ___ Spectrum and waveform of audio recording of "Propagation_02" test

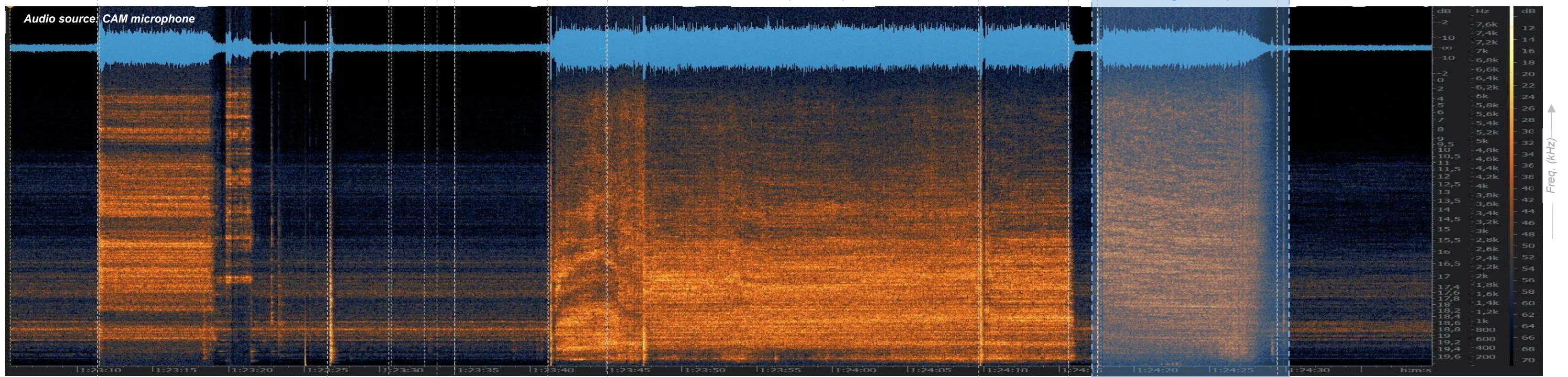
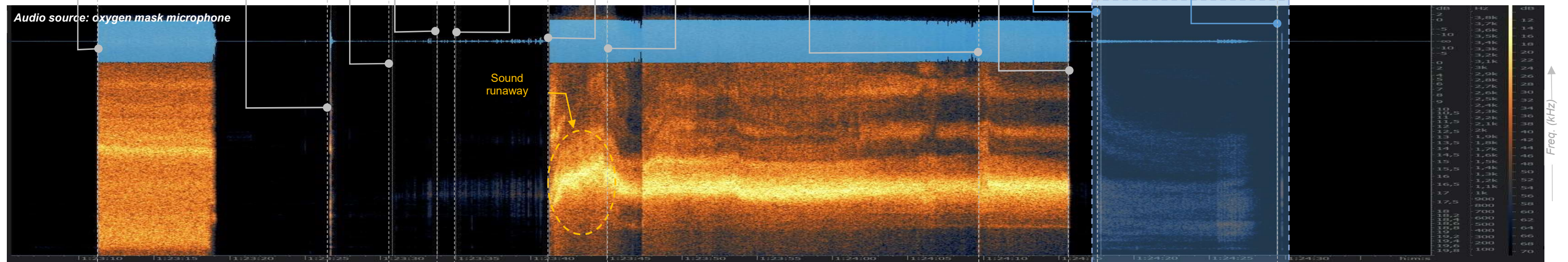
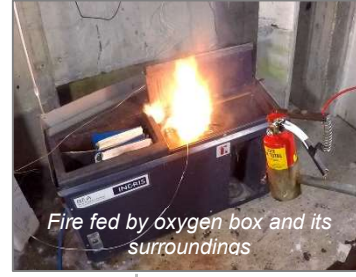
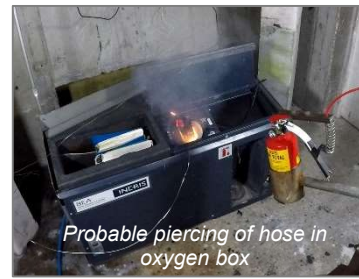


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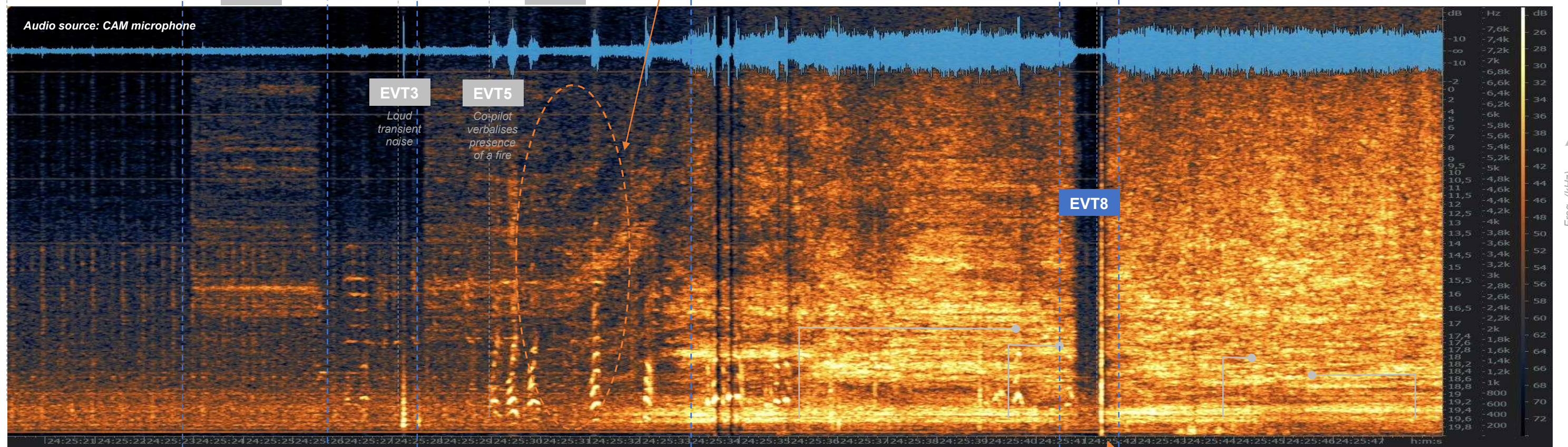
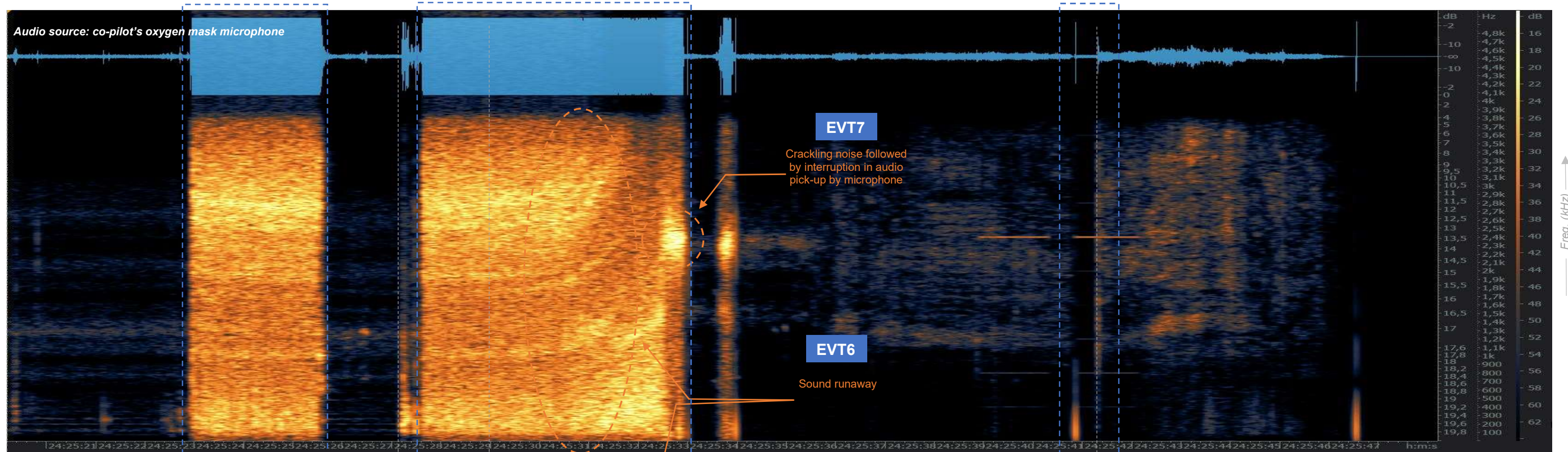
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* residual embers from a previous aborted remote lighting of a fire flame up

6 ___ Spectrum and waveform of audio recording of "Propagation_03" test



7 ___ Spectrum and waveform of occurrence recorded on CVR of MS804



Noise of oxygen flow in co-pilot's mask
Probable cause: mask EMERGENCY knob being pressed

Noise of continuous oxygen flow in co-pilot's mask
Undetermined cause/start of leaking noise has a very similar spectrum to EVT2

Leaking noise momentarily stops
Duration: 0.5 s
Loud transient noise (detonation)

