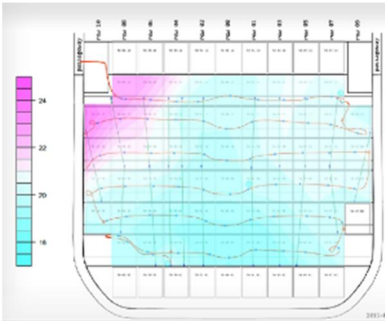
1. What can be done to improve the fire detection in a container cargo under deck?

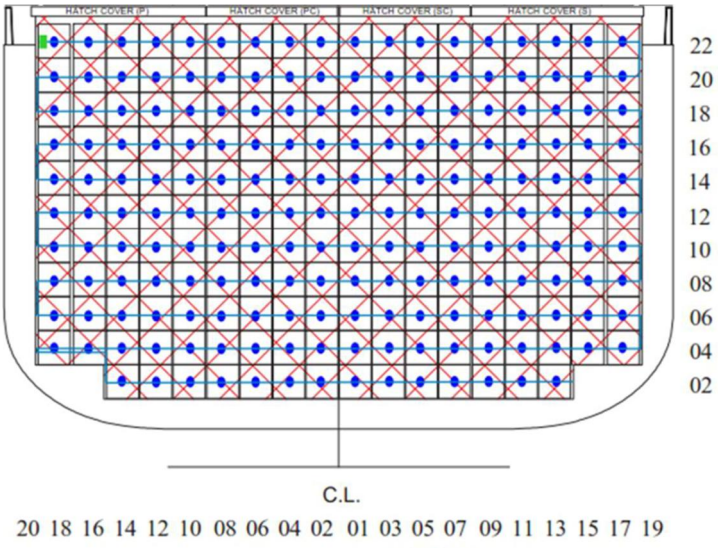
Fires of containerized cargo are always "heating/temperature events". Hence, temperature is the first detectable physical parameter which deviates from regular condition and shows anomalies is temperature.

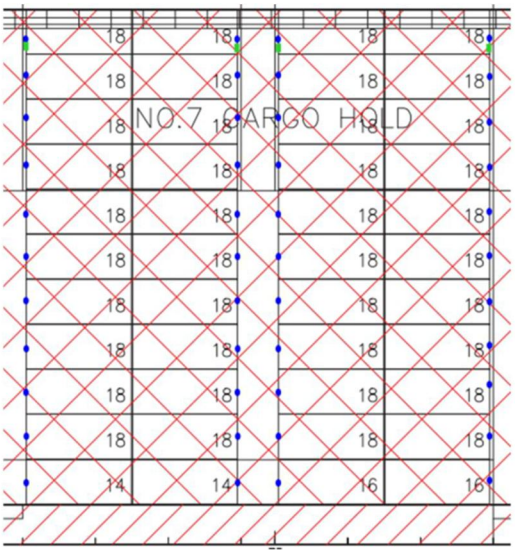
Fires and incipient fires in containerized cargo can be detected and located in an early phase by a temperature monitoring system installed in the container cargo holds.



Basic requirements for such systems are:

a. One temperature measurement point (sensor) per container.
b. Positioning of the temperature sensors in front (centered) of the container end wall with a max. distance of 20cm from the container wall. The blue dots in illustrations below indicate the sensor positions:





c. Temperature measurement by all sensors at least every 5 seconds (data resolution).
d. Analysis of spatial and temporal temperature gradients in real-time for alarming.

Efficiency of this approach

Such temperature monitoring systems allow:

- Detection of container fires in an early phase when there is still ambient temperature around the concerned container in the cargo hold.
- Exact localization (bay-row-tier coordinates) of the concerned container.

The personnel on-board is informed about the exact location and in such an early phase that it is safe to approach the concerned container, to assess the situation and to take early and informed decisions on the further actions.

Technological feasibility

The requirements for continuous temperature monitoring of containers on a containership are very specific and rule out some technical approaches which work well in other application domains. The technological challenge is to measure/retrieve the temperature value of each container on a fully-laden containership.

Optical systems
Optical systems (thermal imaging, video-based systems) require unobstructed view to the objects to be monitored. On a containership an unobstructed view to containers is given only to a small percentage of the containers. Optical systems have the best reach on the vessel´s top area. There they could be used complementarily to other systems.

Wireless solutions
The space between containers on a laden containership is narrow and confined by metallic environment. These are adverse conditions for any approach based on wireless systems.

Linear heat detection systems
Linear heat detection systems (e.g. fibre-optical systems, sensor cables) are generally adequate for the fire detection application on containerships. Such systems are known from terrestrial applications.

The actual suitability for fire detection of containerized cargo on containerships must be assessed individually for each linear heat detection system.

Economic feasibility

We can only speak for our own solution and expect the cost to be in the range of < 1% of the total cost of a container vessel.

2. What can be done to improve the fire detection in a container cargo on deck?

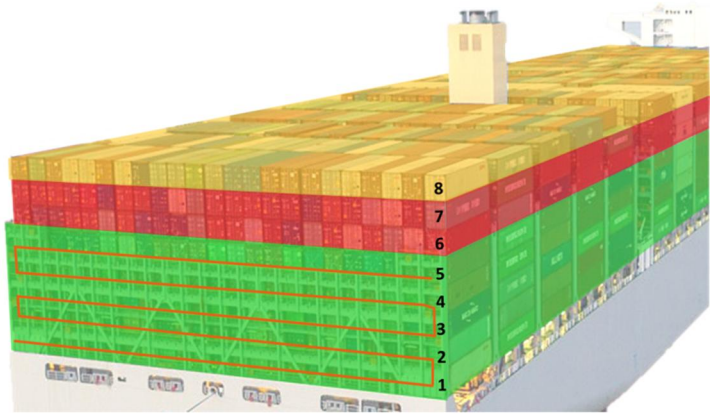
See input given above on question 1 "What can be done to improve the fire detection in a container cargo under deck?"

Specifics for solutions on deck:

The temperature sensors must be positioned close to the containers. Hence, temperature sensor systems need to be mounted on the ship structure. Under deck there is no limitation – all containers may be reached, e.g. by using the cell guide structure.

On deck containers might be stacked higher than the cell guide structure. Hence, these containers cannot be covered by such sensor systems. An optical system (thermal imaging cameras) could be used as a complementary solution to monitor the temperature of the containers on the highest tier level. See illustrated example below:

Green: Containers which can be monitored by linear heat detection systems fixed on cell guides.
Yellow: Containers which could be monitored additionally by thermal imaging cameras.
Red: Non-reachable containers.



3. What can be done to enable a more precise and quick fire localisation?

Localization

In general, the achievable degree of localization of a sensor system depends on the measurement resolution of the sensor system.

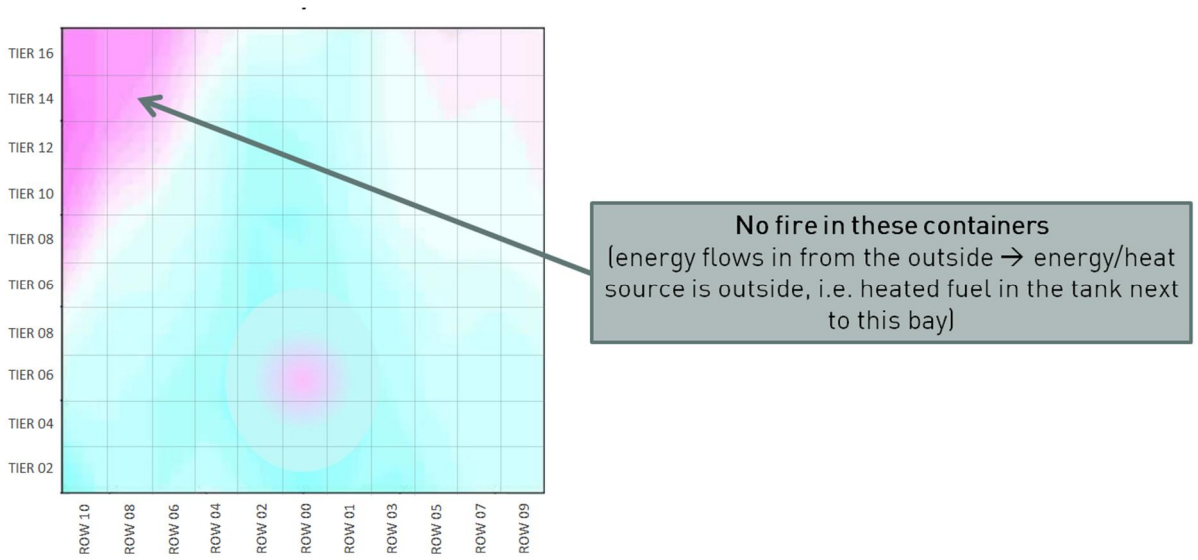
Hence, if a fire/heating event in containerized cargo should be localized, the concerned container needs to be identified. Consequently, an adequate fire detection system must provide (at least) one sensor per container.

Quick and precise fire detection

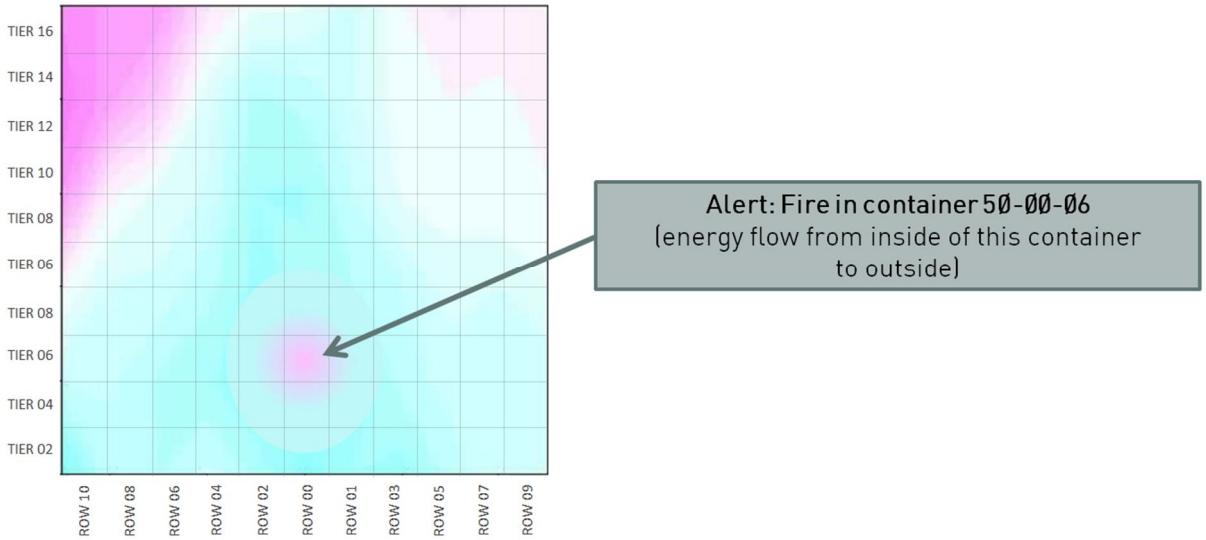
For the precise and quick detection of a fire/heating event of containerized cargo the temperature gradients must be identified very early and need to be correctly interpreted.

This can be achieved by:

- Adequate data resolution and real-time analysis
  Measurement by all sensors at least every 5 seconds. The analysis needs to be conducted continuously in real-time ("live-analysis").
- Energy flow analysis
  If the temperate of one container rises (temporal gradient) it must be compared to the temperatures of the adjacent containers (spatial gradients):
  - If an adjacent temperature is higher, then there is no fire/heating event in the observed container. In that case the energy flows in from the outside and might be caused e.g. by the sun, heated fuel, other heat sources or a fire in an adjacent container. See illustrated example below:



  - If the temperature of the observed container is higher than the temperatures of the adjacent containers, there is definitely a fire/heating event in the observed container and an alarm shall be triggered. See illustrated example below:



- False alarm avoidance
  Analysis of spatial temperature gradients is required to prevent false alarms which would be triggered if only temporal temperature gradients (temperature rise of a container) are taken into account.
- Additional temperature sensors
  Under deck additional temperature sensors should be provided to measure the temperature of the hull next to each container or at least at each tier level in a bay (starboard and port). In this manner spatial temperature gradient analysis can also be conducted for those containers adjacent to the hull and increases the efficiency of the fire detection system.

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