

Fire-fighting of multiple simultaneous fires at the heavily damaged storage area of Sisak Oil Refinery

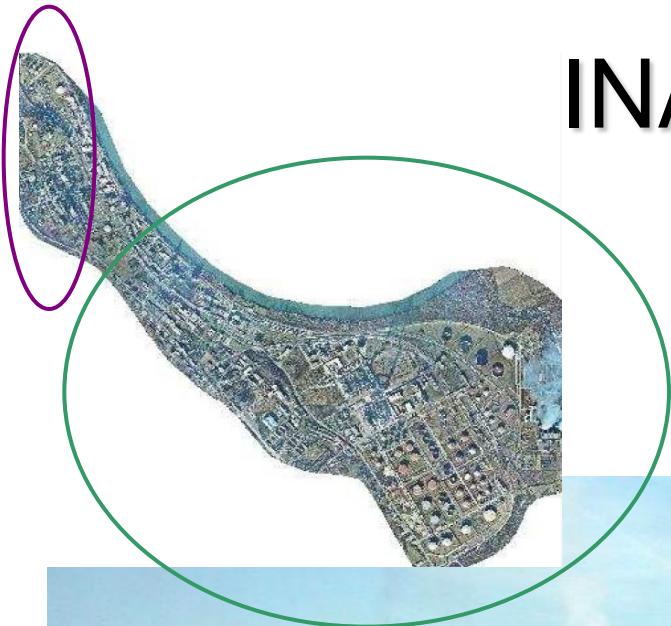
- Ivica Billege, Refinery Manager* (now INA DSD Advisor)
 - Ivan Pavlenić, Refinery Fire-fighting Chief* (now SINACO BC Sisak Manager)
 - Boris Čavrak, INA HSSE Head* (now HSE Advisor at MOL)
- (* at the time of events)

1935.

Shell, 1927, 170 t/day



INA Sisak Oil Refinery in 1991



Area: 1,980,000 m²

Railways: 23 km

Roads: 34 km

 **Old part of Refinery**

 **New Refinery**



Basic Refinery Data

- Process units: ADU, VDU, FCCU, DCU, BTX, Bitumen, Unifing, Platforming, HDS, MEROX, Petroleum coke Calcinator...
- Storage capacity: 1 million tones (1/3 for crude oil, 1/3 for feedstock and semi-products and 1/3 for final products)
- Crude oil supplies: by pipelines (Adria Oil Pipeline and oil pipeline from domestic crude oil fields) and river barges.
- Products delivery: road, railroad, river barges.



Fire water supply system

- Fire water supply from the river Kupa; two electric and diesel powered pumps, 33-55 m³/min, 3 additional electric powered pumps.
- Fire water retention 10,000 m³.
- Fire water pumps: 2 electric powered pumps, 12 m³/min at 18 bar; 2 diesel powered pumps, 20 m³/min at 18 bar.
- Semi stable air foam systems on storage tanks; stable systems of dispersed water (NFPA); fire hydrants network (30 km, 400 hydrants...).





Fire fighting vehicles

- **Vehicles #3, #4 and #6:** pumps 5,400-6,000 l/min; roof monitor 4,000-5,000 l/min; foam concentrate tank volume 5,000 l; water tank volume 5,000 l; dry powder tank 1,000 kg.
- **Vehicle # 5:** pump 6,000 l/min; roof monitor 5,000 l/min; foam tank 7,000 l; water tank 3,000 l.
- **Vehicle #14:** pump 3,400 l/min; roof monitor 2,400 l/min; foam tank 7,000 l; water tank 1,000 l.
- **Vehicle #10:** foam tank 25,000 l; monitors 2 x 4,500 l/min.
- **Vehicle #15 (Hydraulic platform, 32 m):** pump 6,000 l/min; monitor 5,000 l/min; foam tank 2,000 l.
- **Vehicle #9:** pump 1,600 l/min; foam tank: 7,500 l.

Sisak Refinery location



Attacks started on September 2, 1991...



... one mortar grenade exploded at 18:50 on the roof of 10,000 m³ crude oil tank (with 4,700 m³ of oil inside...), fire started...

Fire-fighting action:



- Water spray cooling system was activated on the burning storage tank and on storage tanks nearby.

- Fire brigade came on site in 3 minutes,
- Action started with 5,000 l/min heavy foam monitor,
- Fire was extinguished in two minutes.



Fire on October 7, 1991

- At 16:40 a few 20" gasoline and diesel pipelines inside the pipe channel were damaged after grenade explosion, and exit pipeline from the 10,000 m³ gasoline tank was punched too...
- Fire spread along the pipe channels with 10-20 pipelines (open concrete trenches, 4 m wide and 1.5 m deep, with overall length of 900 m).
- Fire spread was localized on 500 m length of pipe channels.
- The majority of valves were open because of fuel delivery.
- The reachable and functional valves on the product pipelines were closed and cooling water on exposed storage tanks was activated.
- The quantity of a foam concentrate in Refinery was 120 tones.

The biggest fire in the Refinery History



Max. flame front:

➤ Length:

500 m

➤ Height:

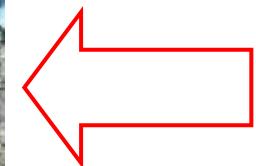
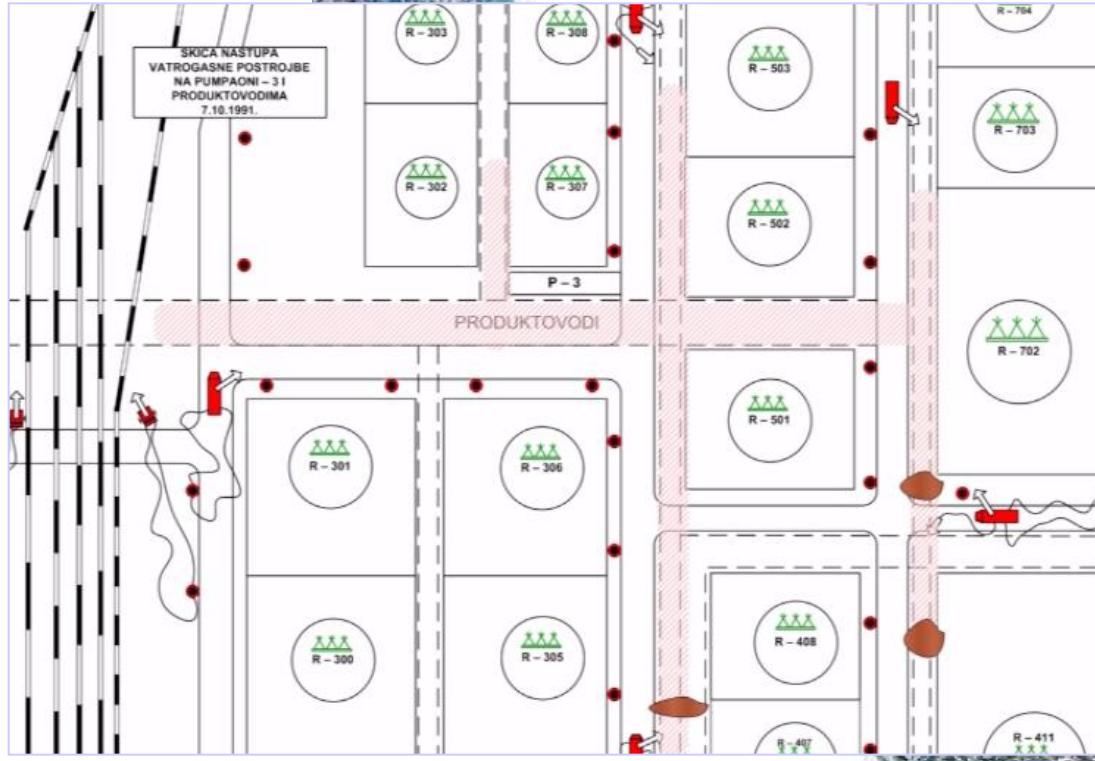
100-150 m

➤ Possible approach:

50-60 m
(protected)



The burning pipe channels





Scary reality...

- During firefighting action three firefighting vehicles (#3, #5 and #14) had faults (design faults) and went out of action.
- Mobile monitors (2,400 l/min) were used as a replacement.
- From 14 firefighting teams who came to help, just two were equipped with appropriate firefighting vehicles (INA-OKI and the City of Zagreb Fire Brigade), and thus useful in action.



Before and after...

- At 18:30 the reserves of foam concentrate were reduced to 60 tones, at 21:30 to 30 tones...
 - Trucks with sand and bulldozers were ordered...
 - The foam was used only when necessary...
 - Water jets were used for additional cooling of exposed tanks...
 - Additional 12 tones of foam and 4 trucks with sand came at 22:00.
- 

The fire was extinguished after 9 hours and 35 minutes

- The fire was finally extinguished at 02:15am on October 8, 1991.



Used resources:

- 102 m³ of foam concentrate (92 m³ from the Refinery, 10 m³ from other fire brigades),
- 60 m³ of sand,
- 650 kg of dry powder,
- 21 firefighting vehicles (12 from the Refinery, 9 other),
- 163 firefighters (86 from the Refinery).

And immediate repairs...



**More than 2,000 tones of steel material
were cut and removed...**



Fires on October 18, 1991



#1 – at 14:45

#2 – at 15:00

#3 – at 15:20

#4 – at 15:21

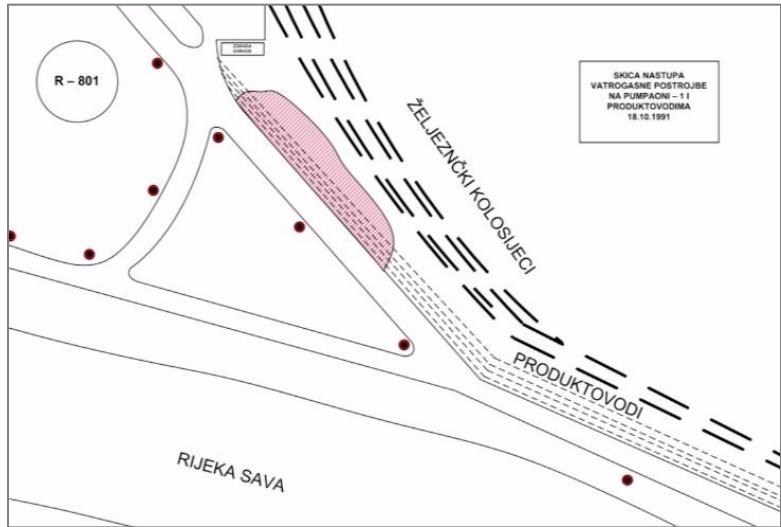
#5 – at 15:42

→ In less than
one hour five
simultaneous
fires happened...

Fire #1, main product pipelines, two-level pipe rack, 8+10 pipes of 3" to 12"

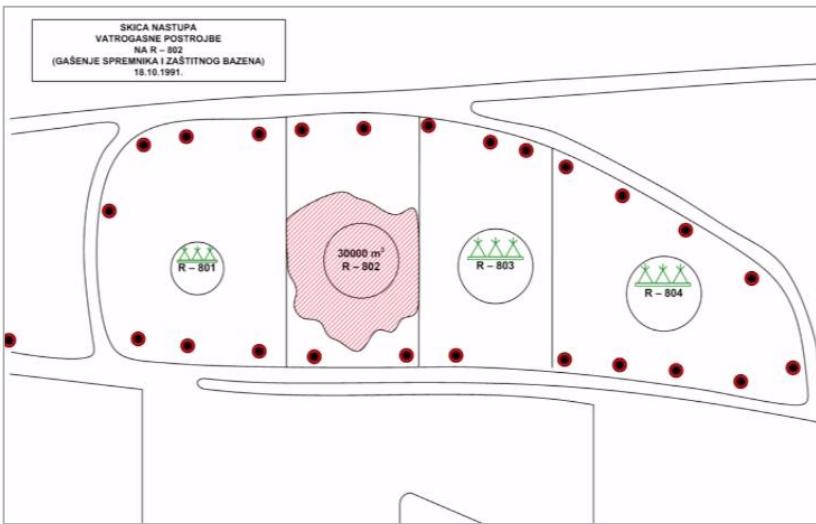
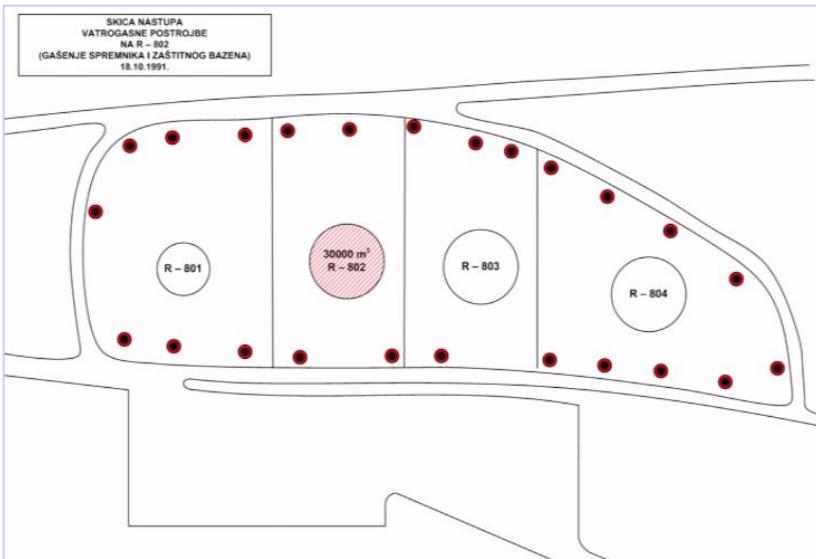


#1, Pipelines fire, extinguished at 17:30



- At 14:45 grenade explosion damaged six product pipelines (gasoline, diesel, LPG), fire started on 150 m²...
- At 14:47 firefighting vehicles #6 and #8 come on site, started firefighting with heavy foam monitors.
- At 14:48 vehicles #2, #5, #14 and #3 came on site...
- Firefighters were laying on the floor during firefighting, because of grenade explosions in the vicinity (two firefighting vehicles were damaged...).
- Fire was extinguished at 17:30.

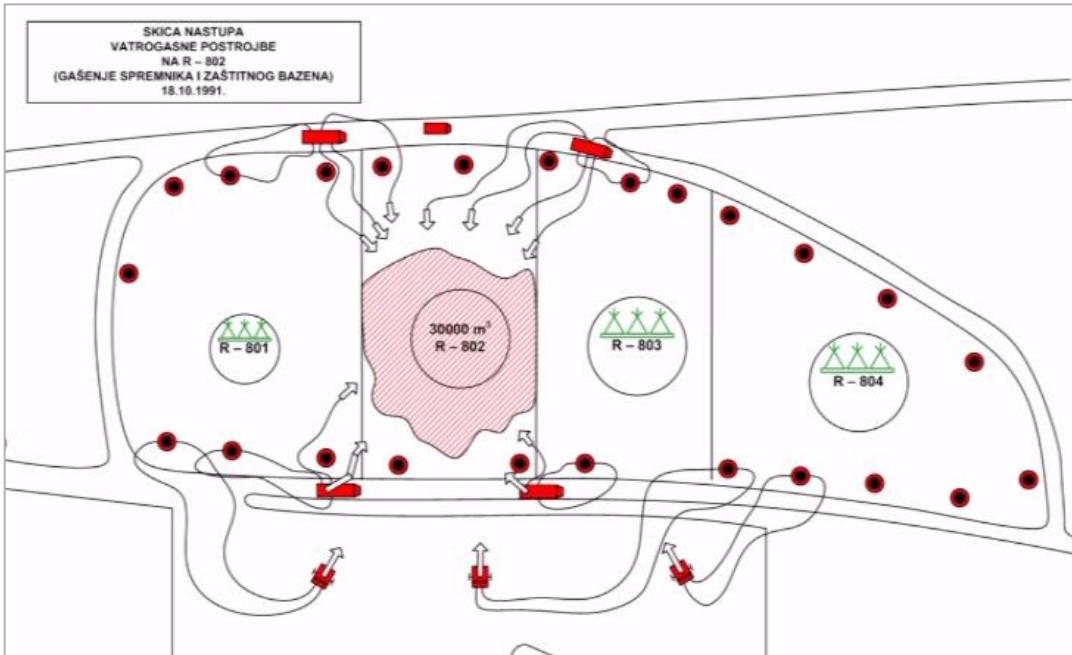
Fire #2, Crude oil storage tank; 30,000 m³



- Tank R-802 was hit at 15:00, oil spillage happened, fire started ...
- Cooling water systems were activated on the tanks nearby.
- Firefighting vehicle #10 started with cooling of pipe channel exposed to overheating.
- Two grenades exploded in vicinity, two firefighters were injured and taken to the hospital, firefighting vehicle #10 was damaged (holes on the foam tank).

Fire #2, Crude oil storage tank, 30,000 m³

- Because of intensive artillery fire, firefighters and firefighting vehicles were withdrawn from the fire scene to depots... Cooling was continued with two mobile monitors (2,400 l/min).
- Firefighting action was reestablished at 19:00.



- External help came (14 fire brigades with 16 firefighting vehicles from Sisak, Zagreb and Kutina, but only few were suitable for action...).
- Refinery firefighting vehicles #3, #5 and #6 were involved in firefighting action, together with INA-OKI and Zagreb Fire School vehicles...

Fire #2, Crude oil storage tank; 30,000 m³

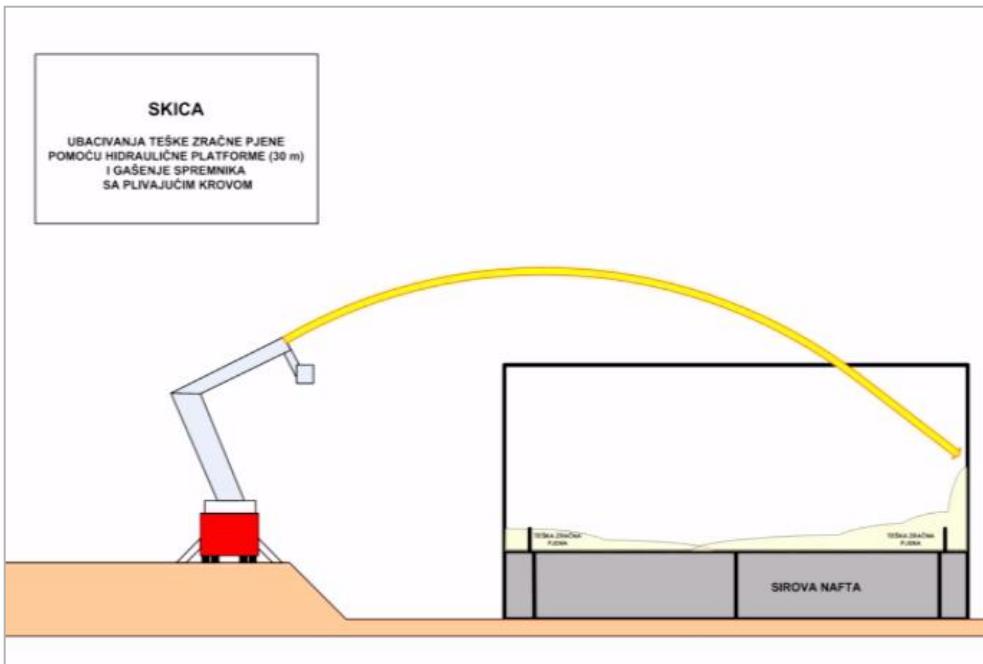
- Around 23:45 fire of spilled crude oil inside dike area was finally extinguished (after falling of crude oil level inside the tank bellow the hole produced by grenade explosion, because of spillage and pumping the crude oil from R-802 to R-804 and R-210).
- Semi stable firefighting system on R-802 was damaged by explosion, so action continued during night by cooling and control of fire.



Fire #2

➤ The precise guiding of coordinated action with heavy foam was organized from the platform (radio communication...), started at 06:00, with two heavy foam monitors (total of 7,000 l/min), filling the seal ring area inside tank.

➤ Fire was finally extinguished at 08:00, on October 19, 1991; after 17 hours of firefighting action.





Fire #3, Product pipelines

- Fire started at 15:20; parallel with two other active fires (#1 and #2), in the open pipe trench of 300 m length.
- Fire front was attacked from both sides, with four heavy foam monitors (8,000-9,000 l/min overall capacity), plus parallel cooling of exposed pipelines by mobile monitors of 2,400 l/min capacity (to prevent ruptures of overheated pipelines).
- Dry sand (20 m³) was put to pipe channels on both sides, to prevent spreading of fire.
- Storage tanks exposed to heat from the burning pipe channels were cooled by stable water spray systems.
- 250 kg of dry powder was also used for final fire-extinguishing.
- Fire was completely extinguished at 17:50; 40 minutes after starting active firefighting action on fire #3.

Fire #4, Oily water retention tank (10,000 m³)

- Fire on oily waste water retention tank of 10,000 m³ capacity (open roof) started at 15:21.
- Firefighting action started at 18:10 (after extinguishing all others fires except damaged crude oil tank fire).
- Fire was extinguished in 20 minutes, with action of roof mounted heavy foam monitors from the two firefighting vehicles (after the main shaft failure on vehicle #14; this firefighting vehicle was replaced with vehicle #3).
- Additional prolonged cooling was used on a tank walls, for prevention of possible re-ignition.
- Firefighting vehicles were moved back on the site of the big crude oil tank fire (R-802; 30,000 m³).



Fire #5, Tank truck loading platform

- Product pipelines on tank cars loading platform were damaged by fragments of exploded shell, at 15:42.
- Fire was extinguished at 16:00, using one S-50 and four S-9 dry powder hand fire extinguishers.



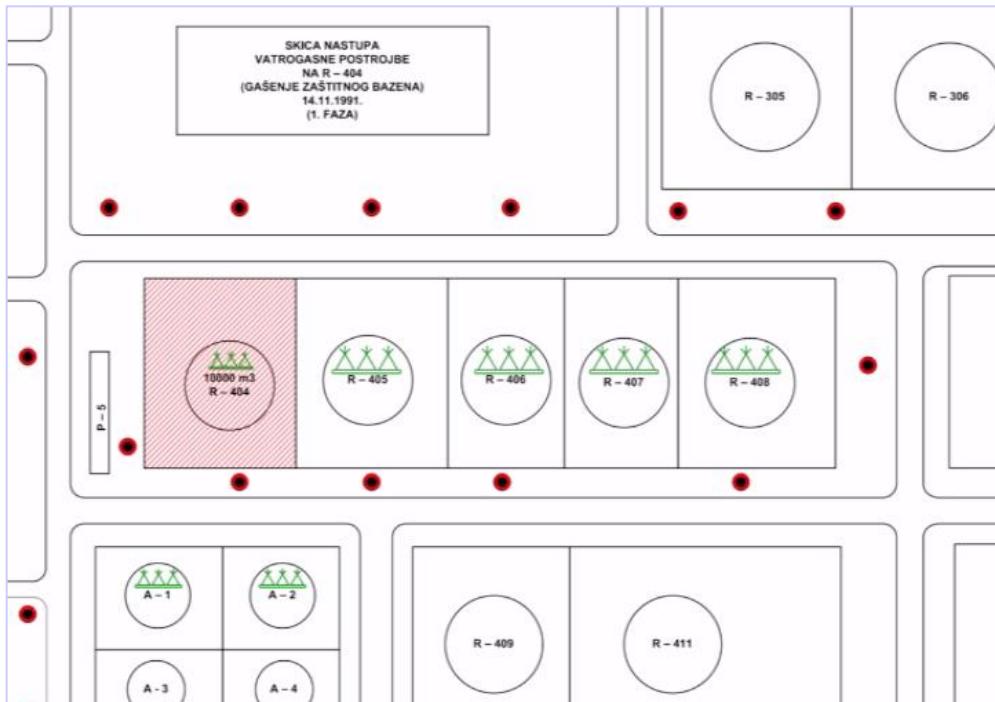
Used resources during firefighting (Oct 18)

- 75 m³ of foam concentrate.
- 2,000 kg of dry „S” powder.
- 20 m³ of dry sand.
- Directly involved 145 firefighters (92 from Refinery, 53 others).
- 125 fire hoses (15 and 30 m) were used in firefighting action.
- 14 fire brigades were on the site with 33 firefighting vehicles (INA Refinery Sisak, INA OKI, INA Petrochemistry Kutina, Airport Zagreb, Radonja Sisak, „Steelworks” Sisak, City of Sisak, City of Zagreb, City of Kutina, Firefighting School Zagreb and voluntary fire brigades from Kutina, Budaševo, Gračenica and Stružec).
- 24 firefighting vehicles were involved in firefighting actions.



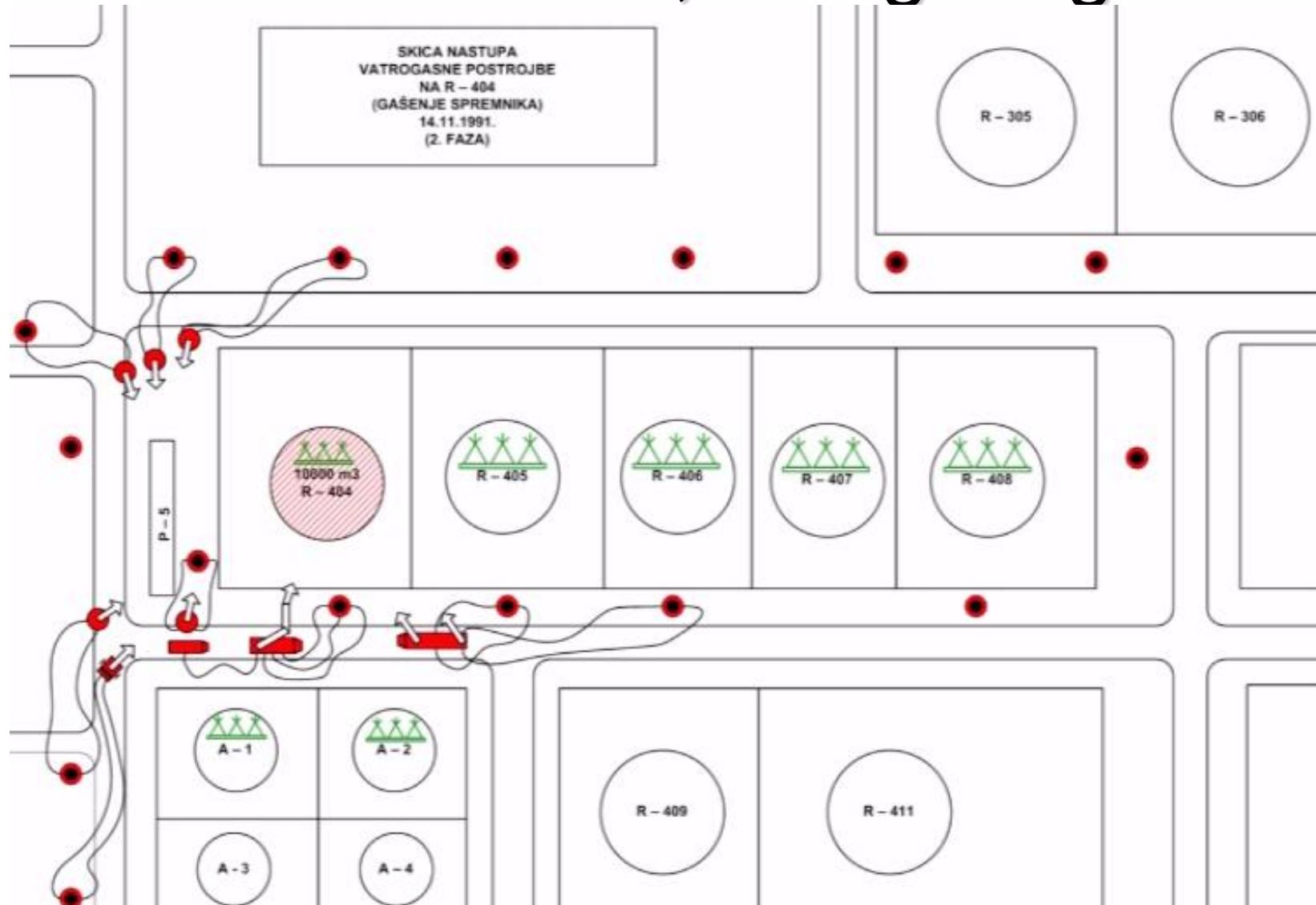
R-404, gasoline tank; 10,000 m³

- Tank was hit and ignited on November 14, 1991 at 9:45.
- Because of high intensity of artillery attack, firefighting action was postponed... Firefighters just activated stable systems for cooling on burning tank and on the tanks nearby.



- Firefighting started at 10:50 with nine Refinery firefighting vehicles. Fire was very strong, with flames 50-60 m high.
- Mobile equipment was used for additional cooling of exposed units.

R-404, firefighting action



R-404

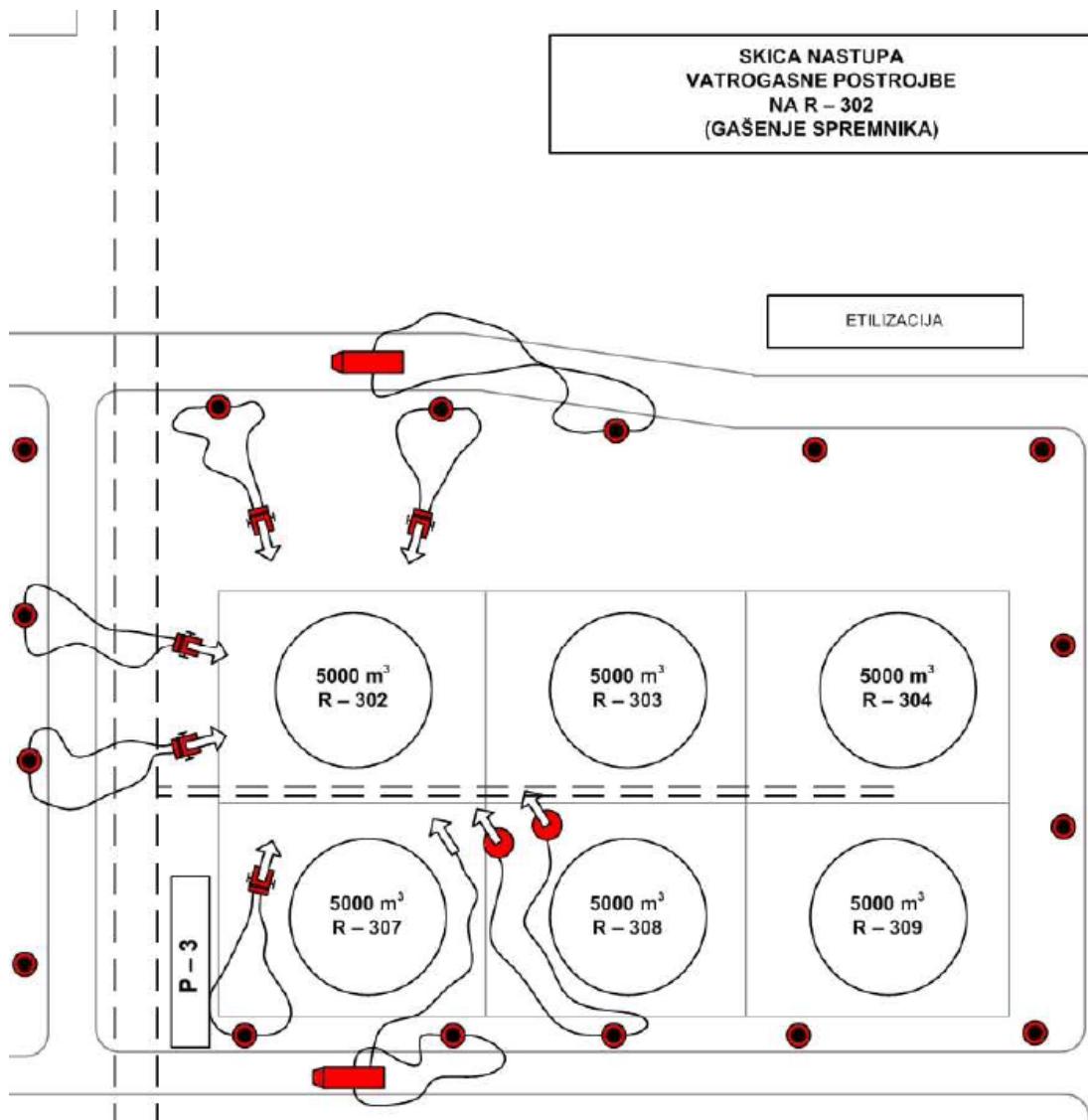


- The firefighting action was stopped at 14:00 and continued at 14:45; because of intensified artillery attack in this period (firefighters and firefighting vehicles were withdrawn to depot; at that moment fire was under control and heavy foam was filling the floating roof...).
- After control of the fire was lost, action started at 14:45 as from the beginning.

R-404

- Heavy foam was injected on the floating roof from the platform (#15, 4,500 l/min) and roof mounted monitor on the vehicle #10 (4,500 l/min).
- Fire was finally extinguished at 17:20.
- 71,600 l of foam concentrate was used during this firefighting action, much more than expected, because of delay in start of firefighting action and stopping of firefighting action between 14:00 and 14:45.
- In firefighting action 62 firefighters were involved (48 from the Refinery) and 14 firefighting vehicles (11 from the Refinery).

R-302, November 14, 1991, at 18:50



- Gasoline 98 octane; tank height 11.2 m; 4,428 m³; fixed roof.
- Direct hit with shell at 18:50, fire...
- Stable cooling system on gasoline tanks and blending unit was activated.
- At 19:25 fire brigade came on R-302, after intensity of artillery fire was reduced.

R-302, Burning gasoline spillage...

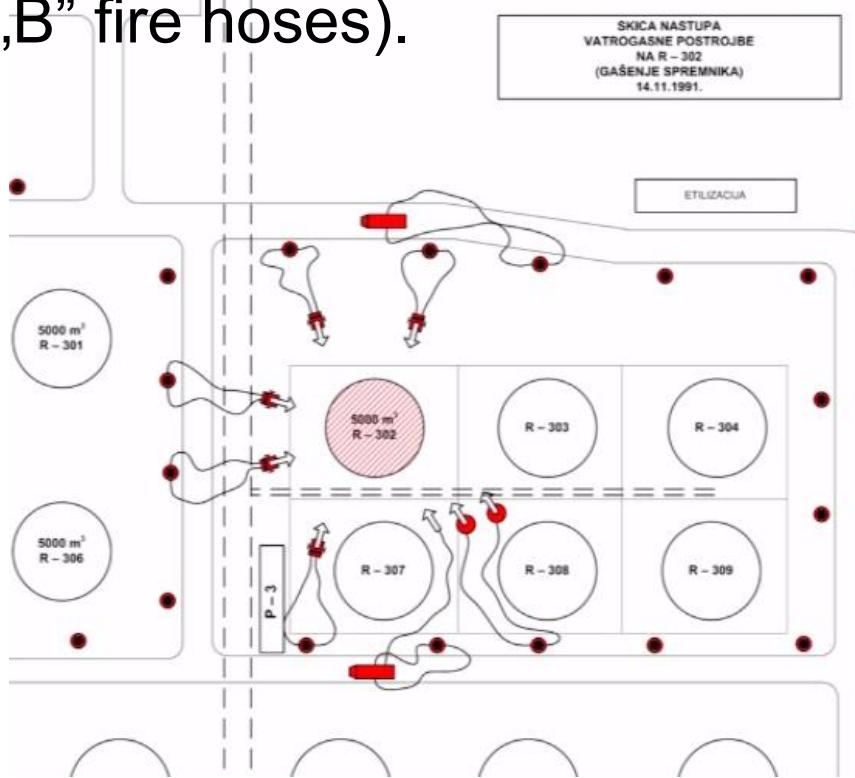


➤ Refinery firefighting vehicle #6 was connected to R-302 semi stable system and pumping foam. Refinery vehicle #4 and INA-OKI firefighting vehicle were preventing spreading of burning gasoline through pipe channels.

R-302



- 8 mobile monitors were used for additional cooling of R-303 and R-308 and gasoline pipelines (water supply from hydrants, „B“ fire hoses).



- Action of pouring foam through tank stable system was stopped, because of damages on the system and poor efficiency (5,000 l of foam concentrate spent, without results).
- Fire was pushed back inside R-302 dike area and controlled.



- Decision was made to control fire inside the dike area, cool R-302 tank walls and prevent melting and collapse of the tank structure, with uncontrolled spillage of burning gasoline...
- Tank was collapsing inwards, in a controlled way...
- The fire was finally extinguished after 30 hours and 55 minutes.
- 31,500 l of foam concentrate was used by 119 firefighters (88 from the Refinery) and 20 firefighting vehicles (13 from the Refinery).

Learning points:

- Refinery had, at the time of events, very good fire water supply system, with proper reliability and capacity (never stayed without water for firefighting and cooling).
- Older firefighting vehicles were not able to work for prolonged periods without failure (low reliability, design problems...).
- Refinery firefighters, although not properly protected (PPE, firefighting actions during artillery attacks), were major and most important element in the Refinery firefighting activities. The Refinery Manager and the Refinery Fire Chief were with their people in every fire, leading and coordinating all activities.
- The great part of firefighting vehicles coming to help were useless (small pumps, low capacity reservoirs for foam or even without foam...), lack of proper PPE and experience in oil fires...

Learning points:

- Coordinated activity of process people and firefighters was essential for efficient firefighting - definition of priorities, (closing of proper valves - which were at that time without remote control); proper cooling of exposed equipment (pipelines, storage tanks...), pumping...
- Radio communication was the only way to properly coordinate complex firefighting actions. The noise from big fires often was limited possibility to keep communication open.
- Limited maneuverability in the case of complex firefighting actions, esp. in the cases of a long pipe channels fires, was producing additional risks.
- Hydraulic shocks were destroying fire hoses (esp. „A” class).

Learning points:

- Strong winds which were very often changing a direction of blowing, smoke and fumes were reducing visibility and producing breathing problems to firefighters and process people..
- Very efficient use of dry sand, esp. in the case of fires on pipelines in pipe channels, was important learning point and the way to reduce consumption of foam concentrate.
- Fast learning from the previous experience and modifications of firefighting practice.
- Well established health care system (sometimes up to four medical emergency vehicles were in the Refinery, with proper medical assistance).

Learning points:

- Because of good luck and established system for protection of the firefighters and process people, just two firefighters were injured during firefighting actions in this period.
- During long firefighting actions drinks, food and replacement were organized to keep firefighters in proper condition. Firefighters who were at their homes were coming voluntarily to help, even in the case of general alerts and blackouts, and staying on duty until the successful end of firefighting actions.
- The Refinery was delivering fuels on the market during the whole period of attacks, sometimes directly pumping spilled fuel from the dikes to the tank cars.

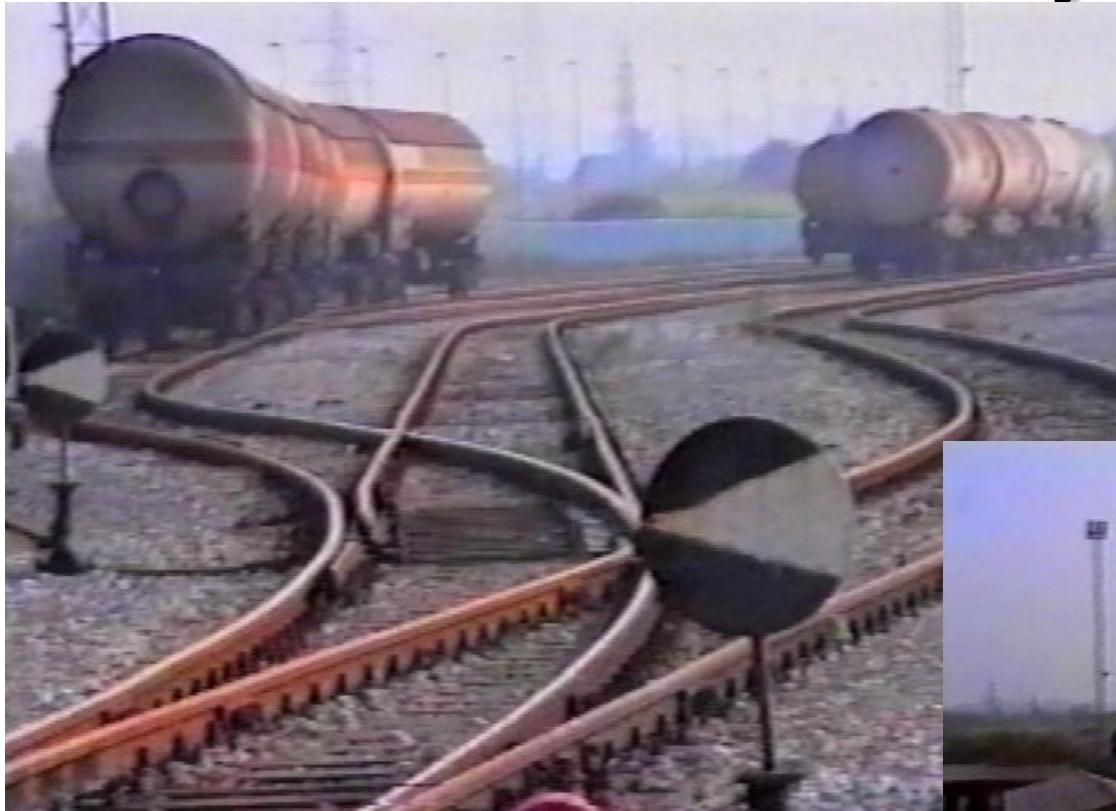
Damages in 1991

- From September 2, 1991 till the end of year, 104 Refinery facilities of different kinds (among them 38 storage tanks) were damaged or destroyed.
- General alerts or air alerts were announced 100 times, during 67 days. 310 different grenades, shells and rockets hit the Refinery area in a 67 days period, producing fires in 20 days (some simultaneously).
- 25 fires happened in this period, as a direct consequence of artillery attacks on the Refinery.
- 338 m³ of foam concentrate and 5,300 kg of dry powder were used in firefighting actions.

Appendix

Fire on the Refinery shunting yard

Fire on the Refinery shunting yard



- 50-60 rail cars on site (LPG, gasoline, diesel, fuel oil).



The September 12, 1993, 17:42



➤ Gasoline rail car was hit with shell and caught fire...

#1 - Removal of the rail-cars nearby...



Cooling, fire control...



Removal of rail-cars on both sides...



Removal of rail-cars on both sides...



Burning rail-car isolated, cooling...



Dry powder hand fire extinguisher...



Fire extinguished, after 1 hour and 18 minutes



Q/A

