

## HInt Dossier

### Explosion at the Skikda LNG Plant, Algeria

Last updated:	2004/11/11	<a href="#">About HInt Dossiers</a>
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<b>Date of incident:</b>	2004.01.19
<b>Location:</b>	Skikda, 500km east of Algiers, Algeria.
<b>Organisation(s):</b>	Sonatrach: State-owned oil and gas company.
<b>Killed:</b>	27
<b>Missing:</b>	0
<b>Injured:</b>	80 (75 classed as 'lost time')
<b>Summary:</b>	At about 18:40, local time (17:40 GMT; all subsequent times are local), on Monday, January 19, 2004, an explosion occurred in a natural gas liquefaction plant. Three out of six gas liquefaction trains were destroyed and two, which were not operating at the time, were damaged. The administration building and the maintenance workshop, together with other buildings, were completely destroyed. The explosion also led to the shutdown of a nearby electricity generating plant and an oil refinery. It took fire-fighters until 04:00 the following morning to bring the fire under control, and several days before all fires were out. At least twenty-seven people died and at least 74 were injured.

## Background

Skikda is a six train natural gas liquefaction plant, consisting of four older liquefaction trains – 10, 20, 30 and 40 – situated on one side of the LNG storage area and two newer ones – 5P and 6P – on the other side. Train 40, where the initial explosion occurred, differed from the two other adjacent trains, using boilers to make high-pressure steam to drive turbines which power plant's refrigerant compressors that are used to liquefy the natural gas. This technology is considered outdated. Train 40 also lacked the mercury removal sections which are fitted to the other trains.

## Chronology

### 04.01.19

At least 27 persons were killed, 72 injured, and seven reported missing in an explosion and fire which destroyed three out of six liquefaction trains at a natural gas plant. The nearby power plant was damaged, leading to a shutdown of the oil refinery, which may also have suffered a fire. The explosion also caused widespread damage in the town of Skikda.

Several survivors blamed the incident on a faulty boiler which was making “suspicious noises”. Some claimed the boiler had been reported as defective over a year ago, but had received only “superficial repairs”.

The explosion which destroyed the LNG plant reportedly also damaged the nearby power plant, forcing the adjoining 335,000 bbl/day oil refinery to shut down. One report said that a fire at the oil refinery took out nearly a quarter of its capacity, but this has not been confirmed. Speaking on state radio, the Energy and Mines Minister Chakib Khelil said: “We have halted the refinery of Skikda as a preventive measure to avoid problems that could result from the blast.” He said oil exports had been formally suspended, but it was not clear from his comments the extent or details of the *force majeure*. He did not say whether the oil installations were damaged, but Sonatrach said pipelines to the port were unaffected by the blast and consequent fires. A shipping agent said the main oil port was shut.

*The author of this dossier visited the Skikda plant in 1993 as part of a delegation from an international insurance company and was horrified by what he saw:*

- Seals missing from high voltage power connectors.*
- Scrap metal lying on top of “temporary” high voltage power cables feeding motors inside the plant.*
- Mild steel studs on stainless steel flanges.*
- Less than full threads penetrating bolts.*
- Relief valves lying on gravel outside the maintenance shop.*
- Workers urinating off platforms and against vessels.*

*He refused to inspect the water treatment plant on the grounds that he was too overweight to be supported safely by a structure so weakened by corrosion. A more recent study by the quasi-official [CNES](#) was no more encouraging.*

## **04.01.20**

*Sonatrach's UK office issued the following press release:*

On 19 January 2004, at 18.40 hrs, the LNG Plant in Skikda was shaken by an explosion which was followed by fire. Three out of six production units of liquefaction from the GL1/K Complex, sustained serious damage during the explosion and ensuing fire.

The Mutual Assistance Programme which exists among units of the Petrochemical Platform [*i.e. the petrochemical and power companies in the Skikda area.*] was activated [*sic.*] by the Management Company of the Industrial Zone (“EGZIK”) in order to limit the disaster to the three units and avoid further damage to other installations in the Complex, calling upon all human and material means of the Platform.

This programme of Mutual Assistance was followed immediately by the “Plan ORSEC” which kicked into action in the presence of the local authorities and the Minister of Energy and Mines who cut short a visit to Constantine to be on site.

The Chairman of Sonatrach together with his staff, the Secretary General of the National Federation of Petrochemicals and Gas Workers and a member of the National Union of Workers (“UGTA”), all left Algiers for the disaster area that same night.

Thanks to the quick reaction to this accident it was possible to tackle both the fires and the rescue of the victims at the same time.

Given the extent of the incident, each Complex of the platform took the necessary safety measures to protect its own installations.

Unfortunately, this accident resulted in the fatal loss of 23 employees and the injury of 74 employees who were subsequently taken to the Hospital of Skikda. After receiving treatment, 42 of the injured were able to leave the hospital, while 5 others were taken to the University Hospital of Annaba.

The Minister of Energy and Mines, Sonatrach and the Workers Federation wish to express their deepest sympathy and condolences to the families of the deceased and assure them of every support during these difficult times.

It has to be noted that the people of Skikda showed great solidarity with the victims of this disaster and spontaneously came forward to donate blood.

Despite the level of the blast, damage to buildings in the city of Skikda was limited given its distance away from the site. A psychological counselling unit was set up to help the victims and their families.

The Sonelgaz Electrical Power plant, situated adjacent to the LNG Complex tripped due to the shockwave of the blast. No major damage was reported, and it will be put back into service once the necessary checks have been made.

In the same way, the installations of the LNG Complex not affected by the disaster will be put back into service once all the necessary checks and technical inspections have been performed.

The cause of the blast will be determined by a proper investigation.

Sonatrach will minimise the impact on the LNG deliveries to her customers. It should be reminded that Sonatrach has a unique flexibility in the world by being able to use its gaz pipeline capacities for export.

#### **04.01.23**

On January 23, an eyewitness who survived the explosion, described [see [The Ryad Testimony](#), below.] how he heard a small explosion in unit 40 and immediately thought that the boiler had leaked, because a similar incident had occurred six months earlier. He looked towards the boiler and saw a cloud of white vapour. He “barely had time to draw breath” when there was a second small explosion, followed by a third, much louder which destroyed the plant. Also on January 23, the official government news agency reported the deputy CEO of Sonatrach, M. Achour Bachir, as saying that safety systems at the plant met the required standards.

*The report to be submitted to Sonatrach [see [Final Report](#)] claims that most witnesses reported an unusual noise before the explosion and that none reported multiple explosions.*

#### **04.01.29**

An industry source quoted Chakib Khelil, Minister of Energy and Mining, as saying that two new liquefaction trains would be built at Skikda. He said this would double the old GL1K I's capacity, implying a 6 billion cubic metres per year plant, and would take two to three years to implement at a “very approximate” cost estimated at \$800 million.

Bermuda-based Insurer PartnerRe said its net exposure was up to \$30 million, and also estimated the cost of rebuilding could reach as much as \$800 million – if the unit was fully insured.

#### **04.02.02**

The refinery remained shut on February 2 and industry sources said it was unlikely to open for a further two weeks. There were rumours that the refinery's cooling system had been damaged.

#### **04.02.18**

On February 18, the quasi-official Algerian news agency AAI reported Chakib Khelil, Minister of Energy and Mining, as saying that preliminary investigations by the inquiry teams had revealed that the incident stemmed not from a defective boiler but from ‘a liquefied gas leak in one pipe’ – which prompted an authoritative US publication to report that it was ‘a gas pipeline leak’ that led to the explosion.

*Khelil's statement is consistent with Ryad's statements. [See [The Ryad Testimony](#), below] Ryad specifically states that the original call from the operators referred to a gas leak *above* the boiler. When he looked towards the boiler, he saw a white vapour cloud. Ryad also specifically mentions two small explosions, followed by a much larger one. If liquefied gas had leaked from, say, a failed pipe above the boiler, it would have made a bang (the first explosion heard by Ryad) followed by the white vapour cloud. This could have drifted down to the level of the boiler, ignited (the second small explosion heard by Ryad), flashing back and causing catastrophic failure of the pipe and the subsequent major explosion and fire. Hypothesis, certainly, but it fits the facts known so far.*

*The hypothesis of the report to be submitted to Sonatrach [see [Final Report](#)] is that a leak occurred in or close to one of the LNG ‘cold box’ cryogenic heat exchangers. Neither is close to the boiler.*

#### **04.03.21**

In a presentation given at an LNG conference in Qatar on March 21, 2004 by Bachir Achour and Ali Hached of Sonatrach, a preliminary account of the accident was given. According to the presentation, a control-room operator noticed rapidly rising pressure within a steam boiler and attempted to correct this by reducing the amount of fuel flowing into the boiler. Despite his effort, the boiler's safety valve activated.

*This is contradicted by the report to be submitted to Sonatrach [see [Final Report](#)] which states that the operator noticed a pressure relief valve discharging on the refrigerant compressor and went to the boiler control panel and closed the fuel valves.*

Another operator near an adjacent train reported that a gas vapour cloud was forming near that boiler. According to Sonatrach, investigators had not yet determined what failed and caused the leak or which type of hydrocarbon gas leaked to form the vapour cloud.

The leaking gas was drawn into the boiler by its air-induction fan. Once inside the boiler's firebox, the gas mixed with air and exploded. The boiler explosion was close enough to the gas leak area to ignite the vapour cloud and produce an explosion. Other factors contributing to the vapour cloud explosion included the absence of wind to disperse the leaking gas, and its ignition in a semi-confined space.

*—The fact that the operator could not reduce the rate of steam generation in the boiler by shutting off its fuel rather suggests that the vapour cloud was partly fuelling the boiler before the explosion. In many large steam-raising boilers, air flow is automatically reduced when fuel flow is reduced. If this were so in this case, it may have provided a mechanism for the flame to propagate back from the boiler and ignite the vapour cloud.*

*It is now clear from the report that there was no boiler explosion, though the boiler was almost certainly the ignition source for a large hydrocarbon release.*

#### **04.04.26**

According to an April 26 statement by M. Mohamed Méziane, CEO of Sonatrach, Train 6 of the LNG complex will re-start in May and Trains 5 and 10 will re-start in September. Trains 20, 30 and 40 were destroyed in the January 19 accident. M. Méziane made his statements during a ceremony to mark the signing of a Safety, Health and Environment (SHE) policy for the company. These three units represent 50% of the capacity of the LNG complex: three billion cubic metres per year of gas or four million cubic metres of LNG. M. Méziane said that the delay in bringing the three trains back on line was due to the need to verify that damaged equipment was now fully functional. Dismissing the idea of a boiler or heat exchanger as the cause of the accident, he said the results of the inquiry would be made public, but did not say when.

#### **04.05.18**

On May 18 the first shipment of 17,000 m<sup>3</sup> of LNG left train six of the Skikda complex, which was slightly damaged in the explosion. The explosion, which has been confirmed as occurring at the level of heat exchanger 40, damaged the control room and other parts of train 6. The official death toll has been set at 27 killed and 80 injured. The commission of inquiry into the incident is expected to release a report in about three months.

#### **04.08.22**

On August 22 the Algerian newspaper La Tribune reported that at a meeting in Washington, USA, between Algerian Energy Minister Chakib Khelil and his American counterpart Spencer Abraham, Abraham reported that Sandia National Laboratories had prepared a report on the physical safety and security of LNG. Khelil agreed with Abraham to the publication of the expert report by a team which recently visited the site of the Skikda explosion.

#### **04.08.22**

No one was injured in the explosion of a boiler, purchased during renovations in 2002 and destined for installation in a desalination plant at the LNG complex. The explosion reportedly made a 1m (3 feet) wide crater. According to local media, quoting “a technician”, the incident was due to corrosion of tubes “which should have been under nitrogen to maintain their good condition”. He said the boiler, which was intended to feed desalination equipment needed to re-start other units, was not in use, but needs to be completely replaced. Because only two out of five desalination units can now operate, re-start of some units is likely to be delayed.

On August 24, Sonatrach issued a press release with a completely different story. According to Sonatrach, a 100 tonne/hour utility steam boiler in train 6 of the plant suffered damage following the failure of several water tubes in the roof of the furnace. The damage occurred as a result of

“overpressure in the entry of the boiler, caused by the instantaneous vaporisation of spilled products”. Consequent disturbance to the auxiliary steam system caused a shutdown of train 6, which had since restarted. Unit 5 was unaffected.

*Details of this incident are unclear. Sonatrach’s version is the more believable, as a water leak inside the furnace would certainly cause a mechanical explosion.*

## 04.08.28

On August 28 the Algerian newspaper *Nouvelle République* reported that a ministerial commission of inquiry had been appointed to investigate the August 22 incident. The paper also reported that the same unit had suffered a gas leak in June, but gave no further details. The paper also said that questions were being asked about “an American company” which had been responsible for testing equipment on trains 5 and 6 before they were brought back into service, following the January explosion.

*The “American company” is said by other sources to have been Halliburton.*

## The CNES Report

In May 2003 the Conseil National Economique et Social (CNES) delivered a report to the Government on natural and industrial risks in Algeria. The report drew attention “fires and explosions in industrial and urban areas”. Skikda was listed amongst the nine sites at highest risk, but largely because of the lack of retention features at the refinery. However, CNES also drew attention to the fact that urban planning in the town of Skikda had not respected safety standards: 18 buildings had been erected on top of gas pipelines and 2,679 were immediately adjacent to industrial zones. These failures to respect safety rules had cost the lives of seven people, injured 44, and damaged 50 homes in the explosion of a gas pipeline in 1998. The two complexes at Skikda and Arzew (in the west of the country) were singled out for attention. The report noted a disturbing trend towards early retirement – forced or voluntary – of experienced staff and a flight of qualified engineers to positions abroad.

## The Ryad Testimony

*The testimony of Kraim Ryad is described below. As of August, 2004, it had been neither proved nor disproved. It is largely consistent with the report discussed in [Final Report](#), below.*

On January 24, *Liberté* published an article under the title ‘*Skikda: Un rescapé de la catastrophe raconte*’ (Skikda: A survivor of the catastrophe talks). This article, which is written in rather poor French, reports statements made by Kraim Ryad. It is worth examining in detail.

Ryad was described in the article as an ‘agent de sécurité’, suggesting, at first sight, that he might be a security guard. As such, he would be unlikely to have any detailed technical knowledge of the plant. However, the phrase could equally indicate that he was a safety technician or similar specialist. This idea is reinforced when he is later described as being a member of the ‘unité d’intervention’, a phrase sometimes used for first-line maintenance, but also, occasionally, used to designate fire, paramedics and other emergency services. A later passage reads: ‘...des collègues de Ryad, à leur tête un contremaître, prennent la direction de l’unité 10, en arrêt technique depuis la veille, pour vérifier le bon fonctionnement des extincteurs.’ Since maintenance workers are typically supervised by a foreman (contremaître), while security guards rarely use the term, and since the workers were going to verify the proper working of the fire extinguishers, this further reinforces the idea that Ryad was a maintenance worker, with – perhaps – special responsibility for safety systems. As a result of these, and other statements, I am inclined to believe that Ryad has sufficient technical knowledge to distinguish different items of plant equipment. What, then, does he actually say?

According to Ryad, at 18:40 one of the operators on Unit 40 telephoned the ‘unité d’intervention’ to report a gas leak ‘above the boiler’. He then says that the foreman and his team, working on Unit 10, started towards Unit 40, but were surprised by an explosion. Ryad, who seems to have been moving towards Unit 40, says that there was a small explosion – nothing important – and he immediately thought that ‘...la chaudière avait cédé...’ and he noted a white vapour cloud in the area of the ‘chaudière’, about 40m away. Unfortunately, this is ambiguous. ‘Chaudière’ is

commonly used to mean steam boiler, but can be used to mean any type of boiler (e.g. reboiler, gas vaporiser – even a domestic water heater) or even heat exchanger. ‘Avait cédé’ is even more ambiguous: it could mean that the unit had ruptured, shut down, or vented to relieve pressure. Ryad recalled that a similar incident had occurred six months earlier, without causing major damage or injury. Almost immediately, he says, there was a second minor explosion, followed by a third, which he describes as ‘heavy and deadly’. Ryad – at least in this article – makes no mention of any vibrations.

## Final Report

*The following information is based upon a report which was received anonymously by Hazards Intelligence. The technical content of the report is such as to leave us in no doubt that it is genuine. For convenience, it is referred to throughout as “The Report”.*

The Report concludes that the explosion was the consequence of a catastrophic failure in one of the cold boxes of Unit 40, which led to a vapour cloud explosion of either LNG or refrigerant. The most probable source of ignition was the boiler at the north end of Unit 40.

*We see no reason to disagree with this or any other of the report’s conclusions.*

*A cold box is an aluminium plate cryogenic heat exchanger. The unit is typically insulated by beads of perlite, a low density volcanic glass, which is held in place by a box-like structure – hence the name.*

*The process in Unit 40 used a mixed refrigerant. Mixed refrigerant gases are often proprietary formulations, but typically consist of a mixture of two or more of the gases nitrogen, methane, propane, ethylene, and higher hydrocarbons up to pentane.*

The Report is based on forensic examination, engineering analysis, the few plant records that survived, and interviews with surviving eyewitnesses.

No less than five minutes before the explosion, several operators passed through Unit 40 and noticed nothing amiss. This and other factors strongly suggest that whatever happened, happened within a very short time, possibly as short as two minutes. This is crucial, because an analysis of the debris suggested that an explosion equivalent to 3-4 tonnes of methane occurred and there are few sources within Unit 40 that could supply such a mass in such a short time.

Almost all the witnesses reported hearing a loud, unusual noise, not a relief valve lifting, shortly before the explosion. At least five eyewitnesses reported seeing a vapour cloud at the north end of Unit 40, extending out to the nearby maintenance building and to the adjacent Unit 30. [*The maintenance workshop extends along most of the western side of Unit 40.*] All those who saw the vapour cloud reported seeing the cloud **before** the explosion; The Report logically concludes that the vapour cloud was not a consequence of the explosion.

The only records to survive from Unit 40 were those of the boiler, which show no abnormalities. Unit 40 was the only plant not to be fitted with a DCS [Distributed Control System] but the DCS records of the other plants fix the time of the explosion at between 18:37 and 18:38, local time. Pressure changes in the LNG feed pipeline to storage confirm this timing. No damage was found to the boiler consistent with an internal explosion, the boiler was operating when the refrigerant compressor relief valve opened, the position of the boiler is not consistent with the blast pattern, and a boiler explosion could not have produced sufficient energy consistent with the resulting damage. For these and other reasons The Report concludes that a boiler explosion was not responsible for the disaster.

The Report considers the possibility of a BLEVE [Boiling Liquid Expanding Vapour Explosion] and rejects it for several reasons, including the lack of sufficient explosion energy available from any credible source and the absence of any ruptured vessels with appropriate damage.

Bombing or an earthquake were each eliminated because of the absence of evidence.

This leaves only a vapour cloud explosion [VCE] which, The Report notes, is consistent with the vapour cloud seen before the explosion, the sequence of events, the explosion energy, and the damage pattern.

A lengthy analysis in The Report [*which we see no reason to dispute*] shows that the only place from which 2-3 tonnes of methane equivalent could have escaped within less than five minutes was one of the cryogenic heat exchangers known as ‘cold boxes’. Unfortunately, damage was so extensive and the explosive characteristics of methane and the refrigerant so similar, that it has not proved possible to say whether it was methane [LNG] or refrigerant that escaped.

Because it was at Skikda that the problems of mercury in natural gas were first identified and because the Moomba gas plant in Australia suffered a mercury-induced failure not long after the Skikda explosion, there has been some speculation in the technical press as to whether mercury was a factor in the explosion at Unit 40. This idea has been fuelled by knowledge that Unit 40 was the only liquefaction train at Skikda which did not have a mercury removal section. The Report notes that laboratory examination of recovered fragments of cold box ‘A’ did not show any evidence of mercury contamination or attack.

*This does not prove that damage to the aluminium heat exchanger by mercury was not a factor. As far as can be established from The Report, very little of the cold box debris has yet been recovered.*

Given that 3-4 tonnes of methane equivalent must have been released in less than five minutes for a VCE to produce the observed damage, The Report examines all possible sources of such a mass within the required time. The only possible sources are the LNG product line, the refrigerant feed to a cold box, the natural gas feed to a cold box, or the LNG exit from a cold box. However, metallurgical evidence shows that the failure of the LNG product line was a consequence of the fire, not its cause. This is therefore eliminated.

The only scenario which could not be eliminated was cold box failure, followed by ignition from the steam boiler, leading to the VCE. It may also be noteworthy that the cold boxes on Unit 40 have a long history of leaks and other problems. It was not possible to determine whether it was methane, LNG, or refrigerant that leaked.

*It must be said that the report is a model of thoroughness and clarity. Again, we see no reasons to disagree with any of its conclusions, though we feel that the question of mercury damage remains unresolved.*

## **Implications**

### **Aftermath**

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