

# Explosion och brand på krackningsanläggningen på ett oljeraffinaderi.

870322 MARS 1987\_15

På krackningsanläggningen på ett oljeraffinaderi hade en säkerhetsventil avlägsnats för att underlätta drift. Missförhållanden skulle istället upptäckas av operatörerna på plats. En kontrollventil mellan ett högtryckskärl och ett lågtryckskärl med vätgas öppnades av misstag av en operatör. Vätgas under högt tryck (130 bar) kom in i ett kärl som var utformat för 9 bars tryck. Detta kärl sprack vid uppskattningsvis 50 bars tryck. Explosionen förstörde stora delar av utrustningen i omedelbar närhet. Kolväten antändes och resulterade i jetflammar. Operatören utrymde kontrollrummet, slog larm och aktiverade nödstoppet. Hela raffinaderiet stängdes av och katastrofplanen trädde i kraft. Personal evakuerades, företagets interna brandkår ryckte ut och polisen och räddningstjänsten anropades. Vägsräddning sattes upp. Brandröken störde inte omgivningen.

## Inblandade ämnen och mängder

	CAS Nr.	Mängd
väte	1333-74-0	1000 kg
petroleum gaser		3000 kg
flytande kolväten i aerosol		10 000 kg
lätta petroleum ångor		190 000 kg
tunga flytande kolväten		220 000 kg

## Skador:

Människor:	En person dödades vid explosionen.
Materiella:	Ansenliga skador på anläggningen. Mindre skador på en angränsande fabrik.
Miljö/ekologi:	Inga effekter rapporterade.
Infrastruktur:	Inga.

## Erfarenheter redovisade (Ja/Nej): Ja

Förebyggande åtgärder anges.

## Report Profile

### Identification of Report:

country: FA ident key: 1987\_015\_01

reported under Seveso I directive as major accident reports: SHORT+FULL

### Date of Major Occurrence: Time of Major Occurrence

start: 1987-03-22 start: 07:00:00

finish: finish:

### Establishment:

name:

address:

industry: 2002 petrochemical, refining, processing

Petroleum Refinery (Hydrocracking of Heavy Waxy Oils to Spirits and Gas)

Seveso II status: not applicable: Yes art. 6 (notification): No

art. 7 (MAPP): No

art. 9 (safety report): No

**Date of Report:**

short: full:

**Authority Reporting:**

name:

address:

**Authority Contact:**

rep\_cont\_name:

rep\_cont\_phone:

rep\_cont\_fax:

**Additional Comments:**

a) - not applicable -

b) - not applicable -

c) - not applicable -

d) - not applicable -

e) - not applicable -

**Short Report**

country: FA ident key: 1987\_015\_01

**Accident Types:**

release: Yes explosion: Yes

water contamination: No other: No

fire: Yes

description:

ENVIRONMENTAL AND ATMOSPHERIC CONDITIONS:... see Appendix Short Report / description of accident types

**Substance(s) Directly Involved:**

toxic: No explosive: Yes

ecotoxic: No other: No

flammable: Yes

description:

The following substances were released from the LP separator after the explosion:... see Appendix Short Report

/ description of substances involved

**Immediate Sources of Accident:**

storage: No transfer: No

process: Yes other: No

description:

The accident occurred in an oil refinery specialized in cracking heavy oils to spirits and gases (about 7 millions tonnes per year). About 1,200 people were employed and up to 1,000 contractor staff used at major maintenance works. The expl... see Appendix Short Report / description of immediate sources

**Suspected Causes:**

**plant or equipment:** No **environmental:** No

**human:** Yes **other:** No

**description:**

INITIATING EVENT AND CONSEQUENCES:... see Appendix Short Report / description of suspected causes

### **Immediate Effects:**

**material loss:** Yes

**human deaths:** Yes

**human injuries:** No **community disruption:** Yes

**other:** Yes

**ecological harm:** No

**national heritage loss:** No

**description:**

EFFECTS ON PEOPLE:... see Appendix Short Report / description of immediate effects

### **Emergency Measures taken:**

**on-site systems:** Yes **decontamination:** No

**external services:** Yes **restoration:** No

**sheltering:** No **other:** No

**evacuation:** Yes

**description:**

INTERNAL TO THE ESTABLISHMENT:... see Appendix Short Report / description of emergency measures taken

### **Immediate Lessons Learned:**

**prevention:** Yes **other:** No

**mitigation:** No

**description:**

MEASURES TO PREVENT ANY RECURRENCE OF SIMILAR ACCIDENTS:... see Appendix Short Report / description of immediate lessons learned

## **A Occurrence Full Report**

**country:** FA **ident key:** 1987\_015\_01

### **1 Type of Accident**

**remarks:** Due to over-pressurization, a low-pressure separator burst at a pressure of about 50 bar (code 1301). The explosion destroyed the separator and caused the release of flammable gases and liquids (codes 1101 and 1102). The released flammable ... see Appendix Full Report A / type of accident

### **2 Dangerous Substances**

**remarks:** Due to the over-pressurization and subsequent burst of the low-pressure separator were released about 1 tonne of hydrogen, 3 tonnes of petroleum gases and 10 tonnes of hydrocarbon aerosols. From the vessels and pipes damaged by the explosio... see Appendix Full Report A / dangerous substances

### 3 Source of Accident

**illustration:** - not applicable -

**remarks:** The accident occurred in an oil refinery (code 2002) specialized in cracking heavy oils to spirits and gases (about 7 millions tonnes per year). The explosion occurred in a hydrocracker unit in which waxy oils reacted with hydrogen at high ... see Appendix Full Report A / source of accident -  
remarks

### 4 Meteorological Conditions

**precipitation none: fog: rain: hail: snow:**

Yes No No No No

**wind speed (m/s):**

**direction (from):**

**stability (Pasquill):**

**ambient temperature (°C):**

**remarks:** The morning was fine and cold with only a slight breeze.

### 5 Causes of Major Occurrence

**main causes**

**technical / physical** - not applicable -

- not applicable -

- not applicable -

- not applicable -

- not applicable -

**human / organizational** 5302 organization: management attitude problem

5303 organization: organized procedures (none, inadequate, inappropriate, unclear)

5304 organization: training/instruction (none, inadequate, inappropriate)

5308 organization: design of plant/equipment/system (inadequate, inappropriate)

5401 person: operator error

**remarks:** The accident occurred because of an operator error (code 5401) in opening the control valve on the liquid line from the HP to the LP separator without noticing that liquid contents in the HP vessel was draining away. The error was caused bo... see Appendix Full Report A / causes of major occurrence

### 6 Discussion about the Occurrence

- not applicable -

**Type of Accident** country: FA ident key: 1987\_015\_01

**event:**

**major occurrence** - not applicable -

**initiating event** - not applicable -

**associated event** - not applicable -

**event:**

**major occurrence** 1101 release: gas/vapour/mist/etc release to air

**initiating event** 1301 explosion: pressure burst (rupture of pressure system)

**associated event** - not applicable -

## **Dangerous substances**

**country:** FA **ident key:** 1987\_015\_01

### **a) total establishment inventory**

**CAS number: identity:** Petroleum Gases

**name from Seveso I Directive:** - not applicable -

**name from Seveso II Directive:** - not applicable -

**category from Seveso II:** - not applicable -

**other hazards (1):** - not applicable -

**other hazards (2):** - not applicable -

**maximum quantity (tonnes):** 3

**use of substance as:** NORMAL FINISHED PRODUCT

**b) substance belongs to relevant inventory directly involved:** Yes

**actual quantity:** 3 **potential quantity:** 3

**c) substance belongs to relevant inventory indirectly involved:** No

**actual quantity:** -1 **indir\_pot\_quant:** -1

### **a) total establishment inventory**

**CAS number: identity:** Light Petroleum Spirits

**name from Seveso I Directive:** - not applicable -

**name from Seveso II Directive:** - not applicable -

**category from Seveso II:** - not applicable -

**other hazards (1):** - not applicable -

**other hazards (2):** - not applicable -

**maximum quantity (tonnes):** 190

**use of substance as:** NORMAL FINISHED PRODUCT

**b) substance belongs to relevant inventory directly involved:** Yes

**actual quantity:** 190 **potential quantity:** 190

**c) substance belongs to relevant inventory indirectly involved:** No

**actual quantity:** -1 **indir\_pot\_quant:** -1

### **a) total establishment inventory**

**CAS number:** 1333-74-0 **identity:** Hydrogen

**name from Seveso I Directive:** - not applicable -

**name from Seveso II Directive:** - not applicable -

**category from Seveso II:** - not applicable -

other hazards (1): - not applicable -

other hazards (2): - not applicable -

maximum quantity (tonnes): 1

use of substance as: NORMAL FINISHED PRODUCT

**b) substance belongs to relevant inventory directly involved:** Yes

actual quantity: 1 potential quantity: 1

**c) substance belongs to relevant inventory indirectly involved:** No

actual quantity: -1 indir\_pot\_quant: -1

**a) total establishment inventory**

CAS number: identity: Hydrocarbon Aerosols

name from Seveso I Directive: - not applicable -

name from Seveso II Directive: - not applicable -

category from Seveso II: - not applicable -

other hazards (1): - not applicable -

other hazards (2): - not applicable -

maximum quantity (tonnes): 10

use of substance as: NORMAL FINISHED PRODUCT

**b) substance belongs to relevant inventory directly involved:** Yes

actual quantity: 10 potential quantity: 10

**c) substance belongs to relevant inventory indirectly involved:** No

actual quantity: -1 indir\_pot\_quant: -1

**a) total establishment inventory**

CAS number: identity: Heavy Hydrocarbons Liquids

name from Seveso I Directive: - not applicable -

name from Seveso II Directive: - not applicable -

category from Seveso II: - not applicable -

other hazards (1): - not applicable -

other hazards (2): - not applicable -

maximum quantity (tonnes): 220

use of substance as: STARTING MATERIAL

**b) substance belongs to relevant inventory directly involved:** Yes

actual quantity: 220 potential quantity: 220

**c) substance belongs to relevant inventory indirectly involved:** No

actual quantity: -1 indir\_pot\_quant: -1

**Source of Accident - Situation** country: FA ident key: 1987\_015\_01

**situation**

**industry**

**initiating event** - not applicable -

**associated event** - not applicable -

**activity/unit**

**major occurrence** - not applicable -

**initiating event** - not applicable -

**associated event** - not applicable -

**component**

**major occurrence** 4011 general pipework/flanges

**initiating event** - not applicable -

**associated event** 4011 general pipework/flanges

**situation**

**industry**

**initiating event** - not applicable -

**associated event** - not applicable -

**activity/unit**

**major occurrence** - not applicable -

**initiating event** - not applicable -

**associated event** - not applicable -

**component**

**major occurrence** 4007 machinery/equipment (pump, filter, column separator, mixer, etc.)

**initiating event** - not applicable -

**associated event** 4007 machinery/equipment (pump, filter, column separator, mixer, etc.)

**situation**

**industry**

**initiating event** 2002 petrochemical, refining, processing

**associated event** 2002 petrochemical, refining, processing

**activity/unit**

**major occurrence** 3102 process: chemical continuous reaction

**initiating event** 3102 process: chemical continuous reaction

**associated event** 3102 process: chemical continuous reaction

**component**

**major occurrence** 4002 reaction vessel; pressurised

**initiating event** 4002 reaction vessel; pressurised

**associated event** 4002 reaction vessel; pressurised

## **B Consequences Full Report**

country: FA ident key: 1987\_015\_01

### **1 Area concerned**

**affected**

**extent of effects installation:** Yes

**establishment:** Yes

**off-site; local:** No

**off-site; regional:** No

**off-site; transboundary:** No

**illustration of effects** - not applicable -

**remarks** The explosion of the LP separator caused extensive damages to vessels, pipeworks... see Appendix

Full Report B / area concerned - remarks

## **2 People**

**establishment popul. emergency personnel off-site population**

**total at risk** 200

**immediate fatalities** 1

**subsequent fatalities**

**hospitalizing injuries**

**other serious injuries**

**health monitoring**

**remarks** The number of people put at risk by the missiles thrown by the LP separator expl... see Appendix

Full Report B / people

## **3 Ecological Harm**

**pollution/contamination/damage of:**

- **residential area (covered by toxic cloud)** Suspected

- **common wild flora/fauna (death or elimination)** Suspected

- **rare or protected flora/fauna (death or elimination)** Suspected

- **water catchment areas and supplies for consumption or recreation** Suspected

- **land (with known potential for long term ecological harm or** Suspected

**preventing human access or activities)**

- **marine or fresh water habitat** Suspected

- **areas of high conservation value or given special protection** Suspected

**remarks** In the Original Report there is no evidence of significant ecological harms.... see Appendix

Full Report B / ecological harm

## **4 National Heritage Loss**

**effects on:**

- **historical sites** not applicable - **historic monuments** not applicable

- **historic buildings** not applicable - **art treasures** not applicable

**remarks** No data available.

## **5 Material Loss**

**establishment losses off site losses**

**costs (direct costs to operator) (social costs)**

**in ECU** ECU ECU ECU



material losses 7E+07 7000

response, clean up, restoration

remarks The accident caused extensive damages to vessels, pipeworks and buildings within... see Appendix

Full Report B / material loss

## 6 Disruption of Community Life

establishment/plant evacuated disabled/unoccupiable destroyed

- nearby residences/hotels No No No

- nearby factories/offices/small shops No Yes No

- schools, hospitals, institutions No No No

- other places of public assembly No No No

interruption of utilities etc. no / yes duration

- gas No

- electricity No

- water No

- sewage treatment works No

- telecommunications No

- main roads No

- railways No

- waterways No

- air transport No

significant public concern none local level national level

- off site populations No Yes No

- media interest No No No

- political interest No No No

remarks Outwith the hydrocracker unit, the effects of the explosion were not severe, exc... see Appendix

## 7 Discussion of Consequences

# C Response Full Report

country: FA ident key: 1987\_015\_01

## 1 Emergency Measures

taken - on site - not applicable - - not applicable -

- not applicable - - not applicable -

- not applicable - - not applicable -

- off site - not applicable - - not applicable -

- not applicable - - not applicable -

- not applicable - - not applicable -

still - on site - not applicable - - not applicable -

required

- not applicable - - not applicable -

- not applicable - - not applicable -

- **off site** - not applicable - - not applicable -

- not applicable - - not applicable -

- not applicable - - not applicable -

**continuing contamination or danger**

-**on site** not applicable

-**off site** not applicable

**remarks** - not applicable -

## **2 Seveso II Duties**

**pre-accident evaluation**

**Article item not due yet not done done/submitted evaluated**

**6 notification** No No No No

**7 policy (MAPP)** No No No No

**9 safety report** No No No No

**9, 10, 11 update** No No No No

**11 internal plan** No No No No

**11 external plan** No No No No

**13 informing public** No No No No

**9, 12 siting policy** No No No No

**post-accident evaluation**

**Seveso II duty was actual were actual compared with actual**

**contingency consequences consequences, the**

**addressed? addressed? predicted extent was?**

**Article item**

**7 policy (MAPP)** not applicable not applicable not applicable

**9 current safety report** not applicable not applicable not applicable

**11 internal plan** not applicable not applicable not applicable

**11 external plan** not applicable not applicable not applicable

**13 informing public** not applicable not applicable not applicable

**9, 12 siting policy** not applicable not applicable not applicable

**evaluation of safety organisation**

**organisational element element existed did element relate to actual circumstances of**

**yes / no no / partly / yes adequate?**

- **written policy objectives** No

- **specified management** No

**structure**

- **specified responsibilities** No

- specified working procedures No

- specified procedures for No

assessment/auditing of

management system

- specified procedures for No

review and update of

management policy

- specified general training No

procedures

- specified emergency No

training procedures

evaluation of ecological impact control

organisational element element existed did element relate to actual circumstances of

yes / no no / partly / yes adequate?

- ecological status review No

before incident

- potential ecological No

consequences assessment

- ecological impact review No

after incident

- ecological restoration No

procedures

- subsequent review of No

restoration success

remarks - not applicable -

### **3 Official Action Taken**

legal action

- not applicable -

other official action

- not applicable -

### **4 Lessons Learned**

measures to prevent recurrence

After the accident the followi... see Appendix Full Report C / lesson learned - prevent

measures to mitigate consequences:

- not applicable -

useful references:

The effects of the LP separato... see Appendix Full Report C / lesson learned - references

### **5 Discussion about Response**

- not applicable -

## **Appendices for the FA / 1987\_015\_01 report**

**Appendix Short Report / description of accident types:**

## ENVIRONMENTAL AND ATMOSPHERIC CONDITIONS:

The morning was fine and cold with only a slight breeze.

## ACCIDENT CASE HISTORY DESCRIPTION:

A control valve on the liquid line between the HP and the LP Separators was opened in error and the liquid allowed to drain. High pressure hydrogen passed uncontrolled into the closed LP Separator which had limited pressure relief capacity. It overpressurised

rupturing at an estimated pressure of 50 bar. The explosion disintegrated the separator and also damaged other vessels and pipes. Released flammable substances were ignited resulting in jet-fires.

The hydrocracker unit was commissioned in the early 1970's. The potential for high pressure gas breakthrough into the LP separator was recognized in the design and the flow control valves in the line from the HP separator to the LP separator had provided to automatically close should liquid level in the HP Separator reach a critical pre-determined low point. The safety system was arranged to operate from either of a pair of low level magnetic float switches mounted on a bridle tube attached to the HP Separator. In a safety audit and in a review of pressure relief capacity within the hydrocracker complex which were carried out in 1975, the operator of the refinery concluded that high pressure gas breakthrough into the LP Separator would not arise because there was a safety trip actuated by low liquid levels. As a consequence the pressure relief valve on the LP Separator was sized only for fire engulfment on the vessel and was of comparatively small size. Throughout the 1970's the output of the hydrocracker was limited by a series of operational problems. By the early 1980's these were mostly overcome and throughput started to rise to exceed the design capacity of 23,000 barrels/day. At these high flow rates it was discovered that the liquid in the HP Separator became very turbulent. The rapidly changing liquid levels caused spurious trips of the control valve which in turn caused severe operational difficulties. The low liquid level control valve trip system also lost favour for various other reasons. For example frequent blockages of the pipework leading to the level detectors caused by build up of hard carbon residue and by the solidification of waxy liquids in cold weather. The system was unreliable and therefore was distrusted. Furthermore trips would be over-ridden prior to shut-down so that residual liquid in the HP separator could be emptied. At low throughputs or during standby operation trips would also be over-ridden so that the valves could be opened to allow liquid remaining in the line from the HP separator to be blown clear to prevent accumulation of solidifying wax. As a consequence, in the early 1980's the control valve trip was removed and not replaced. It was left to the operators to detect dangerous low levels and close the valves when they judged it appropriate. Removal of the safety system was authorized at operations supervisor level. Maintenance and instrument engineering managers were aware of the situations and turned a blind eye to it.

## Appendix Short Report / description of substances involved:

The following substances were released from the LP separator after the explosion:

- Hydrogen (C.A.S. CODE:1333-74-0, E.E.C. CODE: 001-001-00-9): amount involved = 1,000 kg.
- Petroleum Gases: amount involved = 3,000 kg.
- Hydrocarbon Liquids in released aerosol: amount involved = 10,000 kg.

The following substances were released from the nearby pipeworks and vessels damaged by the explosion:

- Light Petroleum Spirits: amount involved = 190,000 kg.
- Heavy Hydrocarbons Liquids: amount involved = 220,000 kg.

## Appendix Short Report / description of immediate sources:

The accident occurred in an oil refinery specialized in cracking heavy oils to spirits and gases (about 7 millions tonnes per year). About 1,200 people were employed and up to 1,000 contractor staff used at major maintenance works. The explosion occurred in a hydrocracker unit in which waxy oils reacted with hydrogen at high temperature and pressure in presence of a catalyst to form light petroleum spirits and gases (approximately 23 m<sup>3</sup>/h). From the hydrocracked liquids, the hydrogen gas was first removed in a high-pressure (HP) separator operating at 130 and then further in a low-pressure (LP) separator vessel operating at 9 bar. Liquids then passed to fractionation with gas and unreacted waxy residues recycled back to the reactors. The refinery is in an industrial area with the hydrocracker unit some distance from factory's boundaries as shown on the map attached to the Original Report.

## Appendix Short Report / description of suspected causes:

### INITIATING EVENT AND CONSEQUENCES:

A control valve on the liquid line between the HP and the LP Separators was opened in error and the liquid allowed to drain. High pressure hydrogen passed uncontrolled into the closed LP Separator which had limited pressure relief capacity. It overpressurised rupturing at an estimated pressure of 50 bar.

### CAUSES:

The accident occurred because of an operator error (due to both the insufficient training of the operator and to the inappropriate procedures) in opening the control valve on the liquid line from the HP to the LP separator without noticing that the liquid contents in the HP vessel was draining away. Alarms did not operate because they had been previously disconnected without taking into account the decrease in safety. The main reason for the disconnection of the alarms was due to avoid operational difficulties because of the insufficient design capacity of the plant.

## Appendix Short Report / description of immediate effects:

### EFFECTS ON PEOPLE:

8 people were directly involved in the explosion and the subsequent fire (1 person was killed by explosion). The smoke from the fire did not affect the locality.

### MATERIAL LOSS:

The accident caused extensive damages to vessels, pipeworks and buildings within the hydrocracker complex (the cost of rebuilding of the hydrocracker has been estimated in about 50,000,000 UK Pounds [about 7 MECU]).

Outside the establishment, damages occurred in an adjacent factory (rupture of a steam line and damages to a building caused by a large fragment of metal through the roof).

The cost of these damages has been estimated to be about 0.007 MECU. \_\_

### OTHER:

A small radioactive source, part of a level detection unit, was lost in the blast. It is presumed to have landed in its heavy container on deep mud flats to be buried to a considerable depth. It presents absolutely no danger to anyone.

### MAP OF THE ACCIDENT AREA:

The approximate extent of broken windows and cladding and the points where the missiles had thrown are shown on a map attached to the Original Report. The effects of the LP separator burst were equivalent to those of an explosion of 90 kg of TNT.

### **Appendix Short Report / description of emergency measures taken:**

INTERNAL TO THE ESTABLISHMENT:

Before evacuating the control room, operator initiated the emergency shut-down and venting system of the hydrocracker unit. The on-site emergency procedure was activated. This included the shut-down of the entire refinery, the evacuation of non-essential personnel, the mobilization of the refinery fire brigade and the call on-site of engineering management staff. The extensive refinery fire fighting system was quickly brought into use.

The area major incident control committee (comprising Police, Fire Brigade and representatives from major companies in the area) was called into operation to co-ordinate the emergency measures. Fire brigades from Central Scotland attended. Supplies of equipment essential for fire fighting were brought on-site from companies in the locality under a mutual aid system.

EXTERNAL TO THE ESTABLISHMENT:

Road blocks were set up. Occupiers of neighbouring factories were asked to inspect their sites for damages. It was not necessary to evacuate any housing.

### **Appendix Short Report / description of immediate lessons learned:**

MEASURES TO PREVENT ANY RECURRENCE OF SIMILAR ACCIDENTS:

After the accident the following measures were established:

- 1- during the rebuilding of the hydrocracker, a full pressure relief on the LP separator, as well as improved instrumentation and fail-safe shut-off valves in series with level-control valves to be included;
- 2- rigorous procedures to be adopted in order to drain the HP separator of liquid as shut-down;
- 3- the systems for reporting plant defects, for testing interlocks and trips, for authorising equipment changes and for training operators have been tightened up;
- 4- routine audits to be carried out rigorously.

Senior management were taking a much closer interest in the safety performance of refinery departments.

### **Appendix Full Report A / type of accident:**

Due to over-pressurization, a low-pressure separator burst at a pressure of about 50 bar (code 1301). The explosion destroyed the separator and caused the release of flammable gases and liquids (codes 1101 and 1102). The released flammable liquid and gases took fire (codes 1202 and 1203). Due to the difficulties in fighting the fire, leaking petroleum spirit spread over an area of 35,000 m<sup>2</sup> and, 5 hours after the explosion, a serious flash-fire occurred (code 1204).

### **Appendix Full Report A / dangerous substances:**

Due to the over-pressurization and subsequent burst of the low-pressure separator were released about 1 tonne of hydrogen, 3 tonnes of petroleum gases and 10 tonnes of hydrocarbon aerosols. From the vessels and pipes damaged by the explosion were released about 190 tonnes of light petroleum spirits and 220 tonnes of heavy hydrocarbons liquids that took fire. No data are available about the total establishment inventories of these substances.

### **Appendix Full Report A / source of accident - remarks:**

The accident occurred in an oil refinery (code 2002) specialized in cracking heavy oils to spirits and gases (about 7 millions tonnes per year). The explosion occurred in a hydrocracker unit in which waxy oils reacted with hydrogen at high temperature and pressure in presence of a catalyst to form light petroleum spirits (code 3102). The components involved were the low-pressure separator and the nearby vessels and pipes (codes 4002, 4007 and 4011). The refinery is in an industrial area.

### **Appendix Full Report A / causes of major occurrence:**

The accident occurred because of an operator error (code 5401) in opening the control valve on the liquid line from the HP to the LP separator without noticing that liquid contents in the HP vessel was draining away. The error was caused both by insufficient training of the operator (code 5304) and by inappropriate procedures (code 5303). Alarms did not operate because they had been previously disconnected, to avoid operational difficulties due to insufficient design (codes 5302 and 5308).

### **Appendix Full Report B / area concerned - remarks:**

The explosion of the LP separator caused extensive damages to vessels, pipeworks and buildings within the hydrocracker unit. Outside the establishment it caused the rupture of a steam line and threw a large metal fragment through the roof of a building in an adjacent factory. The smoke from the fire did not affect the site. The approximate extent of broken windows and cladding and the points where missiles had thrown are shown in a map attached to the Original Report.

### **Appendix Full Report B / people:**

The number of people put at risk by the missiles thrown by the LP separator explosion were about 200. Inside the establishment, 8 people were directly involved in the explosion (1 person killed).

### **Appendix Full Report B / ecological harm:**

In the Original Report there is no evidence of significant ecological harms.

### **Appendix Full Report B / material loss:**

The accident caused extensive damages to vessels, pipeworks and buildings within the hydrocracker unit. The re-building cost of the hydrocracker has been estimated in about 70 MECU. The explosion caused material damages in an adjacent factory (rupture of a steam line and damages of a building): the estimated total cost of these damages was about 0.007 MECU.

### **Appendix Full Report B / disruption of community life:**

Outwith the hydrocracker unit, the effects of the explosion were not severe, except for one nearby factory where a steam line was ruptured and a large metal fragment was thrown through the roof of a building. The smoke from the fire did not affect the locality.

### **Appendix Full Report C / lesson learned - prevent:**

After the accident the following measures were established:

- 1- during the rebuilding of the hydrocracker, a full pressure relief on the LP separator, as well as improved instrumentation and fail-safe shut-off valves in series with level-control valves to be included;
- 2- rigorous procedures to be adopted in order to drain the HP separator of liquid as shut-down;
- 3- the systems for reporting plant defects, for testing interlocks and trips, for authorising equipment changes and for training operators have been tightened up;
- 4- routine audits to be carried out rigorously.

Senior management were taking a much closer interest in the safety performance of refinery departments.

### **Appendix Full Report C / lesson learned - references:**

The effects of the LP separator burst was estimated to be equivalent to those caused by an explosion of 90 kg of TNT.