CHAPTER TWO

Radically new threats

"I see a radical novelty, a 'major risk' without precedent in the nature of consequences that certain technological developments can bring about. To the mechanical accident that can kill or maim the twentieth century has added a further dimension, even if its proportions are yet unknown: the disaster that overtakes the integrity of life.

In all these cases the risk is run not only by the victims at the time: it affects life itself by transmission to the descendants. The statistical scourge of monsters and those born with an infirmity because of the hazards of nature, has been extended by the necessities of the human genius (...). This is where Prometheus is as successful as Nature ... or God by striking his (own) descendants in what is considered the most precious and the most sacred: life, not by destroying it but by working its transmission to future generations".

J. J. Salomon (1)

I. THE DISASTERS OF THE INDUSTRIAL ERA: EIGHTEENTH TO TWENTIETH CENTURY

Faced with the risks presented by modern technology an observation has recently been suggested for consideration: History is strewn with drama such as mine or railway disasters; the demand by modern society for safety must not veil the considerable progress that has been made in this field. The argument deserves closer examination. What were the contemporary dramas of the rise and development of the industrial age? What has become of them? These are the very first questions to be asked if one wants to appreciate subsequently the progress achieved in matters of safety, the shifts and changes brought about in the field of risk.

We therefore propose hereafter a short account of the typical risks of that period of industrial upsurge. The purpose of the account is to spell out the categories and orders of size to be considered. It is not at all an attempt at an encyclopaedic work. The basic data for this undertaking were derived from the work of J. R. Nash (2) which constitutes, to our knowledge, the only available reasonably complete account of the disasters.*

Let us emphasise that, given the perspective of our endeavour, we shall enlarge on some points where reflections on questions of responsibility can be made.

1. THE GENERAL CONTEXT OF THE SAFETY OF POPULATIONS IN COUNTRIES UNDERGOING THE PROCESS OF INDUSTRIALISATION IN THE EIGHTEENTH AND NINETEENTH CENTURY

Without wishing to give a complete picture, one can supply several important elements in the context of 'safety' as it appears at the beginning of the period considered here.

1st. Great scourges which still exist in Europe

Disasters of natural origin are still of great importance even if considerable progress has been made in this field.

Famine, a constant scourge since the Middle Ages, will soon disappear. Thus, as Jean Fourastie remarks, the year 1709 marks a turning point: from that year onwards "one no longer finds towns and whole regions abandoned to the furies of hunger; one no longer finds men eating children; never again will human flesh be sold in the market at Tournus" (3, p. 77). From 1770 on the crises of agricultural production no longer brought about collective death with the exception of the case of Ireland**which on account of the poor quality of its soil and the implacable yoke imposed on it from outside experienced a hecatomb from 1846 to 1849 (more than a million and a half dead) (4, pp. 91-102; 5, pp. 9-39).

Epidemics are also on the retreat. In France, leprosy had been overcome during the fourteenth and fifteenth centuries, typhus in the eighteenth; the plague raged for the last time in 1722 in Marseille. Smallpox caused 80,000 victims in 1798. Cholera struck still, being brought to Europe in connection with British trade: Paris was struck in 1832 (18,000 dead), in 1849 (10,000 dead), in 1853-54 (11,500 dead), in 1865-66 (11,000 dead), in 1873 (854 dead); in Europe as a whole, cholera claimed millions of victims between 1826 and 1837. Tuberculosis was also rampant (250,000 dead in England between 1851 and 1855). The last great epidemic in European countries was the one of 1917-1919: 'Spanish Influenza' caused more than 20 million deaths (4, pp. 103-120; 2, pp. 732-734; 6, pp. 9-18).

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*Certainly, it appears insufficient or inexact on certain points, which is inevitable, but the wealth of information which it supplies is such that it constitutes an obligatory stopping point for reflection. It mitigates a deficiency which all those who nowadays work on the subject of major risk deplore.

**The Irish were caught up in a dramatic situation brought about by the following factors: potato disease; a real estate law which made agriculture extremely vulnerable; a blockage of maritime development imposed by England which left them no resources other than those of the soil; the sacred doctrine of laisser-faire which for a long time forbade public assistance; martial law, the cold and typhus; the refusal by the London government to consider the situation. A revolt which only incensed the English still more: to a new demand for help in 1848 the Prime Minister retorted: "Parliament will never accord a loan to Ireland: so great is its fury against seditious, lying and ungrateful Ireland" (5, pp. 9-39).

The other great curtain raiser was war: it was waged many times before the bloodbath of 1914-1918.

Also in the chapter on great natural disasters belongs the case of the destruction of Saint-Pierre in Martinique on May 8, 1902 following the eruption of Mont Pele (30,000 dead, 2, pp. 430-437; 8, pp. 10-15) and also the eruption of Krakatoa (between Java and Sumatra) which in 1883 caused a great flood that killed 40,000 people. In Europe, Italy was struck several times (2, pp. 311-315); the biggest earthquake was the one on December 28, 1908: between Messina, Reggio Calabria and other cities 160,000 dead were counted*(2, pp. 364-370).

2nd: Safety in everyday life

Would everyday life call for more emotion about the phenomenon of accident? For a good part of the population the dramatic nature (which, however, showed improvement during the period) made insecurity a constant feature which a major accident could not accentuate much. The living conditions of the poor at whose expense industrialisation was accomplished are well known. Two illustrations of these are worth mentioning; the first one is brought up by J. Fourastie and deals with the life style of the masses:

> The peasant's home, poor but in the fresh air, was exchanged for infected hovels. The working hours of the peasant, bearable in the fields, were adopted in unhealthy, evil-smelling factories. The moral and social framework of the village disappeared and gave way to the anonymous masses confined in inorganic suburbs. It was the hideous era of the proletarisation of man. (3, p. 88).

The second one, taken from a present day British paper, reminds us of the dangers of everyday work:

> The machines required frequent greasing but it would cost money to stop them for this purpose. As a result, they were oiled while they were running. It was difficult for an adult to reach the greasing points. Children are smaller. Therefore children would grease the running machines. As a result children were maimed and killed.

The workers nowadays are suffocated by such practices. This is certainly difficult to understand until one realises that the fear of famine is more pressing than the fear of a violent death caused by a machine. The first was a certainty if you did not have work; the second was a wager in which you could take part.

The mouse goes into the trap for its cheese, the fish on the hook for its worm, the worker into the spinning mill for his bread (7, p. 15).

2. DISASTERS OF WHICH THE NATURE IS NOT NEW

1st: The great fires in towns

Very large-scale fires have, sometimes generalised, marked the development of towns throughout history. Thus London suffered badly on a number of

*Other cases of massive destruction the prime cause of which had been earthquakes but where the most serious damage was caused by fire following the earth tremor are examined hereafter.

occasions: in the years 700, 982, 1212, 1666 (13,200 houses burned down). The same happened to Nantes in 1118, Berlin in 1405, Moscow in 1570, Oslo in 1624, Edinburgh in 1700, Lisbon in 1707, Copenhagen in 1728 etc. (2, pp. 654-662).

This type of disaster struck again in the eighteenth and nineteenth centuries even though the towns had organised themselved better and better against the danger. London had another serious fire in 1748 (200 houses destroyed). Moscow saw 1,800 of its houses on fire in 1752. London suffered from fire again in 1834: Parliament fell prey to the flames. New York was afflicted three times (1835, 1845, 1845). Chicago had its big fire in 1871: 18,000 houses burned down, between 250 and 300 dead. Side by side with these examples one also remembers those of Canton (in 1822, 85 per cent of the city destroyed) or of Cairo (1824, millions of victims) (2, pp. 654-662).

Together with these immediate fires one must also take into account the fires following earthquakes. Three cases attract attention: Tokyo in 1857 (107,000 dead); San Francisco in 1906 (700 dead, 75 per cent of the city devastated, much more by the fire than by the earthquake); Tokyo-Yokohama in 1923: more than 143,000 dead, 300,000 houses destroyed.

Lisbon, 1755. On November 1, 1755 Lisbon was struck by three very strong earthquakes. After these earth tremors the city was further afflicted by a big seismic tidal wave and a gigantic fire. The number of deaths was between 50,000 and 100,000. An earth tremor also claimed 10,000 victims in Morocco; various European cities felt it. The seismic tidal wave was also noticed in England, in the Antilles and in Northern Europe. The philosophical and religious agitation was intense as Voltaire's and Rousseau's writings witness; some went on a search for heretics to burn. The king's secretary was more pragmatic in his reply to the head of Portugal who questioned himself about what attitude to take: Sir, we must bury the dead and feed the living (2, pp. 336-339).

San Francisco, 1906. Built between two seismic geological faults, the city had seen extremely fast development since 1848. Within twelve years the population grew from 800 inhabitants to 40,000 (in 1860). Its wooden dwellings brought about a large number of fires (1849, 1850, 1853, 1854); its location was the reason for several earth tremors (1857, 1865, 1868, 1895). In 1906 it had 450,000 inhabitants.

The fire chief had warned those in authority on several occasions about the inefficiency of fire rescue equipment. Six months before the disaster the National Board of Fire Underwriters had warned: San Francisco has defied all traditions and all principles by not having been on fire yet. This is to the credit of the vigilance and efficiency of the fire police but it will not be possible to escape the inevitable indefintely. The main water supply had been installed across one of the geological faults.

On April 18, 1906 shortly after 05.00 h a violent tremor was felt. The earthquake, measuring 8.3 on the Richter scale, was, however, not to be the most destructive factor. In fact, the gas pipelines were broken; so were the water supply lines. Ten minutes later the fire raged; an hour later fifty sites on fire were counted. The fire fighting equipment was insufficient and a dramatic fact had to be realised: San Francisco had practically no water left.

On the scene the General in charge of the local garrison took the situation in hand, knowing the weaknesses of the municipality which was run by a mayor known to be incapable and corrupt. His military regime soon took on the shape of (quasi) martial law.

Within a few hours the fire became uncontrollable. Having no water available an attempt was made to stem the spreading of the disaster with dynamite; but lack of training again caused setbacks and victims. Nevertheless the ferry was saved and 50,000 people evacuated.

The bill was heavy: between 400 and 1,000 dead, 10 km^2 of the city burned out, more than 28,000 houses set on fire (2, pp. 490-507; 5, pp. 143-167; 8, pp. 16-24).

Tokyo-Yokohama, 1923. On September 1, 1923, starting at 11.58 h, the region of Tokyo-Yokohama was shaken by a series of very strong tremors (8.2 on the Richter scale). To witness this intensity: the indicators of the local seismometers just broke. Two hundred and thirty seven tremors were counted on the first day, 92 the next day, 1,200 within a month. Added to the tremors were seismic tidal waves that ravaged the coast. Again it was fire that caused the most damage.

The earthquake had struck at the time lunch was being prepared; hearths were overturned and fire broke out in some hundreds of places. In Yokohama the big oil and petrol tanks cracked and more than 100,000 tonnes of hydrocarbon spread through the canals and the river to the port. Yokohama was 80 per cent destroyed and people who fled by boat were caught by the fire.

To make things worse the wind speed increased. Sparks fell on highly inflammable rubble. Within three quarters of an hour the situation became dramatic; people trying to escape were turned into torches, bridges caught fire, the water boiled in the canals. This heat caused "fire storms"; cyclones formed and swept the city, spreading the fire and blowing the flames in every direction. One of these tornadoes hit an army clothing warehouse: between 40,000 and 45,000 people had sought shelter there, not many survived.

It was not the best scientific explanations that guided the spirits then. Using the disaster to his own advantage the emperor put the blame on the Koreans and the socialists for having displeased the spirits and for being responsible for the lootings. The terror spread, the Koreans fled where they could. Martial law was imposed on September 2.

The lack of water, the lack of food, communication problems (carrier pigeons were used for messages) made the fight against the disaster and even just survival very difficult. Diseases appeared with epidemics of dysentry and typhoid: more than 3,700 people were killed by them.

In the end, 200,000 injured, more than 140,000 dead, 500,000 homeless were counted in the area. More than 300,000 houses had been destroyed (2, pp. 285-288; 6, pp. 19-45; 8, pp. 41-47).

2nd: The great fires in buildings

House fires are not typical risks of the industrial era: the great historical event is the destruction of the Alexandria library in 500 AD. These disasters were still not sufficiently prepared for in the eighteenth, nineteenth and twentieth centuries as the following account shows (2, pp. 654-662).

1772: Theatre at Zaragoza (Spain) 77 dead
1781: Palais Royal, Paris, 20 dead
1836: Theatre at St. Petersburg (Russia) 700 dead

1845: Theatre at Canton (China) 1,670 dead
1863: Jesuit church, Santiago (Chile) 2,000 dead
1876: Brooklyn Theatre (USA) 295 dead
1881: Ring Theatre, Vienna (Austria) 850 dead
1887: Opera Comique, Paris, 115 dead
1897: Charity Bazaar, Paris, 150 dead
1899: Hotel Windsor, New York, 92 dead
1903: Iroquoi Theatre, Chicago, 602 dead
1938: Nouvelles Galeries and Hotel Norilles, Marseille, 100 dead
1940: Night Club, Natchez (Miss., USA) 198 dead
1942: Night Club, Boston (USA) 491 dead

The Ring Theatre, Vienna, 1881. Following an incident the fire caught the stage curtains and immediately spread over the stalls which held a capacity crowd on that evening of December 8, 1881. This caused panic, all the more so as the lights suddenly went out and, against the regulations, there was no emergency lighting.

In addition, the emergency exit signs were either non-existent or insufficient in the corridors of the dress circles. At the time when the flames penetrated the stage curtain and leapt out into the auditorium the spectators in the dress circles who tried to escape rushed off in the wrong directions which led into dead-ends. Tens of them who had discovered a real emergency exit found themselves in front of padlocked doors.

That was not yet all of the negligence. From the start of the fire the fire brigade on duty and the stage hands had fled without starting the alarm (the key to it was in the pocket of one of the firemen) and without lowering the safety curtain.

They did not dream of activating the five fire hydrants installed on the stage and intended for such instances (5, pp. 56-57).

Outside one police officer declared very hastily: there is nobody left in there. The action by the fire brigade was directed towards the protection of adjacent buildings: any chance of extinguishing the fire had been excluded from the start. Some people nevertheless broke into the theatre to save the disaster victims, but to do this the doors had to be smashed with axes; right at the start of the fire a policeman had thought it wise to lock them up to prevent the crowd from trying to rescue family or friends caught in the fire.

The Opera-Comique, Paris, 1887. This again was a rapidly spreading fire; there was an auditorium caught up in panic on account of the fumes and gases, the darkness (the emergency lights were insufficient to penetrate the smoke screen), the padlocked doors, the malfunction of the fire fighting equipment inside. But in contrast to the Vienna disaster the equipment outside was efficient: the fire police used the 24 metre ladders for the first time (5, pp. 71-86).

However, this drama had been foreseen. The unsafe state of the theatre or at least of the part reserved for the staff had been recognised. A member of parliament had even raised a question on the subject in the chamber thirteen days previously. The minister himself had emphasised the seriousness of the situation, showing a touching perspicacity in the use of statistics:

The Minister of Education and the Arts:

I repeat that this situation is quite dangerous, and it is certain that if fire broke out in the Opera-Comique, and this eventuality is unfortunately nearly certain within given time ... (Shouts of diverse opinions). With your permission: there is no theatre that has not been on fire, even several times, within a century. This is a statistical fact; it follows that we can consider it probable that the Opera Comique will have a fire ... (Laughter). I hope, however, that this will not be soon.

In the present situation if the fire occurred during a performance there would be disaster. It is certain, as has just been mentioned, that we would see several hundred people perish. This is a very serious responsibility, an eventuality which deserves the highest degree of attention from government and parliament.

Now, the question is how to provide for this, and here we are faced with difficulty ... All I can do is to submit the question to my colleague in charge of Finance (Laughter).

If the Minister of Finance feels he can accept these propositions we would together draft this law and submit it to the budget commission.

Here, then, gentlemen, is the state of affairs; this is what I propose to do (Very good! Very good!).

The Speaker: The incident is closed. (9, p. 988).

That was on May 12, 1887. On May 25, one hundred and fifteen people died in the ruins of the Opera-Comique. Without the efficient intervention of the fire police the toll would have been higher still. This drama did not change attitudes: in 1923 the Opera Comique was again on fire, claiming 103 victims.

The Charity Bazaar, Paris, 1897. The charity sale organised by the principal French and European aristocratic families for the benefit of works of welfare took place, in that year, in a sort of hangar, hastily constructed and decorated with highly inflammable material. The light bulb of a cinematograph proved to be defective. An unfortunate use of ether, a match and the fire was spreading about within seconds; the ceiling collapsed on 1,200 people crowded together inside. Scenes of panic and terror developed in the hangar, good manners often gave way to savage brutality. More than 120 victims were counted (5, pp. 87-106).

Michel Winock has shown (10) the repercussions of this drama clearly. It unleashed a number of forces that found in it a means or a pretext for expression: the gruesome, the perverse, the war of the sexes, the class struggle, irrationality, antisemitism, the collective fear of death. We retain two reflections that are pertinent to our subject. The first one is by G. Clemenceau who was astonished that there could be two standards of emotion depending on whether it was elegant ladies of the aristocracy or miners who became victims of a fire-damp explosion (by the way: nine years later G. Clemenceau had to face the drama of Corrieres). The second one is by the Dominican padre who preached at the commemorative service in Notre Dame at which the President of the Republic and members of the government were present. His message centred on two points: the sin of pride in this scientific century*; the divine wrath at the departure from the straight and narrow path**by the oldest daughter of the church:

*An allusion to the supposed prime cause of the disaster: the light bulb of the cinematograph.

**Taken to be the deeper cause of the tragedy.

- He (God) wanted to teach a terrible lesson at the pride of this century in which man incessantly talks about his triumph against God.

From the flame which it (the scientific century) claims to have snatched from Thine hands like the classical Prometheus Thou hast made the instrument of Thy revenge.

France has deserved this chastisement by a further departure from her traditions. Instead of marching at the head of Christian civilisation she has consented to follow like a servant or a slave doctrines which are as alien to her spirit as they are to her baptism.

France, having chosen the evil road of apostasy, has been visited by the "angel of destruction" (10, p. 38).

<u>3rd: The great maritime disasters</u>

The risks of maritime navigation have been experienced through the ages. Industrial development was to make safer ships available; but the growth in size of the vessels made the tolls heavier when the drama occurred. The major defeat in this field was the tragedy of the Titanic in 1912. Before dealing with some of its key factors we submit the following recapitulation which gives an order of magnitude (2, pp. 675-709):

			Registered peaks (fleets excluded)			
Century	No. Victims	No. events	Civilian		Military	
			Year	Deaths	Year	Deaths
16th	100	1	1586	450		
	500	2				
	1,000	1 (fleet)				
	Thousands	1 (Armada 1588)				
17th	100	15	1656	644 (collision)		
	500	3				
	1,000	2 (fleet)				
	Thousands	2 (fleet)				
18th	100	20	1770	700	1772	900
	500	4				
	1,000	2 (fleet)				
	Thousands	4 (fleet)				
19th	250	66	1866	738	1811	2,000 (coll.)
	500	10				
	1,000	1				
	Thousands	1			1865	1,517 (fire)
20th	250	41	1912	1,547		
(1900-1949)	500	12	(Titanic)			
	1,000	11	1948	2,750	1949	6,000 (evac.)
	Thousands	2	(China, mine explosion)			

Table 6: The great maritime disasters

The Titanic, 1912. The *Titanic* "the biggest vessel of all time" (53 metres high, more than 250 metres long), the most powerful (55,000 HP), the fastest (24-25 knots), the most luxurious was the pride of the British White Star Line.

On April 10, 1912 it left Southampton for its first Atlantic crossing.

Confidence in this giant was limitless. The *Titanic* had been equipped with a partitioning system with automatic shutters which divided the hull into 16 compartments. Lloyds of London had issued it with a certificate of unsinkability even though the partitions, strangely, were not high enough to shut every compartment hermetically. It was thought that in case of trouble there would always be time to intervene before the water reached the height of the partition and spilled over into the adjacent compartment. Such was the blind confidence that one of the ship's officers thought he could assure a female passenger at embarkation by declaring: Not even God himself could sink this vessel.

Aboard this liner were 2,207 people of which 1,316 passengers: the flower of the international financial aristocracy in the first class, 706 emigrants in third class (plus goods worth half a billion dollars). The first two days of this first crossing of the *Titanic* passed without problems. In the morning of the third day, April 14, the temperature was even mild for the season. However, the weather conditions were changing, and the *Titanic* was warned of this several times.

At 09.00 h a telegram warned of the presence of drifting ice in the area it was approaching. Early in the afternoon, two further telegrams confirmed this information: the *Titanic* was speeding straight into a dangerous area.

At 19.30 h while the temperature was dropping further a fourth message confirmed to the liner that it was inside the danger area.

Nobody worried. There was actually no question of rerouting or accepting delay, or of slowing down. Only the lookouts were instructed to pay special attention. The *Titanic* continued to speed on like a fireball through the night. Nevertheless, a fifth signal was sent to the liner.

In the radio room the first operator, Philips, was in touch with the station at Cape Race. Suddenly his frequency was picked up by a transmission from a nearby freighter, the Californian, which transmitted:

Listen, old chap, we are blocked in here with ice all around us ...

Shut up, Philips replied savagely. I am talking to Cape Race, and you are messing up my communication!

It was 23.40 h. At this time, the lookout, incredulous and before long paralysed, before raising the alarm saw an iceberg shaping up quite near. "An iceberg straight ahead of us! We'll hit it!" On the bridge the officer made the boat turn. There was only a small impact; few people noticed it. The ship stopped, the captain was put in the picture; he ordered an inspection.

Some passengers began to worry: There is nothing serious, set your minds at rest! Stay in your cabins. The crew is taking care of your safety.

Some of them were not duped. In the smoking room for instance the tremor had been felt and a sailor was heard shouting: We have hit an iceberg.

In fact, the iceberg had ripped the hull open over a length of 90 metres. The six forward compartments were flooded.

At 00.50 h the captain had to plan the evacuation of the ship. The distress signal was sent out but was not picked up by the only vessel in the immediate vicinity, the *Californian* which was stopped ten miles away (having stopped in view of the danger from the ice). At the time radio watch was not obligatory.

The evacuation turned into disorder and terror: the classical evacuation exercises had not been carried out, the sailors did not know their assignments. There were lifeboats for only about half of the embarked people. At least 1,000 people were condemned to drown. There were no life belts for the third class passengers. In first class there were sour faces about these life-vests being passed on and soon the life-boats were boarded to which the emigrants from third class had no access: force had to be used to safeguard the privileges of the first class passengers; a good number of them hardly condescended to embark on these frail small boats which they were offered. Why quit the unsinkable vessel? The noise of the escaping steam did not facilitate operations.

The 'water-tight' partitions showed their limits, and the vessel sank faster and faster. While the lifeboats were lowered, some of them half empty, the emigrants went into the attack. Shots were fired and stopped their attempt. Six hundred and sixty people had embarked on lifeboats. One thousand five hundred people were left on the wreck, the stern of which soon rose to a vertical position. From his lifeboat the chairman of the Star Line saw his jewel sink into the sea. The survivors were rescued: there were 705 out of the 2,207 who had embarked on the *Titanic*.

Among those who perished the largest number were emigrants, people who had been unable to afford a place in first class (11, pp. 45-46).

3. THE NEW GREAT RISKS OF THE INDUSTRIAL ERA

1st. Mining disasters

Mine disasters have struck English workers since the seventeenth century; the first half of the twentieth century was the most murderous period. In Europe the main reference point remains the disaster at Corrieres (1906, 1,099 dead).

The table on the following page gives an indication of the scale of the major mining accidents (2, pp. 710-720).

Courrieres, 1906. On the morning of March 10, 1906 about 1,780 workers had gone down into the three pits of the mine at Courrieres which was considered to be one of the safest in the basin of the Pas-de-Calais. Towards 06.30 h, however, a very large explosion occurred; gas invaded the tunnels which were transformed into furnaces. 1,099 dead were counted. It was not a fire-damp explosion but a phenomenon that was little known in France at the time, a 'dust explosion' i.e. a rapid inflammation of large quantities of dust in the air.

These were the only statements made unanimously. Emotions, some families had lost up to seven members; social antagonisms, problems between the staff of the mine and the government engineers who were legally in charge of the rescue operations and the enquiry, rivalries between young and old unionists, an electoral aspect, the sometimes unsatisfactory information given by the

Period	No. accidents	No. victims	Average per accident	Maximum recorded dead	Distrib./ Category
1700-1749	5	198	40	69 (GB 1708) 60 (GB 1710)	50 -: 2
1750-1799	6	180	30	39 (GB 1767) 39 (GB 1799)	50 -: 0
1800-1849	32	1,513	47	102 (GB 1835	50 -:10 100 -: 1
1850-1899	194	11,614	60	550 (Upper Silesia 1895) 361 (GB 1866)	100 -:25 200 -: 4 300 -: 1 400 -: 0 500 -: 1
1900-1949	255	30,000-33,000	118-130	3,700 (GDR 1949*) 3,000 (China 1931) 1,549 (China 1942) 1,099 (China 1906)	50 -:59 100 -:35 200 -:14 300 -: 8 400 -: 3 1,000 -: 4

*Accident in a uranium mine in the GDR. According to sources there were: 2,300 dead (*Berlin Telegraph*), 1 dead (Soviet source), 3,700 dead (chief of Leipzig fire police).

Table 7: Mining disasters

government (which had actually resigned at the time of the drama; soon afterwards reformed with G. Clemenceau at the Interior Ministry), there were so many factors that promised confusion, controversy, violence and finally repression.

Courrieres was more than a mining disaster. Not only did it leave behind several hundred invalids for life, 562 widows, 1,133 orphans as well as hunger, cold, misery and bitterness but it was also going to be the cause of rage and the response to it: martial law declared by Clemenceau who sent in troops to patrol the miners' dwellings. There were arrests of responsible unionists, an unfounded theory of a 'plot' before the resumption of 'normal' work and the holding of the programmed elections.

About the antecedents of the accident and the responsibility of the operating company

The following two series of observations can be offered. The first one reflects the action and the feeling of the miner's delegate; the second one gives the analysis by the General Mining Council which debated the accident at its sessions of May 10 and 17, 1907.

a) The point of view of the miners. The pronouncements and reports by the miners' delegate Simon are at the root of the rumours about the murderous negligence of the mining management at Courrieres. Since November 28, 1905 i.e. nearly four months before the disaster, Simon had pointed out in his inspection report the lack of air in the tunnels, the large quantity of coal dust in the atmosphere and the need to moisten it. On February 16 of the following year he recommended not to let the workers go down into pit No. 3 and to supply more air. On the 17th he made the same remarks. On March 3 i.e. a week before the explosion he repeated, even more strongly, the same recommendations; as the company paid no attention to his observations, little by little very heavy noxious gases accumulated in the abandoned seams and a fire broke out which the engineers were unable to control. Trying to contain it they decided to wall it in with fire-proof cement bricks. Delegate Simon stood up against this solution which he considered extremely dangerous and advocated flooding of the seam in which the fire raged.

The workers employed on the construction of the wall also were aware of the danger: "Several of us did not go down into the mine on Saturday because they foresaw the misfortune. We noticed definite signs of unrest with the horses which scared us." (12).

b) The analysis of the General Mining Council. Considering that if, as shall be shown, it has not been possible, despite the most persevering and attentive investigations, to establish the exact cause that started the fire which resulted in the disaster of March 10, 1906 it cannot be denied that its extension appears to have been due to the spreading, subsequent to various circumstances, of the ignition of dust through the whole expanse of the working area of pits Numbers 2, 3, and 4-11 over a length of about 3 km and a width equal to 1,500 metres surface.

Considering, as concerns the start of the fire, that everything points to its starting in the Lecoeuvre tunnel, without this actually being possible to establish with absolute certainty, it remains then impossible to establish whether this ignition must be attributed to an unforeseen eruption of firedamp or to the explosion of a shot or again to that of a packet of explosives and one can in this respect only establish hypotheses.

That in these circumstances neither the use of open-flame lamps in the Lecoeuvre tunnel instead of safety lamps, the use of which was obligatory on this site in the terms of Article 74 of the regulation of February 8, 1905, nor the use of explosives of the type Favier No. 1 instead of safety explosives which, it seems, was obligatory because of the prefectorial order of March 28, 1898 could not be established as having had a definite cause and effect relationship with the accident and as being susceptible to attribute on account of this a responsibility to the operating company.

Considering that it emerges, on the other hand, from all statements on observations made, that the cause of the accident cannot be found with the fire in the Cecile seam:

That this fire, the importance of which has been considerably exaggerated and against the dangers of which all necessary measures had already been taken, did not in itself constitute a serious cause of danger of the sort that would forbid access to the mine for the workers.

That there is therefore no responsibility established on this ground;

Considering that one can nevertheless establish as having contributed to a considerable degree to the seriousness of the disaster certain general arrangements consisting mainly in the freely established communications between the tunnels Numbers 2, 3, and 4-11 and in the imperfection of the ventilation which resulted at the same time from a rather irregular mode of distribution and the absence of embanking in the large strata;

That the spreading of the explosion over such a vast expanse was in effect the consequence of the fact that the working areas of the three tunnels in question intercommunicated to a large extent;

But that these arrangements really were proved to be so defective only by the fact of the disaster itself;

That as the mine at Courrieres was not plagued by fire-damp its division into independent areas of limited size did not seem called for, no more than the ventilation, the communication between the tunnels appeared on the contrary justified by safety considerations, particularly in order to ensure escape for the staff in case of an accident in one of them, especially in case of an incursion of water;

That as regards danger from dust neither experience nor lessons derived from practice permitted the suspicion, in a mine with no fire-damp, of the possibility of a fire of such magnitude, explosions of dust alone, in the absence of fire-damp, previously recorded in France having never spread over more than 50-80 metres from their point of origin, exceptionally to 180 metres at the mine of Decize (accident on February 18, 1890).

That therefore these arrangements, no matter how open to criticism they may appear today on account of the consequences they had, could not before the accident be criticised;

It is (our) opinion that the local service engineers were correct in concluding that the incident cannot have legal consequences (13, pp. 484-486).

About the rescue operation

The rescue operations were conducted in 3 phases:
March 10-11:

Attempts were made by all possible means to go to the rescue of the victims and to assess the size of the disaster.
March 11-30:

The government engineers who took charge of organising the rescue and the enquiry held the conviction (supported by various witnesses from among the miners and from their own inspections in the mine) that there were no survivors in the mine and that there was too much danger to the rescuers.*

*In its support for this evaluation which it considers well founded the General Mining Council in its Notice of 1907 brings up the following two facts.

On December 12, 1866 an outbreak of fire claimed 334 victims at Oaks Colliery in Yorkshire, England. The following day, December 13, the rescuers were taken by surprise by a further explosion. Twenty eight of them perished and the mine had to be closed without recovering the bodies or any survivors who might have been left.

On June 14, 1894 at Karwin (Austria) a first explosion had claimed one hundred and sixty five victims. The following day, June 15, a second explosion killed seventy rescuers and again the mine had to be closed.

The reversal of the ventilation was ordered, the mouth of pit No. 3 closed and the battle against the fire launched.

After March 30:

Things took a dramatic turn on March 30: thirteen workers emerged from the mine alive. From the time when, contrary to expectations, there appeared some chance of rescuing survivors one could for a moment forget the caution that the fire had demanded in the second phase of the rescue. Without worrying about the danger to which one might be exposed explorations in all parts of the mine, to which one could at all penetrate, were quickly organised.

On the rescue opinions differed even more strongly than on the previous point.

a) The viewpoint of the delegates for the safety of the mine workers. We take up the observations of the two delegates, members of the commission set up by the Ministry of Public Works, who submitted a minority report:

First Mistake: The refusal to free the access to pit No. 3.

We have noted with regret that Mr Bar, the Chief Engineer of the Courrieres company has rejected the suggestion by Mr Reumaux, Engineer and General Agent of the mines at Lens who soon after the disaster and as soon as he arrived on the accident site, demanded that the tangle of beams and planks be broken up, which had formed a blockage at a depth of 170 metres after the explosion and completely obstructed pit No. 3. The mistake is in our opinion even more serious since Mr Bar only objected that he feared that the lining of the mineshaft would be damaged which lining at that depth no longer exists. The chief mining engineer Mr Petitjean, the miners' delegate Simon, the mine worker Vincent, Mr Thiery, the Director of the mining company at Douchy, have for their part deplored that the opening of pit No. 3 was not proceeded with, be it with dynamite, or by employing some heavy weight; this approach had to be the most favourable for the rescue explorations undertaken in search of survivors. The events that followed actually confirmed these opinions.

> ... We are led to conclude that on account of the refusal by Mr Bar to permit the crushing of the obstacle floor which obstructed pit No. 3 the Courrieres company has incurred the most serious responsibility and committed inexcusable mistake (14, pp p. 164).

Second Mistake: The reversal of the ventilation on March 12.

In these circumstances departing from the mistaken idea that there could be no more survivors, and while memorable precedents made it obligatory to keep up hopes regardless, it was decided to reverse the ventilation; by definitely condemning pit No. 3 as an approach for penetration and rescue, it was changed from air supply pit to air exit pit and abandoned pits No. 3 and 4-11 in the same act, even though on the day of the disaster at 6 o'clock in the evening workers had come out alive through these tunnels (15, pp. 465-466).

Third Mistake: No consultation with the safety delegates.

We must put on record above all that at the council of engineers held at Courrieres-Operations on March 11, the day after the disaster, a council in which twenty five engineers took part, no reference was made to the lamps, the experience and practical knowledge of any of the miners' delegates.

> ... On March 16 a further council of engineers from the mining corps and engineers from companies in the vicinity met. Despite orders from the minister the miners were not consulted etc.* (14, p. 469).

On March 15 a telegram from the Minister of Public Works asked the Inspector General, Mr Delafond, to "pursue the enquiry, associating to this enquiry the direct cooperation of the miners' delegates from the districts concerned". At no time did the minister give Mr Delafond the order to consult the miners' delegates on the organisation of the rescue operations (14, p. 469).

Fourth Mistake: The setting up of an isolation barrier which walled in for good all those who might have survived after the explosion.

Fifth Accusation: The most serious and the one that "the majority of the commission thought almost useless to record" (14, p. 472), the lack of consultation as expressing a rather more commercial than humanitarian preoccupation:

> This fact (the lack of communication) gives us all the impression that the issue in this consultation was only to save the mine and that there was no longer any preoccupation among the engineers with the rescue of the surviving miners (14, p. 472).

b) The viewpoint of the majority of the commission. Having presented and rejected the remarks by the minority the other members of the commission concluded:

1. The operations have been performed, from the start, by the government engineers in accordance with the legal arrangements governing the mines in such cases. The responsibility of representatives of the company in this respect cannot be called into question.

   The safety delegates of the mine workers had not been legally heard; they could present all their observations by entering them in their registers; they have made no use of this facility.

2. There is no indication that would permit the assumption that miners who had survived the asphyxiation of the first few days perished later on in the mine for lack of effort which could have been made. The autopsy has in fact shown that the miners which have been claimed to have died long after the disaster were burned and asphyxiated at the beginning.

   Attempts at self-preservation, of which traces have been found in the course of the excavation work, were made by surviving or dead miners as early as the first day.

   The eight miners who originally were together with the thirteen who escaped on March 30 died from asphyxiation, five of them on the first day, three on the second or third day while trying to get to the mine shaft.

   The survivors did not find anyone alive in the mine.

*There is a certain inexactitude which the majority challenges (but the correction perhaps further strengthens the interest in the question raised).

3. The rescue work was particularly difficult on account of the exceptional size of the workings and the tangle of the tunnels struck by the accident.

   The programme and the means adopted for the execution of this work conformed to the standards of the profession and were dictated by the very circumstances of the accident.

   The removal of obstacles from pit No. 3 by violent means could not be undertaken because of the dangers involved and because of the particularly serious consequences which could result for subsequent rescue work.

   Pit No. 3 being inaccessible to traffic the reversal of the air stream was justified by the apprehension that one had reason to have, especially after what the delegates had said, concerning the intensity and the dangers of a spread of the fire in Cecile; it permitted to have, in case this happened, the most practical ventilation; it contributed to the removal of the noxious gases which during the first few days had prevented a breakthrough to the thirteen survivors.

   The setting up of barriers in the access ways at Josephine and Julie had been made necessary by the new fire that broke out in Josephine after the accident; this fire created a particularly dangerous situation for the workers employed in the rescue operation and demanded an especially cautious approach in order to avoid a further disaster which one could not sufficiently control.

   These barriers, while their presence was considered necessary, did not actually harm any of the survivors.

4. Summing up; the commission feels that no reproach can be made to anybody for the organisation and implementation of the rescue operation after the disaster.

The above report having been read to the fully assembled commission on Tuesday, May 8, at Douai, Messrs Cordier and Evrard*confirm that their personal conclusions have been faithfully represented; they declare to be unable to change them.

The President of the Commission

signed: Carnot

(14, pp. 481-483)

As concerns the most serious accusation raised by the minority against the company and those in charge the majority without considering such accusations worth mentioning ... uses, nevertheless, the opportunity to confirm again, as the Minister of Public Works has already done in Parliament on April 3, that Mr Delafond has always concerned himself exclusively with the mission incumbent upon him concerning the victims without thinking even for a moment of saving a few tonnes or a few thousand tonnes of coal.

c) The opinion of the General Mining Council. Concerning the rescue operations and the respective statements after the completion of the enquiry by the special commission under the presidency of the Inspector General, Mr Carnot:

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*The two minority members.

Considering that the final statements with regard to the fire that occurred in the Cecile seam have established that this fire consisted only in the burning of limited timberwork (some 2,000 kg of wood), infinitely less important and less worrying subsequently than the witnesses given at the start of the rescue operations led one to believe, particularly those of the miners' delegate from pit No. 3;

That these witnesses have weighed heavily on all decisions taken, making one believe that there was an imminent danger which was far from being as serious as it was said to be;

Considering the excavation of pit No. 3, for which the engineers in charge of the rescue have been reproached for not having used violent means as required, has in the end taken less than thirty seven working days, and this by using stronger means than were originally available and in circumstances which were much more favourable.

That it follows from this that the continuation of the work in conditions which were dangerous for those who had to carry it out could not within reasonable time have brought any useful result;

Considering, on the other hand, that the reversal of the air stream which at a time was so strongly criticised and the start of the ventilator of pit No. 4 brought about, according to the statements made later, the gradual improvement of the air in the tunnels south of pit No. 3 thanks to which the four "survivors" were able to leave their point of refuge and proceed without being asphyxiated to the exit of pit No. 2;

The opinion is that it emerges from the statements made after the completion of the commission's work quoted above that abandoning the excavation work on pit No. 3 and reversing the air stream were justified by the event and that it is specifically this reversal of the air stream which made it possible for the survivors to escape death (13, pp. 490-491).

2nd. Railway disasters

Railways were developed since 1830. The first big disaster occurred between Versailles and Paris on May 8, 1842; more than 60 dead were counted. This means of transport was responsible for an increasing number of victims up to the middle of the twentieth century. The table on the following page gives a brief summary of all the events that occurred and their seriousness (2, pp. 736-743).

These facts expressed in figures, established on the basis of a series of disasters, have to be adjusted upwards if one takes into account all accidents that occurred. The *Revue Scientifique* published more complete statistics in 1882 as P. Legrand reports (4, pp. 165-166). We have selected some of these figures:

Germany 1879	541 derailments and collisions in motion
	2,727 accidents altogether
	411 killed, 1,322 injured
England 1881	42 killed, 1,161 injured
France 1866-1877	773 accidents
	218 killed, 2,158 injured.

Period	No. accidents	No. Victims	Average per accident	Maximum recorded	Distribution/ Category
1833-1849	11	90-136	8-12	54-100 (Versailles 1842)	10 -: 1
1850-1900	76	3,500	46	216 (Mexico 1881)	50 -: 14
				200 (Turkey 1882)	100 -: 5
				178 (Russia 1882)	200 -: 2
1900-1949	191	12,000	60	600 (Mexico 1915)	50 -: 28
				543 (France 1917)*	100 -: 11
				500 (Rumania 1927)	200 -: 7
				500 (Spain 1944)	300 -: 0
				426 (Italy 1944)	400 -: 1
					500 -: 3
					600 -: 1

*Troop transport.

Table 8: Railway Disasters

Breaking of axles (as on May 8, 1842) on the line Versailles-Paris, loaded with passengers (4, pp. 152-154), switching point errors as at Quintinshill (GB) in 1922 (chain collisions, 227 dead, 246 injured, mainly military personnel, 8, pp. 34-37), highly inflammable materials, inadequate arrangements (such as the shutting of doors in a way that they could not be opened as on the Versailles-Paris train in 1842) were among the factors that explain the size of the tribute paid by the railways. The *Revue Scientifique* offered the following analysis in 1882:

> To get an exact picture of how well or how badly a network is run as regards accidents one would have to know all the conditions under which it works and particularly all the problems that occur. It is for instance certain that a track that has only minor gradients and bends with a large radius presents less dangers to the passengers and to the operators than one that has not been constructed with the same advantages ... There will always remain, despite the greatest precautions, the cases of force majeure such as the breaking of axles, the cracking of rails or their displacement by evildoers, the fortuitous obstacles in the way of the trains caused by flooding, by accumulations of snow, level crossings for people and animals, derailments caused by obstacles put on the track deliberately etc. (5, pp. 165-166).

Lagny-Pomponne, 1933. On December 23, 1933, at about 20.05 h, 25 km from Paris, the express train from Paris to Strassburg ran into the Paris to Nancy train which had stopped and was just about to start moving again. Going at 105 km/h the express train pulverised four coaches of the other train which was packed like all other trains just before Christmas Eve. Excluding the disaster of Saint-Jean-de-Maurienne (a train packed with military personnel which derailed in 1971), this was the worst disaster in French railway history. There were two hundred and thirty dead, one hundred and forty injured, and a further collision with the train coming from Reims was avoided only thanks to the presence of mind of the conductor of the Nancy train who had run along the track and set up lamps and signals. The night, the fog, the distance from Paris made the rescue difficult.

At first, the mechanic and the driver of the express train were arrested but this double arrest did not have the expected effect: it caused intense emotions; the two railwaymen were set free two days later. The legal enquiry concluded that the "mistake" was due to the equipment and the weather conditions.

The railwaymen's federation proceeded with its own enquiry from which the following observations are taken:

The rolling stock was in such a defective state that it could only be called "an apalling mess" as attempts were made to arrange the large number of additional trains that were wanted for the Christmas season. In addition, shortage of staff caused considerable delays.

Trains departed at too short intervals and "without instructions for reduced speed having been issued to the mechanics".

The signal system had been known to be unsatisfactory since 1926/27 as can be seen from the studies published in the *Revue Generale des Chemins de Fer*. The visibility of the signals was insufficient and the fog on December 23 constituted an aggravating factor; even the functioning of the signals was faulty.

Following the disaster a new regulation was worked out which specifically excluded the use of coaches not made of metal for the transport of passengers (6, pp. 85-104).

Couronnes, 1903. Even below the earth's surface the railway can cause disaster, as witness the event on August 10, 1903 on the Paris Metro, Porte Dauphin — Nation line.

18.53 h

The train No. 43 runs along the platform of Barbes station towards Nation. Thick smoke emerges from it; a short circuit has caused a fire. The passengers are evacuated, and the back engine pushes the train out of the station. Passing Jaures, the conductor requests an extinguisher. At the next station (Combat, later Colonel Fabien) the fire increases in intensity. The train cannot continue.

19.23 h

The following train has to leave its passengers on the platform of Jaures station; it (then) catches up with the accident train. Flames lash out again; the convoy stops at 25 metres from Menilmontant station which has been evacuated.

Thick smoke spreads toward the station which the train has just passed. In there is a stationary train, overloaded because it has taken on the passengers evacuated from train No. 43 at Barbes station and those of the next train who had been evacuated at Jaures station. Many among the 250 passengers protest: they want to be reimbursed.

The air became too thick to breathe. People wanted to get out but this was no longer easy, given the darkness and the smoke. There was trampling, asphyxiation, error of direction; the temperature rose to 80°C at the top of the stairs. It was the next morning before the fire police managed to get down to the Couronnes and Menilmontant stations. Eighty four dead were counted. Some observations must be put on record:

Apart from the recriminations from passengers who were determined to claim their 'threepence' before making sure of their escape, the following must be considered: on the site of the accident there were in the end three trainloads of passengers; electrical installations were rudimentary; the coaches were made of wood; the Metro on this line was only three years old; finally: the power supply circuit for the trains was the same as the one for the stations; an accident on a train caused a power failure, the sequence of events from the accident to disaster was therefore quasi-automatic (15).

3rd. Explosion of gunpowder and ammunitions

The risk presented by gunpowder was felt in a precocious fashion: in 1645 a third of the city of Boston was destroyed by an explosion of this origin (2, p. 654). But the danger became much more acute from the eighteenth century onwards (2, pp. 654-662):

1769:	A quarter of the town San Nazzarro (Lombardy, Italy). destroyed by a gunpowder explosion: 3,000 dead.
1856:	Lightning strikes a warehouse on the island of Rhodes: 4,000 dead.
1905-1914:	3 big accidents in the USA, CHINA, USA — 19, 20, 30 dead.
1911:	2 accidents (USA, Belgium 31,110 dead)
1916:	7 accidents (of which one in Russia — 1,000 dead; one in Austria — 195 dead: one in France — at Double Coronne — 30 dead).
1917:	5 accidents (of which one in Archangel, Russia — 1,500 dead; one in Bohemia — 1,000 dead; one at Halifax, Nova Scotia, Canada on December 6 — 1,600 dead).
1918:	4 accidents (of which one at Hamont, Belgium — 1,750 dead (train carrying explosives) one in Austria — 382 dead; one in USA — 210 dead).
1919-1929:	10 accidents (of which in 1919 at Longwy, France — 64 dead (train); the Peking arsenal in 1925 — 300 dead).
1930-1940:	3 accidents (of which one at Lanchow, China — 2,000 dead in 1935; one in Madrid in 1938 — hundreds dead).
1940-1944:	8 accidents (of which one in Yugoslavia — 1,500 dead in 1941; one in Port Chicago in California — 321 dead in 1944; one in Bombay — 1,376 dead in 1944).

4th. Explosions of factories and installations

Industrial development led to the use of explosive products in connection with pressure apparatus. New types of accidents appeared.

1858:	Explosion in the London docks — 2,000 (?) dead.
1869:	Boiler explosion at Indianapolis — 27 dead amongst a crowd of 15,000 people gathered for a state fair.

1901: Explosion in a clothing factory at Manchester — 14 dead.

1907: Explosion in a steelworks at Pittsburg, USA — 59 dead, many vanished.

1912: Explosion of a locomotive's boiler at San Antonio, Texas — 800 kg fragment projected over a distance of 400 metres, another of 450 kg over 700 metres; 26 dead, 32 injured.

1915: Explosion of a car petrol storage tank in Oklahoma — 44 dead, 2 blocks of flats destroyed.

1915: Dust explosion in a Swiss factory — 30 dead.

1917: Explosion in a factory at Montreal — 25 dead.

1917: Explosion of 3 factories at St Petersburg, Russia — 100 dead.

1921: Explosion at Oppau in a factory of Badische Anilin (BASF), Germany — 565 dead, 4,000 injured, town destroyed.

1926: Explosion in an electrometallurgical factory at St Auban, France — 19 dead.

1927: Explosion of a cistern of hydrocarbon at Pittsburg, USA — 28 dead.

1928: Explosion in a factory in Massachusetts, USA — 23 dead.

1933: Explosion of a hydrocarbon storage at Neuenkirchen, Germany — 100 dead.

1933: Explosion in a rubber factory in Shanghai — 8 dead.

1939: Explosion of a cellulose factory (with release of chlorine) at Brachto in Transylvania — 62 dead.

1942: Explosion of a chemical factory in the province of Limbourg, Belgium — 200 dead, 1,000 injured.

Halifax, Nova Scotia, Canada, 1917. The French freighter *Mont Blanc* came from New York where it had loaded 5,000 tonnes of explosives and inflammable goods; at Halifax it was to join a British cruiser which should escort it on its way to Europe. At the time it arrived in Halifax on December 7, 1917 the *Mont Blanc* was struck by another ship. Scuttling was not possible: the fire had already started and soon the explosion was felt up to 100 km away. Half the town was in ruins (3,000 houses, 6 km^2 destroyed. Out of 550 children in the Halifax area there were seven survivors; at least 1,200 (4,000) victims were counted, more than 8,000 injured. The rescue equipment was destroyed. Snow fell soon and helped fighting the fires which had broken out but made rescue operations difficult and hit the 25,000 homeless hard. Martial law was declared (2, pp. 227-228; 8, pp. 38-40).

Bombay, India, 1944. This is a replica of the explosion at Halifax. On April 12, 1944 a freighter of 7,200 tonnes carrying nearly 1,400 tonnes of highly explosive equipment (torpedoes, mines, incendiary bombs) exploded in the port of Bombay. Nearly 1,400 dead and 3,000 injured were counted. The port was wiped out (2).

5th. Great dam breaks

Dams have existed since the times of antiquity. However, the industrial era has given them a new function in addition to that of irrigation: the generation of electricity. Technology was also further developed. There was a move from earth-filled to masonry-type dams (out of 500 dams on record in 1830 only sixteen were of this type). As prototypes they were in the beginning disappointing; in the USA where people worried less about failures because of the very distant locations of many of the dams, in that country where one had to reckon with insufficient knowledge of raw materials and with the audacity of the pioneer spirit, people went ahead without employing any engineers (out of fifty five great American dams before 1900 there were 19 dam failures).

At the opposite end of the scale, the Japanese dams, built by a society with a very ancient, rich civilisation and thousand-year-old practices, have defied the centuries.

Let us add here that the dams built by the English in India have encountered very many failures (the rate is even higher than in the United States). Actually, seven out of thirty eight dam failures which occurred before 1900 happened on constructions made by the French in Algeria, a country the hydrology of which was very little known at the time of construction (16, p. 10-11).

Since the nineteenth century the viability of constructions was substantially improved. The number of dam failures recorded during construction and for the first twenty years after being put into service has developed as follows: (17)

Dams built between:	1850 and 1899:	4.0%	(out of 600 constructions)
	1900 and 1909:	3.5%	(out of 400 constructions)
	1910 and 1919:	2.6%	(out of 600 constructions)
	1920 and 1929:	1.9%	(out of 1,000 constructions)
	1930 and 1949:	0.7%	(out of 1,900 constructions)

P. Goublet has prepared the following list of disastrous accidents (we restrict ourselves here to the prewar period):

1802: Puentes, Spain — 608 dead
1864: Dale Dyke, Great Britain — 250 dead
1968: Iruka, Japan — 1,200 dead
1889: South Fork River, USA — 2,000 — 4,000 dead
1895: Bougey, France — between 86 and more than 100 dead
1911: Austin, USA — between 80 and more than 700 dead
1923: Gleno, Italy — 100 — 600 dead
1928: San Francisco, USA — 400 — 2,000 dead.

6th Air Disasters

Ikaros' dream came true in the eighteenth century with the launching of balloons carrying men in their gondolas. The Montgolfier brothers designed the vehicle; some heroes had to be found but the king refused permission and allowed the first test only with prisoners under death sentence. However, Pilatre de Rozier succeeded in getting permission and went up into the air on November 21, 1783. From that day on the balloon starts multiplied. Accidents occurred. Pilatre was the first victim: pressed for time and money and the challenge he crashed with his collaborator on June 13, 1785 while trying to cross the Channel. Between 1802 and 1885 at least twenty five fatal accidents were recorded (disappearance, fire, asphyxiation, crash) (4, pp. 193-228).

The early twentieth century saw the launching of airships, vessels of quite a different dimension, designed for the transport of a large number of passengers over long distances. These machines were built by the German count Zeppelin who founded the Zeppelin company with Dr Eckener. Between 1910 and 1944 it arranged more than 2,000 flights and carried more than 10,000 passengers in its first four vessels. The British launched themselves on the same course with the idea of building up a transcontinental fleet for use in its relations with the Commonwealth. A series of grave accidents crushed the hopes placed in this technical venture (2, p. 661).

1913: Destruction by fire of the German airship LZ-18 — 28 dead.
1919: Explosion of Zeppelin L-59 — 23 dead.
1921: Break-up of the British airship R-38 — 44 dead.
1922: Crash of the Italian airship Roma — 34 dead.
1923: Disappearance of the airship Dixmude, operated by France — 52 dead
1929: Break-up of the American airship Shenandoah — 14 dead.
1930: Crash of the English airship R-101 — 48 dead.
1931: Crash of the American airship Aken (?Akron) — 73 dead.
1937: Explosion of the German Zeppelin Hindenburg — 36 dead.

The accident of the Dixmude marked the demise of the airship in France. The R-101 accident put an end to the English attempt. The fire of the Hindenburg under the eyes of the American press and at a time when the Reich rather needed combat aircraft dealt a fatal blow to the German programme. The disappearance of the largest, most elegant of those 'lighter than air' ships signalled the death of the airship (at least for a long time) as a means of transport.

As for the Hindenburg, the question may be raised whether recent changes and a maintenance fault, which had not escaped Dr Eckener, but were brushed aside by the military chiefs for propaganda reasons, did not play a part in its tragic end. With the R-101 there is no doubt: the causes of the accident were not to be found just on the technical side. The same applies to the case of the Dixmude.

The disappearance of the Dixmude, 1923. The most beautiful flower of French aeronautics came out of German workshops and was delivered under the terms of the Versailles treaty. After various disappointments (due to sabotage at the point of origin) the Dixmude could take to the air.

The use that was made of it was much too strenuous: some of the operating parts of the airship were modified; test flights were made without maintenance and without sufficient examination. The (intended) record run overruled these safety considerations. Even incidents that occurred during a flight in 1923 did not induce more caution. Political demands led to the Dixmude taking to the air again; its commander had argued in vain: as it is, the Dixmude is certainly fragile and incapable of intensive service. It was designed for war raids and not for cruising.

However, on December 18, 1923, the airship had to go on a flight over the Sahara. There were only thirty nine life-vests and forty parachutes on board for fifty one passengers. There was no landing base other than the one from which it took off. Never had an airship been so intensely employed before a cruise of such importance. No checks had been made. On December 21 it disappeared in the sea during its return journey.

The Commission of Enquiry had some difficulty in establishing its credibility when it concluded: "No responsibility can be established". Its explanation, that the accident was caused by lightning, was disputed by most of the experts.

Fifty one people, among them the elite of French aeronautics, disappeared in this accident which established a new record in the accounts of those in charge of the programme: the number of people killed in one and the same air accident (6, pp. 47-60).

The disaster of the R-101, 1930

To set up its intercontinental fleet the British built two airships, the R-100 and the R-101. The two competed with each other the second one being (financially) backed by the government; the air ministry was squeezed, the more so as the trials of the R-100 had yielded good results: the competitor had made a return trip to Canada.

After a trial on June 28, 1930 during which the R-101 dropped dangerously it was decided to extend its length in order to make it less 'heavy'; one was in a hurry; the secretary of state wanted a voyage to India within three months. The departure actually took place on October 4. To the haste were added certain arrangements intended to have a publicity effect: one wanted to make a luxury hotel of it, and in order to compensate for the surplus weight of the silver-plate the crew had to do without parachutes. On October 5 the R-101 crashed near Beauvais in France.

The Commission of Enquiry was explicit:

The R-101 left for India while one could see that it had not (yet) completed the trial periods of the experimental stage (...). The conclusion cannot be avoided that the R-101 would not have left for India in the evening of October 4 had there not been reasons of a public nature according to which it was highly desirable that this was done if at all possible.

This can be added to the comment made by the only surviving officer: the R-101 has proved one thing, namely that politics and experimental work do not mix.

The shock caused by the disaster was so great that all further development of airships in the UK was stopped. The R-100 was grounded for a year before being scrapped and sold by weight for £400. Worse still: so many men of talent perished in the R-101, the elite of English aviation engineers took part in the historic voyage, that the development of civil aviation in England was set back by several years. (8, pp. 48-54).

7th. Collapse of large structures

a) Bridges. In the lists of accidents drawn up by R. Nash (2, pp. 721-723) one finds twelve cases of bridge collapses of which four in the United States cost many lives. In Europe, the major disaster occurred at Yarmouth in England: a bridge crumbled under the weight of spectators of an aquatic event; there were 250 dead. In France the latest accident of the period occurred at Libourne: fifteen victims were mourned. There was also the collapse of a bridge in Scotland in 1879 as a train passed over it which gave additional force to the wind which blew at gale force; there were no survivors, one hundred people were cast into the water.

b) Collapse of buildings. There are fifteen accident cases recorded in Nash's list (2, pp. 712-723). In France there were: the collapse of the Palais de Justice at Thiers in 1885 (30 dead), of a building in Vincennes in 1929 (nineteen dead) and of the Palais de Justice in Bastia in 1932 (fifteen dead).

8th. Intoxication and Poisoning

Accidents of this kind were reported (2, pp. 721-723):

1923: Poisoned rice in China - 22 dead.

1930: Poisoned soup in Bombay - 30 dead.

1936: Chemical poisoning of rice in Japan, 15 dead.

1938: Poisoned rice in Japan - 15 dead.

REFERENCES

(1) J. J. SALOMON, De Lisbonne (1755) à Harrisburg (1979). Le risque technologique majeur: un formidable défi. *Futuribles 2000*, no 28, novembre 1979, pp. 5-10.

(2) J. R. NASH, *Darkest hours — A narrative encyclopedia of worldwide disasters from ancient times to the present*. Nelson Hall, Chicago 1976 (812 pages).

(3) J. FOURASTIE, *Machinisme et bien-être. Niveau de vie et genre de vie en France de 1700 à nos jours*. Les Editions de Minuit, Paris, 1962 (251 pages).

(4) P. LEGRAND, Fléaux et catastrophes jusqu'au XIXe siècle. *Les grandes catastrophes*. Tome 1, Editions Famot, Genève, 1977 (246 pages).

(5) Ch. A. TIXIE, Grandes catastrophes de la fin du XIXe siècle et au début du XXe. *Les grandes catastrophes*. Tome 3, Editions Famot, Genève, 1977 (247 pages).

(6) Ch. A. TIXIE, Grandes catastrophes de 1781 à nos jours, *Les grandes catastrophes*. Tome 4, Editions Famot, Genève, 1977 (253 pages).

(7) P. KINNERSLY, *The hazards of work: how to fight them*. Pluto Press, London, 1973.

(8) F. KENNETH, *Les grandes catastrophes du XXe siècle*. Editions Princesse, Paris, 1976 (152 pages).

(9) Chambre des députés, quatrième législature, Session ordinaire de 1887, comptes rendus in extenso, 52 séances, *Séance du jeudi* 12 mai 1887, pp. 987-988).

(10) M. WINNOCK, L'incendie du Bazar de la Charité. *L'Histoire*, no 2, mai-juin 1978, pp. 32-41.

(11) A. AMZIEV, La nuit infernale du Titanic. *Les grandes catastrophes maritimes*. Les dossiers "histoire de la mer". Ed. Arnaud de Vesgre, Neuilly, 1979.

(12) D. COOPER-RICHET, Drame à la mine. *Le Monde*, dimanche 25 novembre 1979.

(13) Avis du Conseil Général des Mines sur l'accident des mines de Courrières du 10 mars 1906. *Annales des Mines*, Tome XII, 1907, pp. 484-492, En annexe au texte de Ch. E. Heurteau: La catastrophe de Courrières.

(14) Rapport de la commission chargée par M. le Ministre des Travaux Publics, des Postes et des Télégraphes, de procéder à une enquête sur les conditions dans lesquelles ont été effectués par les ingénieurs de l'Etat

les travaux de sauvetage à la suite de la catastrophe survenue aux mines de Courrières le 10 mars 1906. *Annales de Mines*, Tome XII, 1907, pp. 445-483. En annexe au texte de Ch. E. Heurteau: La catastrophe de Courrières.

(15) J. PERRIN, La R.A.T.P. multiple les précautions pour prévenir les risques de courts circuits et d'incendies dans le métro. La nuit, si tragique de Couronnes. *Le Monde*, 8 août 1978.

(16) A. GOUBET, Risques associés aux barrages. Note du Comité technique permanent des barrages, juin 1979, (26 pages).

(17) Note interne. Service Technique de l'Energie Electrique et des Grands Barrages Direction du Gaz, de l'Electricité et du Charbon. Ministère de l'Industrie, du Commerce et de l'Artisanat (11 pages).

II. DISASTERS IN LARGE-SCALE INDUSTRY. THE POST-WAR PERIOD

Still concerned with making available a better appreciation of actual risks we shall now examine how dangers linked with the general development of technology and industry in the post-war era were capable of causing disasters. These have been numerous and grave. New risks have appeared, increasing a feeling of insecurity while everyday life appeared to be safer.

Here again synthesizing studies fail. However, we shall find good reference material amongst them, mainly that supplied by J. R. Nash, already quoted (1), and by R. Audurand (2). The list of events established by R. Audurand will be put forward in an annex. Within our text we shall abide, as before, by categorisation, illustration and order of magnitude without missing out, where appropriate, on questions of responsibility.

1. THE SAFETY CONTEXT IN INDUSTRIALISED COUNTRIES SINCE THE WAR.

1st. Great risks of natural origin

Famine has disappeared in industrialised countries; the same is true of epidemics which puts the developed regions of the world in quite a different situation from that of the remaining three quarters of the planet (for instance: at least 800,000 died in Nigeria in 1968 from famine; 200,000 in all of Africa and India in 1973/74*.

Great dangers such as earthquakes, typhoons and seismic tidal waves can no longer cause a feeling of insecurity to the people in industrialised countries, apart from Japan and, to a certain extent, the United States on account of tornadoes (for instance cyclone Camille in 1969: two hundred and fifty eight dead). One figure clearly shows the disparity between the rich and the poor of this earth: about 95 per cent of the deaths caused by such disasters occur in the Third World**(3, p. 3). The progress made in the field of communication and information sometimes enhances the awareness of these disasters of the poor.

Some disasters that occurred from time to time in Europe must, nevertheless, be mentioned. Heavy storms have been experienced in northern Europe, for instance in 1949 (thirty nine dead), 1951 (twenty two dead), 1951 (sixty three dead), 1954 (fifty eight dead) etc. Recently, on August 14, 1979, a storm caused fifteen deaths in the Irish Sea among the contestants in the Fastnet race. Hurricane Capella, in 1976, caused damage estimated at more than three billion Deutschmark (4, p. 38).

These storms can cause floods. Those in Holland in 1953 (1,853 dead), the worst floods since 1521, and in North Germany in 1962 (three hundred and forty three dead) were the most serious ones. (1, pp. 670-672). Sometimes one must also face cold waves (1954: one hundred dead; 1956: nine hundred and seven dead) or heat waves (1957: three hundred and forty dead).

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*These figures actually give a wrong picture of the general state of malnutrition in poor countries.

**It must, however, be mentioned that three quarters of the losses of wealth caused by these disasters have occurred in the rich countries which reflects the economic disparity between the 'Ones' and the 'Others'.

The earthquake risk also remains with us: the one in Friaul in Italy (May 6, 1976, more than a thousand deaths) is one example.*

2nd. Risks connected with the occupancy of land

Inasmuch as space is invested, built up, occupied — or, sometimes, by contrast deserted — new problems are met with that can give rise to disasters. Some events have heightened attention in this field even if it is not proven that there has really been, in these cases, risk creation or thoughtless exposure to dangers from nature. The outstanding events in France were mainly: the avalanche at Val d'Isere (February 10, 1970: thirty nine dead), the landslide on the Plateau d'Assy (Haute Savoie, April 16, 1970: seventy one dead of which fifty six were children), the floods in south-western France (July 1977, subsequent to the fall of 154 mm of rain in the night from July 7 to 8) or the one of Morlaix in 1974 (7, 8). The possibility of major rises of the Loire's water level where the flood-threatened area is heavily inhabited is also a worrying factor.

In case of exceptional rises there could be up to 2-3 billion FF of damage and 300,000 people affected (9, 10). For this reason an important protection programme has been set up (which will also be useful for the maintenance of minimum water levels required by the nuclear-electric centres).

Madam,

This morning's paper publishes an advertisement informing hunters that hunting is forbidden on your land.

I have noticed that this news has been unfavourably received by the population in general and by the hunters in particular. I believe you have taken a decision which runs counter to your interests and that on further thought you will change it.

Please keep in mind that fire kills more birds in a day than hunters kill in a year.

I should like to add that if your woodland is intact this is not due to chance but to the spirit of solidarity of the inhabitants of X ... who always immediately went to the scene and fought the fire.

I am afraid that if you uphold the ban this will no longer be the same in the future.

As you will remember, it is now some years since a fire was started accidentally on the edge of the road which runs along the border of your property; you arrived there when we were already on the spot.

If Miss Y ... never banned hunting it was for the reason just mentioned.

I am convinced that you will consider my request and remain, dear madam,

Yours faithfully,

Signed: The Mayor

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*In the Third World earthquakes are more disastrous (Guatemala 1976: 22,000 dead).

A recent letter from a mayor in the south of France to an owner of woodland (Source: Quoted in a study by the Institute for Woodland Development: "For a contractual policy of opening green land to the public", report for the Ministry of the Environment, December 1974, vol. 1, p. 175).

In the same order of things is the progressive disappearance of mediterranean woodland because of large fires. These fires signal among other things dangerous use of land (spread of secondary homes, departure of the inhabitants, diverse refuse dumps, lack of maintenance of the environment etc.). Disaster here is in large measure the result of a dilapidated situation which makes the environment very vulnerable (11), also the result of societal problems (see p.).

3rd. Safety in everyday life

Among the risk factors typical of today's industrial society the following are the main:

a) Risk from cars. In addition to some outstanding occurrences such as the disaster of Le Mans in 1955 (eighty three dead) or bus accidents, there is the daily tribute being paid to this technological innovation: 15,000 killed in Germany, 13,000 in France in 1977. Every year, world-wide, there are about 250,000 deaths and 7.5 million injured on the roads (5, p. 4).

b) Risk at work. Even if working conditions nowadays are less dangerous than in the past, even if the number of victims is on the decline, work accidents in France account for nearly 2,000 deaths a year. In 1978 there were 1,606 deaths on the records of the social security system (6, p. 32) to which must be added the 238 deaths of people not covered by the system. For the three years 1976/77/78 the total number of deaths stands at 5,228 (this is the figure for wage earners covered by the general system).

For work-related diseases which are recognised as such and for wage earners covered by the general social security system the total number of deaths is two hundred and nine (6).

c) Pollution risk. Two big events may serve as examples:

London 1952: The fog in December of that year impeded the exchange of air in the capital; this caused general poisoning of the atmosphere. 4,000 immediate deaths*were counted, and the figure of 8,000 was mentioned for not immediate deaths (1, p. 344).

Minimata 1956-1973: The Chisso company set up at Minimata in 1907; it undertook the manufacture of acetaldehydes in 1932. Soon worrying phenomena appeared; the first human victim was examined in 1956. In 1959 the Chisso company was no longer unaware of its responsibility for the situation. In 1962, one hundred and twenty one cases of disease were acknowledged, 44 people died after prolonged agony. The fishermen had only the choice between polluted fish and famine. Subsequent to measures taken elsewhere (Canada, Japan) the victims rejected compensation as a solution. The court case opened in 1972. In 1973 sentence was pronounced on Chisso. The 'strange disease' of Minamata had caused two hundred and forty three deaths; 1,300 people have officially been pronounced affected; but the real figure was estimated at 10,000 (12, 13).

*4,700 according to Ian Burton (3, p. 73).

In order to draw up a telling balance sheet today one would need to have in-depth epidemiological studies made. Too often these go wrong (even in those cases where specialists and people in authority suspect the existence of increased risk) so that one does not get very far with the examination.

d) Life style. Pollution, stress and types of food can be the origin of certain diseases (cardio-vascular ailments, cancer ...) that can be attributed to the general living situation of the individual (rather than a specific cause).

4th. The very great risks surrounding the safety problem

The post-war period has seen growing awareness of the precarious conditions of man's life and survival. The military question is the most acute; since the creation of thermonuclear weapons and their manufacture in large numbers in some countries, the safety of the world has rested on the equilibrium of terror.

Other than that, worries have been created on account of the large problems of ecological equilibrium: change of climate, carbon dioxide concentrations in the atmosphere etc.

Such is, in brief outlines, the picture in which the specific fact of technological disaster in the post-war era features.

2. DISASTERS KNOWN FROM THE PAST

1st. Fire

(Whole) towns no longer burn down. However, buildings still fall prey to the flames from time to time (1, pp. 660-663):

1946: Hotel La Salle, Chicago — 61 dead
1946: Hotel Winecoff, Atlanta, USA — 119 dead
1947: Danang, West Berlin — 86 dead
1947: Theatre Select, Rueil, France — 87 dead
1949: Hospital, Effingham/Illinios, USA — 77 dead
1967: L'Innovation Department Store, Brussels — 322 dead.

2nd. Navigation

Since 1950 the contribution made by navigation is much less heavy on passengers. Still, according to Nash's list (1, pp. 701-709) four accidents in the bracket of two hundred and fifty to five hundred victims were counted plus a more serious one (1954: seven hundred and ninety four dead on a ferry in Japan).

3rd. Mining

Between 1950 and 1975, ninety three mining disasters were counted world-wide (1, pp. 710-720), causing a total of 6,700 to 7,000 victims with peaks like the accident at Umata in Japan in 1963 (four hundred and fifty two dead) or the one at Wankie in Rhodesia on June 6, 1972 (four hundred and twenty seven dead). In addition to these major incidents there were two accidents claiming between three hundred and four hundred victims, three in the next lower numbers bracket, seven accidents killing between one hundred and two hundred people, twenty causing the death of between fifty and one hundred workers. A clear reduction in the frequency of accidents in Eueope is noticeable. In France, the disaster at Lievin on December 27, 1974 caused forty two deaths. The major mining incident in Europe occurred on the surface at Aberfan in Wales.

Aberfan 1966:

On October 21, 1966 at 09.15 h, 140, 000 tonnes of material from slag heap Number 7 towering above Aberfan, soaked with water, slid down the slope and destroyed a school as well as eighteen houses. The collapse caused the death of one hundred and forty four people of which one hundred and sixteen children (15, 16, pp. 87-93). (We shall come back later to this case which is a completely clear one where helplessness of disaster prevention is concerned.)

4th. Railways

From 1950 to 1975 about one hundred and seventy serious accidents were counted world-wide which claimed more than 9,000 victims (1, pp. 740-743). In the bracket of 100 to 150 victims there were twelve accidents, six in the one hundred and fifty to two hundred bracket, three claimed more than two hundred victims each. (Mexico 1972: two hundred and four deaths; Mexico 1955: three hundred deaths; Pakistan 1957: three hundred deaths).

Western Europe appears to be less and less afflicted, the Third World countries more and more (eleven accidents out of the twenty one that claimed more than one hundred deaths during the period occurred in non-developed countries).

The latest big disaster in France dates from 1972: it was the one at Vierzy (June 16, 1972) which was caused by the collapse of a tunnel just before the arrival of two passenger trains. One hundred and seven victims were counted. England had her most recent large accident (with more than one hundred deaths) in 1952. These are the major incidents in Europe between 1950 and 1975.

5th. Explosions

Accidents caused by ammunitions and fireworks were less serious than in earlier times and less frequent even though they have not been completely eliminated. In France for instance accidents occurred at Pont de Buis (Finistere) and again at Saint Marcel d'Ardeche.

Saint Marcel d'Ardeche 1962. The explosion of the gunpowder factory of Banc Rouge at Saint Marcel d'Ardeche on April 9, 1962 claimed eighteen dead and and fifty one injured. At the summary court at Privas the experts held against the two people in charge:

- Faulty operating methods which did not conform to the rules of the profession;

- Installation of workshops without authorisation and without approved instructions by the directorate and the inspectorate of works and the board of the national gunpowder factory at Sorgues;

- Fault in the constant supervision of the mixer;

- Lack of qualification among the staff (the superintendent of the mixing operation was a delivery van driver);

- Too large a concentration of staff in the vicinity of the most dangerous workshop of the factory.

On these charges, one of the defence lawyers commented:

> Controls were carried out; the Director has never been advised or ordered to take specific safety measures which he is now accused of not having applied (17).

During the period from 1950 to 1975 twelve major accidents were counted world-wide (according to Nash, 1, pp. 661-662) of which one in Colombia claimed 1,200 dead in 1956 (explosion of an ammunition convoy), one in Havana in 1960 (One hundred dead). There was also an explosion and a fire in a Titan 2 missile silo in the USA in 1965 (fifty three dead).

Another type of explosion occurred twice during the post-war period; these were major accidents caused by transport of ammonia nitrate, a very explosive material. Twenty dead, five hundred injured and heavy material damage were reported at Brest when the Norwegian ship *Ocean Liberty* exploded on July 28, 1947. Three months earlier the town of Texas City had been partly destroyed by an explosion.

Texas City 1947

On April 16, 1947 at 09.12 h the French liberty ship *Grandcamp* exploded in the port of Texas City with its 2,300 tonnes of fertilizer which consisted of ammonia nitrate. A fire had broken out and the captain had given the order not to use water: Stop! Don't pour water on the cargo or you will lose it. Steam was used instead from which a gigantic explosion resulted.

There were five hundred and fifty two dead, two hundred disappeared, 3,000 injured. All windows in Texas City were broken and half of those in Galveston, 16 km away. A one tonne object was hurled over a distance of 400 metres, the ship was reduced to fragments which were blown nearly 5 km high and over an area of 9 km. Two aircraft flying overhead were destroyed. The big petrochemical factory of Monsanto was severely damaged when the hydrocarbon tanks caught fire. More than 3,000 dwellings were destroyed. Water and electricity were cut. Fires developed: by noon hundreds of them raged.

The following day disaster came about from a second ship, also loaded with explosive products. The explosion on the *Grandcamp* had caused a fire on it. The tugs called in to remove this second 'bomb' were not strong enough: the ship had been imbedded into another vessel. The second explosion revived fires and caused hundreds of deaths. Shortly afterwards the chief of police told the press: All of Texas City will be destroyed if the wind veers south. Luckily, this did not happen. But the situation was sufficiently dramatic to cause panic. A rumour circulated: the chlorine tanks leaked. Some demanded masks and started running through the streets carrying protective items that were useless — and this did not help to calm the spirits (1, pp. 545-550).

On a quite different scale, which, however, one must not forget, there are the accidents caused by the escape of gas in households such as in Argenteuil in 1970 and at La Courneuve in 1978.

6th. Dam bursts

The reliability of dams has improved since 1950. According to the census taken by A. Goubet (18, pp. 21-22) the following cases were recorded after 1950:

1959: Vega de Terra, Spain 144 to nearly 400 dead (?)
1959: Malpasset, France — 421 dead
1960: Aros, Brasil — 1,000 dead
1961: Babi Yar, USSR — 145 dead
1961: Hyokiri, Korea — 250 dead
1963: Quebrada La Chapa, Colombia — 250 dead
1967: Semper, Indonesia — 200 dead
1967: Nanksagar, India — 100 dead
1976: Del Monte, Colombia — 80 dead
1976: Santo Thomas, Philippines — 80 dead.

It seems that dam breaks affect the industrialised countries less and less*.

The Third World countries are not in the same situation. We shall come back to this later.

3. BIG ACCIDENTS CONNECTED WITH NEWLY ADOPTED TECHNOLOGIES

1st. Fires in buildings incorporating highly inflammable materials

In addition to the case of the very rapidly spreading fire at CES Pailleron which on February 6, 1973 caused twenty deaths there are the cases of the dance hall at Saint Laurent du Pont, the "Cinq-Sept" and of the entertainment complex "Summerland" in the Isle of Man (GB).

The Cinq-Sept 1970. On Saturday, November 1, 1970 this dance hall in the Isere was crammed. The decorations were made of highly inflammable materials. The main entrance featured a turnstile; the other exits had been bolted to prevent frauds. A match that was dropped on a cushion caused the fire, a mass of whirling fumes and flames. The plastic material collapsed. The turnstile was quickly blocked. Within a minute the blazing mass left no more chance to its prisoners; 146 young people met their deaths in it. (16, p. 118).

Safety measures in the club were practically non-existant: insufficient emergency exits (even if they had not been bolted); lack of luminous signs for these exits, lack of fire fighting equipment, no telephone. For the court the Cinq-Sept was the materialisation of everything that is forbidden by the regulations (16, pp. 113-118).

Summerland, the entertainment complex in the Isle of Man, 1973. The Summerland project was an original idea: to create a tourist attraction with great capacity on the Isle of Man that would offer the visitors the charms of mediterranean climate. For this purpose a large complex under a plastic bell was built in which a riviera-like temperature was maintained. Opened in 1971, the centre had seen great success in 1972. The following year it was to be the the theatre of a gigantic fire (15, 19).

The architects were chosen in 1965. A bureau from the Isle of Man (a small company of two architects which had never worked with more than six technicians) joined forces with a larger group that specialised in leisure industry constructions. In this way the great Summerland complex was designed, consisting of seven levels, the access being on the fourth, the outstanding features being the west and south faces and a roof made of Oroglas (acrylic building material).

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*The threat has not been reduced to zero, however, as we shall see later.

The necessary building permits were obtained in 1967, 1968 and 1971 respectively. Work was carried out rapidly because one wanted to open for the 1971 season. In a pamphlet the centre was presented as perfectly safe; the question of fire prevention had been given special attention during the construction; the structures were non-inflammable; any fire would be confined to the hall in which it broke out. The public welcomed this complex. By contrast, it received a mitigated welcome in the world of construction: true this was a first attempt at constituting an artificial microclimate but there had been a systematic reduction of standards in the whole undertaking. However, success was assured in 1972 and the centre contributed 13 per cent to the tourist income of the island.

On August 2, 1973 Summerland was to be the theatre of a gigantic fire. A kiosk which had been used as an entrance gate and had been damaged by a thunderstorm two months earlier had been dismantled and partly removed. There remained some elements including electric wires and various bits of waste that were left at the end of an outside terrace against the wall of Summerland, a galbestos wall. Three young boys set fire to this rubble at 19.40 h. Within a few minutes the kiosk was on fire. The flames ran along the partitioning wall, inflammable material caught fire. The fire invaded the fourth level; fumes spread about; the flames quickly attacked levels 5, 6 and 7. When the wall and the Oroglas ceiling caught fire an enormous conflagration developed through the whole elevation of the building, the fire spreading from east to west, destroying everything inflammable on the fourth level.

Attempts at extinguishing the fire were fruitless. When the fire service — who were called late — arrived they had to declare their impotence: they could perhaps save the adjacent buildings but for Summerland it was too late. Attempts were made to avoid panic but this was impossible. The flames, the gas, the darkness — the automatic emergency generator did not start — the scuffles in the (poorly designed) passages, the emergency doors blocked from the outside or marked 'Private' or not leading to any safe place, parents swimming against the stream in search of their children: there was no longer much chance for action. Fifty three dead were counted.

Authorisation for departure from standards given without sufficient strictness. The construction, of course, required permits. In particular observation of rule No. 39 of the Isle of Man law was mandatory which prescribes that all buildings must have non-inflammable outside walls which resist fire for two hours. Rule No. 50 requires that the roof must offer appropriate protection against fire from a neighbouring building. According to rule No. 47 fire prevention devices must be set up for all inflammable walls.

A first request for a permit was filed in October 1967. The authorities commented that the Oroglas did not meet the requirements of rule No. 39. The local architects pleaded that even if it was not fire-resistant — which is what the Chief Fire Officer had stressed — it was not inflammable. The Chief Fire Officer concluded his examination of the application by stressing: since the complex does not present exposure to a risk coming from another building and as it is unlikely that there would be trouble at the level of the emergency exits I raise no objection against the project. The official permit stated however, that there was deviation from rule No. 39.

The second permit was requested in July 1968: the local engineer in charge of the application remarked that one of the materials used (the Galbestos) instead of the concrete foreseen in the initial project did not conform to the requirements of rule No. 39; it was inflammable and not resistant to fire. The permit was issued nevertheless, on the same terms as in 1967.

Finally in 1971, the external construction having been completed a third request, concerning the interior arrangements, was filed. The rules for theatres (of 1923) had to be conformed to which foresee the presentation of a plan and the supply of an estimate of the number of people the building would accommodate. These two requirements were not respected. The Chief Fire Officer was mainly preoccupied with the fact that he did not know how to apply the regulation for theatres to such an unusual complex. Finally he recommended (on June 8, 1971) to issue the permit specifying, however, that all appropriate safety arrangements had to be adopted without delay. The permit was in fact issued.

The materials used. The concrete which had originally been foreseen as the building material for the face of the building that was attacked by the kiosk fire (east face) had been replaced by an inflammable building material, the Galbestos, which did not resist fire for two hours but only for a few minutes. This is why the fire could spread to the inside of the building. The literature on the subject of this building material was so inexplicit that the architect had thought it was non-inflammable.

The decorator for his part had also substituted an inflammable material, Decalin, for a safer material that had been foreseen at the start. He did not know the properties of this Decalin nor that it was inflammable.

As for the Oroglas, it had never been subjected to significant tests for the scale of its use in Summerland.

The evacuation: an accumulation of design and management faults. The commission was to take up quite a number of serious faults:

- insufficient signposting;
- difficult access for fire fighters;
- most emergency exits on the same side of the building;
- possible chimney effect above the main exit;
- insufficient space at the bottom of the main escalator and at the main exits (congestion); two other exits defective;
- doors not functioning as fire screens, did not shut;
- emergency doors not equipped with panic bars but with keys (a key had to be fetched which meant running to an office);
- emergency doors marked "Private";
- emergency doors obstructed by a parking lot;
- emergency doors not leading to a safe place;
- darkness all over on account of poor maintenance of the emergency generator.

2nd. Risks presented by highrise buildings

Highrise buildings give cause for concern especially when the recommendations concerning the building materials to be used inside are not adhered to.

Sao Paulo 1974. The Joelma tower was twenty five stories high; the first ten stories were reserved for parking. Above these there were usually 1,000 people working; at the time the fire broke out only five hundred people were in the building. The fire spread at great speed on account of the ventilation system and of inflammable building materials that had been used despite open criticism from the mayor which had been repeated for weeks.

In addition, safety measures were dropped during construction. A single unprotected staircase (in a central position) served the whole building while at least two enclosed staircases would have been necessary

Helicopters, impeded by currents of heat from the fire, by fumes reducing visibility for the pilots and under certain conditions stopping the engines and by the environment (buildings, TV antennae etc.) could not be considered normal means of rescue.

Appeals for calm by the fire service were fruitless: many jumped in order to escape the flames and met a quick death under the eyes of 10,000 veritable 'spectators' who blocked all approaches and impeded the work of the fire service who by acts of sheer heroism managed to save some people.

It soon became clear to the authorities that only a few people could be saved, and they authorised TV to say so. This heightened the impulsive sensations of fascination and horror (...) Three hundred thousand cars*(?) soon squeezed each other into the nearby streets while the fire grew worse (16, p. 121).

In the end a heavy-duty helicopter could make several shuttles between the roof and a place of safety; it managed to save about one hundred people before the roof collapsed. One hundred and seventy seven victims were counted (1, p. 292; two hundred and twenty according to 16, p. 119) and two hundred and ninety three suffered severe burns.

It was ensured that new regulations were enforced. The director of the Police technical department indicated that there were not enough laboratories to set up a prevention plan to test all building materials (16, p. 123).

3rd. Aircraft accidents

The scale of air disasters follows the growth in the capacity of aircraft and the increasing density of air traffic (1, pp. 632-641).

Until 1949 the figure of fifty five deaths**was not surpassed (in-flight collission over Washington, November 1, 1949). In 1950 the peak reached eighty dead (Wales, March 12); it rose to one hundred and twenty eight deaths in 1956***(collision between a Super Constellation and a DC 7, June 30, Arizona), and to one hundred and thirty six deaths in 1960 (collision between a DC 8 and a Super Constellation, December 16, New York).

While the average number of victims per accident increased, the peaks (also) continued to rise: one hundred and fifty five deaths in 1969 (crash of a DC 9 in Venezuela), one hundred and sixty two deaths in 1971 (Boeing 727 hit in flight by an airforce plane — in that year there had been two hundred near-misses in Japan, six hundred in the United States; one hundred and seventy six deaths in 1972 (crash of an Ilyushin 62 in the USSR, unconfirmed); one hundred and seventy six deaths in 1973 (in Nigeria, crash of a Boeing 707). Recently new orders of magnitude have been recorded.

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*Cars that were soon abandoned by their drivers who wanted to get a better view and cared little about the problems this caused for ambulances and for the fire engines.

**If one leaves aside the crash of an American bomber on an English school in 1944 (Freckleton, August 23, seventy six dead).

***In civil aviation (an American military aircraft crashed in 1953 claiming one hundred and twenty nine deaths).

Ermenonville 1974. On March 3, 1974, soon after take-off from Orly, a Turkish Airlines DC 10 with three hundred and thirty four passengers and twelve crew members on board crashed at Ermenonville. The enquiry showed that these three hundred and forty six people went to their deaths because of the faulty lock on a luggage door that was torn off at an altitude of 3,600 metres; this in turn damaged the floor of the passenger cabin and the three control systems which passed through there (44).

An incident with a similar cause had already occurred two years earlier on a DC 10 (June 12, 1972); the cables had not been damaged on that occasion and the pilot succeeded in making a safe landing at Windsor, Ontario. The necessary modifications demanded by the American federal administration were not made. The administration thought that its correspondence with Mc Donnel Douglas, the manufacturer, was sufficient and that it was not necessary to proceed with the issue of a directive. They were wrong.

Two years after the incident at Windsor some aircraft had not yet undergone the necessary modifications; two DC 10s were even built and sold without these adjustments. Three days after the disaster of Ermenonville an imperative instruction was sent to all DC 10 users. The confidence had cost the lives of three hundred and forty six people (1, pp. 579-584; 16, pp. 125-129).

Santa Cruz 1977. On March 27, 1977 on the airport of Santa Cruz de Tenerife, Canary Islands, two Boeing 747s collided. There were nearly six hundred immediate deaths (21) and a final toll of six hundred and twelve (21).

Chicago 1979. On March 25, 1979 an American Airlines DC 10 crashed at Chicago causing the deaths of two hundred and seventy five people. All DC 10s were grounded for a prolonged period by the American administration (22).

Generally speaking, the average annual number of victims of air accidents is in the order of 1,000 (USSR and China not included). In 1974 it was 1,155 (45).

4th. Accidents on oil platforms

Alexander Kielland 1980. The platform served as a floating hotel for people working on the North Sea oil field Edder (a satellite of Ekofisk) in the Norwegian zone. It sank on March 27, 1980. One hundred and twenty three dead were counted (23).

Gulf of Bohai 1980. A Chinese platform subsided in a thunderstorm in the Gulf of Bohai in June 1980. The accident caused seventy deaths. (24).

4. DISASTERS LINKED WITH LARGE SCALE INDUSTRY

1st. Fires and gas explosions in fixed installations

The manufacturing, stocking and utilisation of highly inflammable and explosive products on the one hand, the work with temperatures and pressures that are much higher than in the past on the other have led to large scale industrial accidents and this despite the precautions taken, the latter themselves being more developed than hitherto.

Below we shall give some measures of magnitude for the phenomenon of conflagration and explosion in large industrial enterprises as well as some cases for illustration, especially the one at Feyzin, the French case of reference.

A recent study by American consultants in the petrochemical industry has produced a list of large scale accidents (the criterion being financial: losses above 10 million dollars) that have occurred since 1950. The table below summarises their study (25):

	No. cases	Total loss in million $	Average loss in million $
1950-59	7	173	24.7
1960-69	16	404	25.2
1970-79	46	1,318	28.6
Total	69	1,895	27.5

Table 9: Estimate of losses incurred by the petrochemical industry during the last three decades because of big accidents: nearly 2 billion dollars.
(Source: 25)

Cleveland 1944. A small tank filled with liquified natural gas — 4,200 cubic metres compared with the tanks of hundreds of thousands of cubic metres which nowadays hold gases that are in some cases more dangerous, but which are luckily of a different design — cracked and burst into flames on October 20, 1944; another small tank cracked twenty minutes later. The heat released was so intense that it set buildings 500 metres away on fire. In addition, the gas expanded through sewers and subterranean pipelines and exploded all over the town. Streets were ripped open, pavements blown up, sewer covers hurled across buildings. There were one hundred and thirty six dead and two hundred injured; seventy nine houses, two factories and two hundred cars destroyed; the bill came to 6.8 million 1944 dollars. Yet, there had been two favourable factors: the time (the accident occurred in the early afternoon when there were few people in the streets) and the wind which blew away from the inhabited area, thereby reducing the impact of the accident (26, pp. 11-12 and pp. 33-36).

Rotterdam refinery 1968. A cloud of explosive gas formed accidentally on January 20, 1968 and found an ignition source. This was a detonation comparable to that of an explosive charge of 10-20 tonnes of TNT. All tanks, installations and buildings within a radius of 200 metres were destroyed. The detonation killed two men and injured another two; 3,500 injured were counted among the inhabitants of neighbouring areas; the shock wave destroyed windows within a radius of 3-5 km. Damages amounted to 125 million 1968 FF.

CDF — Chimie 1972. On January 30, 1972 an explosion occurred in an ammonia synthesis unit at Mazingarbe in the Pas de Calais. The explosion of the reactor — height 25 metres, outer diameter 1.10 metres, volume 160 tonnes, operating pressure 400 bar — caused considerable damage. Two fragments of 2.5 tonnes and 1 tonne were hurled through the control room 25 metres away; three compressors were destroyed by a one tonne piece which bounced on them and crashed 170 metres away. Another one tonne piece crashed toluene pipes 90 metres from the place of the explosion; yet a further piece of the same weight smashed through a villa 300 or 400 metres away after having bounced in the garden. Damage from the blast was incurred up to 2 km away (windows broken, doors twisted, walls cracked, roofs damaged).

Feyzin 1966. The refinery at Feyzin was put on stream in 1964; it was to process 1.7 million tonnes a year; it had had auxiliary installations which included mainly overhead tanks of liquid hydrocarbons of 300,000 m^3 capacity. These stores were in zone B of the refinery area. There were, among others, two spherical tanks which could hold 2,000 m^3 of butane and 1,200 m^3 of propane (the four spheres of propane were numbered from T.61,440 to T.61,443). The following extracts are from the verdict handed down by the Court of Appeal at Grenoble in 1971 (27, 28).

Preliminary technical explanations. In order to avoid excessive internal pressure in the sphere in case of an accident or a conflagration each sphere is equipped with a safety device consisting of two valves installed in the upper part of the sphere, yielding 73 tonnes/hour of gaseous products.

Each also contains a cooling device consisting of two rings of vaporisers installed at the top, the median part and the lower part of the tank respectively. This device is directly connected to the fire extinguishing network by a valve. Its average yield is 2,200 litres/minute for the propane spheres.

The nature of liquified hydrocarbons requires frequent draining during storage to eliminate the water and soda mixed with the product which after pouring off accumulate in the lower part of the tank.

The draining of the spheres is effected by means of two valves located at 5 centimetres distance from each other and are operated by a square key-lock, the lower valve serving as an evacuation pipe that drips into a square draining trap of 50 centimetres side-length and 1 metre depth, linked to the network for used water from the refinery.

On the other hand, gas samples are taken from time to time for analysis of the manufactured products and checking of their standards (28, pp. 38-39).

Antecedents of the accident of January 4, 1966. The draining of manufactured products practised from the start of storage on site (June 12, 1964) had brought to light some problems arising from the device:

- The valves were too close to each other, as the passage of propane from liquid to gaseous state which took place at a temperature of minus 44°C caused an almost simultaneous icing up of both valves;

- Their control by removable keys rather than wheel key-lock presented risks of gas escape in case one of these keys being dropped;

- Their diameter (2 inches) was too large;

- With the draining trap located at the feet of the operator, which meant that he was frequently splashed and sometimes suffered burns to his face and hands by the gushing of liquid into this opening.

- The valves were often difficult to operate.

- Finally, the access to the valves was made difficult by the presence of pipes which the operators had to step over in order to carry out the draining.

Employees had told the management about these problems; things remained practically as they were. Two serious incidents had occurred that gave substance to the apprehension and fears expressed:

a) On August 6, 1964 at about 23.00 h one Robert Tinjod, an operator's mate, had opened — before massively draining the butane sphere 462 — completely the two valves of the tank, letting the liquid flow normally into the drainage tank, and he had climbed on top of the sphere in order to check the gauge there, thinking he had enough time before finishing the draining operation. It was then that the gas shot out in force.

   Tinjod who wanted to shut the valves which were iced up by the passing gas froze his right hand slightly and had to be treated in hospital.

   The draining taps were shut by a manufacturing engineer and one of the firemen on duty who were helped by a favourable wind.

b) On February 26, 1965 at 11.05 h one Isaac Bittoun a chemist, had been assigned with his colleague Godde to carry out the draining of the propane sphere 440 to take a gas sample.

   In these ill-defined circumstances, after the usual emission of water and soda the propane shot out and burned the two men. The safety workers Leseurre and Rossit, after being alerted, intervened. The first one was also burned but the second one managed to shut the valve. The alert had been serious.

This last incident which if the wind had not again been favourable could have developed into disaster even though the motorway had not yet been opened to traffic had subsequently caused the issue of a service bulletin on the method of draining the spheres (March 4, 1965) by Mr Ory, the Chief of Technical Services. It said in particular that after the keys had been attached to the two draining valves the valve on the sphere side was to be opened completely, then the valve on the atmosphere side partly opened, without ever opening it completely in order to be sure that it could be closed, as soon as gas appeared, the closure of the draining valve or, in normal circumstances, of the valve on the sphere side, and then shut the second valve.

Additionally, this instruction indicated, for the control draining on the bottom of the sphere, the facility of using the piping between the two taps as a lock-chamber i.e. by opening the valve on the sphere side, shutting it again immediately, then opening the second valve to the atmosphere in order to empty out the content of the line.

It finally made it obligatory that the taking of laboratory samples had to be done in the presence of a safety officer and that draining was to be carried out by two people.

This bulletin which was entered into the service manual and posted in the pump rooms was generally known to the staff but had never been backed up by practice exercises. Also, some operators kept to their own ideas about the question and to the procedures previously practised (28, pp. 39-41).

The conflagration on January 4, 1966. On January 4, 1966 it had been decided to clean propane sphere 433 at the end of sample taking. Taking part were: Robert Dechaumet, operator's mate, Raymond Fossey, safety officer and Bernard Duval, laboratory helper.

In contravention of the instructions in the service bulletin from Ory this operation was carried out at 06.40 h, i.e. in complete darkness; the lower part of the sphere was lit by the diffused light of a candalabrum and horizontal projectors placed at a certain distance. The temperature was between 4 and 5°C, and there was virtually no wind.

Contrary to instructions Dechaumet first half-opened the lower valve, then fully opened the upper valve, as it emerges from the experts' statements on the pieces recovered as well as from those made by Fossey. The latter whose function it was to watch the work and to intervene if need be did not budge but looked on from a distance. Some dirt ran into the drainage tank, then suddenly the gas shot out in force and struck the operator in the face and on the body.

Dechaument, caught in the cloud, lost his safety goggles and involuntarily unhooked the operating key of the upper valve the fixing nut of which had actually not previously been tightened on the operating square.

Fossey shouted: "You have opened it too wide." Dechaumet who had recovered slightly tried to shut the upper valve but did not succeed in putting the key back on because of the icing caused by the escape of gas. He forgot to try and close the lower valve on which the key was still fixed and refused to keep trying.

Meanwhile Fossey and Duval had raised the alert over the telephone and the "généphone". The three safety officers, Rossit, Roy and Fossey, tried in turn to stop the escape, without success.

Gas escaped from the sphere which at 05.00 h in the morning had held 693 m^3 of propane at the rate of about 3.3 m^3 per second according to the calculations made by the experts. The gas mixture, being heavier than the air and there being hardly any wind blowing, the propane expanded by gravity in the direction of the motorway. Nobody thought of alerting the fire service, the gendarmerie and the CRS.

The cloud, approximately 1.50 metres high, reached the motorway on which there were a number of vehicles between 06.55 h and 07.05 h. Employees from the refinery and from the guard of the factory then intervened on the motorway and on the CD 4 road to stop the traffic. At 07.15 h Robert Amouroux, driving his CV4 Renault, arrived on the scene; he was going from Serezin du Rhone (Isere) to Feyzin to take up his duties in a company working for the refinery. When he arrived at the cross-over linking the CD 4 with the motorway and crossed the gas cloud the latter, no doubt as a result of a spark produced by the vehicle, caught fire.

Panic-stricken Amouroux stopped his car and got out; his clothes caught fire; he ran and threw himself into a ditch a few metres away. He was found, a quarter of an hour later, severely burned, and taken to hospital in Lyons where he died on January 8, 1966.

The scene had been observed by the neighbouring customs post who telephoned the gendarmerie at Saint Symphorien d'Ozon which immediately sent their available staff to the scene. The CRS for their part acting on their own had obtained information on what was happening and shared the work required with the gendarmerie: stopping vehicles on the exposed roads, isolating the danger zone, evacuating the houses and the school of the Razes area of Feyzin which was in serious danger.

Sphere 443 had caught fire: it was a drinks retailer who telephoned the fire brigade in Lyons at 07.12 h. Two other phone calls were received from the refinery a bit later. The direct telephone line had not been used.

At the factory general alert was raised by a siren while the three professional firemen on duty who had been unable to plug the escape tried in vain to extinguish the fire of the sphere by attacking it with powder extinguisher and activating the fixed cooling system of the eight spheres and of the two liquified hydrocarbon towers.

The stock of powder (1,500 kg) being quickly exhausted, Rossit, the chief of the group, tried unsuccessfully to use the foam extinguisher which he had available. This piece of equipment could not function due to lack of water suction; a foam launcher could not be used for lack of pressure.

In fact, while the fire fighting network of the refinery was designed to deliver a maximum of 800 m^3/hour of water the simultaneous opening of the cooling systems for the propane and butane tanks by the safety officers required the use of 1,128 m^3/hour. Therefore, from the beginning of the fight against the fire, water was in dangerously short supply. The situation was aggravated by the fact that the neighbouring Rhone Gas Company which also used the water supply network of the refinery had, as a precaution, also started the cooling system for its two propane spheres and was hosing them with a fire hose.

The fire brigade from Lyons arrived on the spot from 07.33 h onward in successive pickets led in turn by the Adjutant Prevost, Commander Legras (from 07.43 h) and Commander Pierret (from 07.46 h). They joined their efforts with those of the professional and auxiliary firemen from the refinery and were in turn joined by members of the fire fighting team of the nearby Rhodiaceta factory at Saint Fons (Rhone) who arrived at 08.20 h and the fire pioneers of Vienne who after being alerted by the Commander from Lyons arrived at 08.28 h.

As chief of the first intervention picket from Lyons adjutant Prevost occupied himself immediately with sphere 443 which he tried to extinguish with the help of the foam launchers. Being unable to succeed he abandoned the burning tank and concentrated his efforts on the neighbouring propane tank 442.

The rescuers giving up the attempt to extinguish the fire devoted themselves exclusively to the cooling of the other tanks to prevent them from catching fire and hoping that sphere 443 would empty its content which burned as soon as it entered the atmosphere.

However, faced with the drop in pressure already mentioned, Adjutant Prevost and subsequently Commanders Legras and Pierret decided to put a special highpowered fire engine for hydrocarbon fires on suction in the Rhone canal, but for lack of adequate fittings this was sucked in and could only be recovered after some twenty minutes.

On the other hand, the rescuers were handicapped by the customs enclosure the doors of which were padlocked. Employees of the refinery forced the padlocks and then demolished the enclosure with an excavator.

Meanwhile, reinforcements had continued to arrive and authority was passed first to Commander Legras, then to Commander Pierret.

At 07.45 h the important event mentioned above occurred: the release of the safety valve of sphere 443; the gas which escaped through it caught fire immediately causing a fire column of some ten metres in height. This incident was interpreted as reassuring by some of the people in charge at the refinery*: it indicated according to them that the sphere would empty itself completely. They told Commander Pierret and some of his co-workers so.

However, some of the rescuers were gripped by a mute apprehension born of the considerable increase of flames enveloping sphere 443 and the growing turmoil caused by the conflagration.

As to the manner in which the accident was attacked, Commanders Legras and later Pierret had confirmed the measures taken by Adjutant Prevost, restricting themselves to a role of preventing the spread of the accident by hosing the tanks that were likely to catch fire.

The lowering of pressure constrained the rescuers to a dangerously close approach to the tanks as the water from their launchers reached the top only with difficulty. This dangerous situation determined Commander Legras to pull his men back after they had fixed their launchers in firm hosing positions.

Nearly one hundred and seventy people were then in area B.7/1 and in the other areas of zone B. They were firemen from Lyons and Vienne, professional and auxiliary firemen from the refinery and from neighbouring companies or companies working for the refinery, the director, department heads, employees of the factory, supervisors and staff from neighbouring factories and spectators.

The explosion of sphere 443 which occurred at 08.45 h struck most of these people. Added to the waves of burning gas caused by the deflagration were pieces of steel, some of them of considerable weight, that were hurled in some instances over several hundred metres.

Seventeen rescuers succumbed to the explosion or later on to their severe burns. Among the eighty four injured (...) forty two suffered complete disablement for work for more than three months.

However, the explosion had extinguished the fire in the whole of areas B.7/1 and B.7/2 and the southern part of area B.11. The rescuers whose courage had been above praise and some of whom had saved the lives of colleagues in danger while risking their own lives then fell back, taking the injured with them.

On account of this the explosion of sphere 442 at 09.45 h did not cause further victims but, like the preceding one, did cause much material damage as far as 16 km away at Vienne.

Between the two blown-up spheres a crater, 35 metres long, 15.40 metres wide and 2.10 metres deep had opened up (28, pp. 41-45).

2nd. Dispersion of toxic and highly toxic products

A first sub-family of gases includes products with a toxicity similar to that of chlorine and ammonia.

Baton Rouge 1976. On December 10, 1976, 90 tonnes of chlorine escaped from a tank at Baton Rouge (Louisiana) and caused the evacuation of 10,000 people and the blocking of the Mississipi river over a length of 80 km (29, p. 11).

*Our underlining.

Blair 1970. On November 16, 1970 in Nebraska there was an escape from a 32,000 tonne ammonia tank for two and a half hours, causing a release of 140-160 tonnes. The cloud that developed covered 365 hectares up to 2,500 metres from the tank forming a layer of between 2.5 and 9 metres height but claiming no victims (rural area) (22, p. 12).

Putchffstroom 1973. On July 13, 1973, 18 tonnes of ammonia escaped at Putchffstroom, South Africa, leaving eighteen dead of which six were outside. The cloud spread over the town (2, p. 126).

Les Grandes Armoises 1969. Release of 4 tonnes of ammonia during transfer from a fixed to a mobile cistern on May 12, 1969 in the Ardennes. Vegetation was burned over an area of 2 km by 450 metres; various animals were killed. Inhabitants were warned in time and evacuated (2, p. 124).

A second sub-family comprising even more dangerous products can be distinguished: arsenic, hexafluor of uranium, hydrofluoric acid*, acrolèine**, phosgene***etc.

Manfredonia 1976. Between 10 and 30 tonnes of arsenical salt spread following the rupture of an ammonia production tower in Italy in September 1976. Theoretically, 100 milligrams are sufficient to kill a man (31).

Pierrelatte 1965, 1977, 1977; Cadarache 1977. Multiple accidents, the products in question being hexafluor of uranium and fluorhydric acid. In the majority of cases, however, there was no external pollution; no intoxication, no injuries and no deaths (2, pp. 123, 128-129).

Pierre Benite (Lyons) 1976, 1976, 1978, 1978. Multiple incidents at an outfit manufacturing acrolèine, a product of high toxicity (concentration threshold: 0.1 ppm). On July 10, 1976 a wagon of acrolèine tumbled into the Rhone river: the 21 tonnes killed all the fauna down to Vienne (320 tonnes of fish). On December 19, 1976 a container holding 5 tonnes of acrolèine did not stand up to an accidental polymerisation of the product; by chance some electricity cables snapped and the acrolèine caught fire: there was no formation of a toxic cloud that would have been capable of intoxicating the housing areas of this suburb of Lyons. On July 12, 1978 a new escape of acrolèine. People living in the neighbourhood were put to considerable discomfort (33). On October 12, 1978 some hundred kilograms of acrolèine were released into the atmosphere. Discomfort for several thousand people in the area: twelve people admitted to hospital for observation (1, pp. 127-129).

3rd. Transport accidents

a) Land transport. The case of Missisauga-Toronto, one of the most commented-on, is not at all an isolated one. As far as rail transport is concerned the North American continent appears particularly affected. On the day after the accident of the Canadian Pacific train three wagons of liquified propane

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*Threshold: 3 ppm equals 2 milligrams/m^3. Lesions, intoxications (toxicological file INRS No. 6) (32).

**Threshold: 0.1 ppm equals 0.25 grams/m^3. As dangerous as gas used in warfare (file INRS No. 57).

***Threshold: 0.1 ppm. Suffocating, peracute intoxication, fast killer (file INRS No. 72).

exploded in Florida following a derailment (34). The day after a thousand families in Michigan were evacuated following the derailment of a wagon containing fluorhydric acid (35). R. Audurand reports two important events in Florida: in Youngstown in 1978 the derailment of a train caused an escape of chlorine; there were eight dead, one hundred injured, 3,500 evacuated in an area of 100 km^2. At Crestiew in April 1979, 5,000 were evacuated following the derailment of a convoy of twenty eight wagons of ammonia and chlorine (2, p. 129).

In Europe there were two big cases, the first one occurred some time ago, the second one very much in everyone's memory.

Ludwigshafen 1948. The large BASF complex at Ludwigshafen (FRG) employing 22,000 people was partially destroyed on July 28, 1948 by a big explosion. There were two hundred and forty five dead and thousands injured inside as well as outside. It would appear that a wagon containing dangerous products had been left standing instead of being quickly unloaded. It caused an explosion which was soon followed by three additional deflagrations. In addition to the destruction of part of the complex windows were broken within a radius of 8 km (1, pp. 257-258; 28, p. 129).

Los Alfaques 1978. On July 11, 1978 a road tanker carrying 18 tonnes of liquified propylene under pressure exploded near a camping site at San Carlos, Spain. The radiation of heat from the fireball was extremely intense; there were two hundred and sixteen dead and several hundred people had burns (2, p. 128).

Lievin 1968. Explosion of a tank wagon at the chemical (nitric fertilizer) factory of Grande Paroisse (Pas de Calais). Release of 19 tonnes of ammonia. Six dead, twenty people living in the neighbourhood had to be hospitalised with intoxication (2, p. 124).

Saint Amand les Eaux 1973. On February 1, 1973 at 17.30 h an 18 tonne truck of liquified propane under pressure (5-7 bar) overturned in the middle of the town of Saint Amand les Eaux, northern France, on a road bend. The propane escaped, evaporated and formed a gas cloud which spread along the street over about 120 metres. It caught fire when it came in contact with a heat source. At 17.36 h when the rescuers arrived the fire raged. A few minutes later a violent explosion occurred, killing four people instantly and injuring forty others. The tank had broken up into three main parts after the explosion: the front half, practically intact, was found vertically implanted in the nearest building; the bottom had been hurled over a distance of about 450 metres from the site of the accident; the rear half had been ripped open and hurled against a house that was completely destroyed. An Ami 6 car which had been behind the truck when the explosion occurred was hurled over the wall running along the street and over a distance of about 70 metres. In the end there were nine dead, thirty seven injured, some twenty houses damaged and the town was declared a disaster zone (2, p. 125).

To these rail and road accidents must be added those involving gas and oil pipe (line)s.

Port Hudson 1970. This is the very rare case of a detonation (very fast explosion). 112 m^3 of liquid propane had leaked within the twenty four minutes between the escape and the explosion. A propane and air mixture developed which spread over a surface of about 4 hectares and had a volume of at least 30,000 to 60,000 m^3. The blast caused by this explosion was equivalent to that of about 50 tonnes of TNT: the detonation added to a combustion of residual volume that was richer in propane after a whirl of flames. By chance all this happened in a non-inhabited area (27, p. 30). The event could have resulted in a very large scale disaster had it happened in another place. Someone walking 800 metres away was thrown to the ground. A policeman driving 25 km away from the site of the explosion saw his car make a swerve. Three hundred and fifty kilometres away at Kansas City the sky was seen turning red. Up to a distance of 800 metres buildings were seriously damaged; up to 3 km away 60 per cent of the windows were broken; up to 10 km away 30 per cent were broken. In addition, because high pressure can build up according to the surface structure of the terrain there was a pocket of destruction at 13 km from the place of the deflagration and another at 20 km distance. An enquiry report estimated that in an urban area everything would have been destroyed over 4 hectares and people would have been in grave danger in an area of 120 hectares (37).

Huimanguille 1978. The rupture of a gas pipeline on November 1, 1978 caused the deaths of fifty eight people, 800 km southeast of Mexico City (38).

Pavia 1980. The oil pipe line from Genoa to Milan fractured on April 21, 1980 and polluted the river Po over a stretch of 100 km. The several thousand tonnes of petrol spilled caused fears of conflagrations (navigation was suspended, bridges closed), release of toxic vapours, a severe change in the ecological equilibrium, pollution of the groundwater. The river Po flows through the richest part of Italy (39, 40).

b) Maritime transport. Petrol tanker accidents have attracted most attention since the wreck of the *Torrey Canyon* on March 18, 1967. Up to the *Amoco Cadiz* disaster, which does not mark the end of such accidents, there have been a series of events the repetition of which causes concern. Considering only the French and British coasts here there were (41, pp. 133-134):

- On August 19, 1969 the collision between the *Gironde* and another ship — 2,000 tonnes were spilled.

- On October 23, 1970 the collision between the *Pacific Glory* and the *Allegro:* 10,000 tonnes were spilled.

- On May 15, 1971 the collision between the *Herculo* and another ship — 300 tonnes were spilled.

- On November 26, 1974 the collision between the *Chaumont* and the *Peter Maersk* in the access channel of the port of Le Havre. 1,700 tonnes were spilled, 20 km of coastline polluted.

- On January 24, 1976 the *Olympic Bravery*, a completely new petrol tanker of 275,000 tonnes, left Brest for a Norwegian fjord where it was to be anchored on account of commercial problems which inhibited its utilisation. It found a nearer resting place: after leaving Brest and subsequent to an engine breakdown which did not lead to a call for assistance it foundered on the coast of Ouessant. After rupture of the hull the 1,250 tonnes of engine fuel (the tanker was empty) spread and polluted the coast of the island which made implementation of the Polmar plan necessary.

- On October 17, 1976 the East German tanker *Boehlen* sank northeast of the island of Sein; the pumping of the petrol that had not been spilled cost 155 million FF and three human lives.

- On May 8, 1978 the *Eleny V* was rammed in the North Sea, and 24 km of British coastline were polluted.

- On March 7, 1980 the Madagascan tanker *Tanio* carrying 26,000 tonnes of heavy fuel oil and 900 tonnes of engine fuel broke apart. The front part sank during the day. There were four dead. The rear part was tugged in an emergency (2 miles off dangerous shallows) and later towed towards the port of Le Havre. On March 9 the rose-coloured granite coast was struck. The damage to the avifauna seems to have been on the scale of the one caused by the *Amoco-Cadiz* (20,000 birds killed) because of the type of fuel and the location of the oil slicks near the (bird) reservation of Sept Isles (42). The pollution of the coast turned out to be serious as the days went by. The Polmar plan was considered under its administrative and financial aspects and implemented after a few days' delay, immediate measures having been taken, however, from the time of the advice of the accident (supply of barriers and pollution fighting units, setting up of command posts etc.). Cleaning up proved to be difficult. The rose-coloured rocks were affected in depth. A decision had also to be taken on the problem of the wreck which presented a "Damocles sword" for the coast. Assurances of the past had at last to be given up; Aymar Achille Fould declared:

  Those who imagine that if all precautions were taken there would never again be any accident have never seen the sea (43).

REFERENCES

(1) J. R. NASH, *Darkest Hours*. Nelson Hall, Chicago, 1976 (812 pages).

(2) R. ANDURAND, Le rapport de sûreté et son application dans l'industrie. *Annales des Mines*, no 7-8, juillet-août 1979, pp. 115-138.

(3) I. BURTON, R. W. KATES and G. F. WHITE, *The environment as hazard*. Oxford University Press, New-York, 1978 (240 pages).

(4) Centenaire de la Munich Rück: 1880-1980. *Münchener Rückversicherungs Gesellschaft*, Munich, 1980 (102 pages).

(5) T. BENJAMIN, Une étude dans quinze pays de quelques facteurs déterminant le nombre et la gravité des accidents de la route. Première partie: données statistiques de base International Drivers' Behaviour Research Association, Courbevoie, France, 1977 (45 pages).

(6) Statistiques nationales d'accidents du travail. Années 1976-1977-1978. Caisse Nationale de l'Assurance Maladie des Travailleurs Salariés, juillet 1980.

(7) *Le Monde*, 13 février 1974; 14 février 1974

(8) *Le Monde*, 14 juillet 1977; 24-25 juillet 1977.

(9) L'eau en Loire-Bretagne: spécial Villerest. Bulletin trimestriel du Comité et de l'Agence de Bassin Loire-Bretagne, no 11, mars-avril 1976.

(10) P. LAGADEC, Protection et mise en valeur de la coulée verte ligérienne Mécanismes de solidarité pour la prévention et la mise en valeur des grands espaces verts péri-urbains et coupures vertes d'intérêt régional, Vol. 2. Laboratoire d'Econométrie, Ecole Polytechnique et Mission de l'Environnement Rural et Urbain, 1976 (94 pages).

(11) P. LAGADEC, Eléments pour une prospective de l'espace naturel forestier méditerranéen. Centre International de Recherche sur l'Environnement et le Développement, juillet 1977.

(12) F. NEGRIER, L'assurance face aux risques catastrophiques. *L'Argus International*, no 13, juillet-aout 1979, pp. 254-274

(13) F. GIGON, *Le 400è chat ou les pollués de Minamata.* R. Laffont, Paris 1975.

(14) *Le Monde*, 29-30 décembre 1974 (Jugement: *Le Monde*, 22 juin 1978).

(15) V. BIGNELL, Ch. PYM, G. PETERS, *Catastrophic failures.* The Open University Press, Faculty of Technology, 1977.

(16) F. KENNET, *Les grandes catastrophes du XXè siècle.* Editions Princesse, Paris, 1976 (152 pages).

(17) *Le Monde*, 28 février — ler mars 1965. (Jugements: *Le Monde*, 27 mars 1965; appel: *Le Monde*, 13 novembre 1965).

(18) A. GOUBET, Risques associés aux barrages. Note du Comité technique permanent des barrages, juin 1979 (26 pages).

(19) P. LAGADEC, Développement, environnement et politique vis-à-vis du risque: le cas britannique, tome 3: cinq catastrophes. Laboratoire d'Econométrie, Ecole Polytechnique, avril 1978 (113 pages).

(20) *Le Monde*, 29 mars 1977.

(21) *Le Monde*, 27-28 avril 1980.

(22) *Le Monde*, 27 mars 1979.

(23) *Le Monde*, 30-31 mars 1980; *Le Monde*, ler avril 1980.

(24) *Le Monde*, 8 juillet 1980.

(25) A review of catastrophic property damage losses. M. and M. Protection Consultants — A technical Service of Marsh and Lennan, March 1980 (10 pages).

(26) L. DAVIS, *Frozen fire. Where will it happen next?* Friends of the Earth, San Francisco, 1979 (298 pages).

(27) G. MARLIER, Les explosions de vapeurs de gaz liquéfiés (BLEVE). ELF-France — Groupe d'Etudes de Sécurité de l'Industrie Pétrolière. Note du 7 mai 1980 (8 pages).

(28) Extraits des Minutes du Secrétariat-Greffe de la Cour d'Appel de Grenoble, no 220/71, jeudi 25 mars 1971 (68 pages).

(29) Advisory Committee on Major Hazards: Second Report. Health and Safety Commission, Her Majesty's Stationery Office (H.M.S.O.), London 1980.

(30) R. A. STREHLOW and W. E. BAKER, *The Characterisation and Evaluation of Accidental Explosions.* N.A.S.A., National Technical Information Service, Springfield, U.S.A., 1975.

(31) Rapport du Ministère de la Santé et Rapport de l'Inspection Provinciale du Travail. Annexe au Rapport Parlementaire d'Enquête sur la catastrophe de Seveso: Camera dei Deputati VII Legislatura. Commissione Parlamentare di inchiesta sulla fuga di sostanze tossi che avvenuta il 10 Luglio 1976 rello stabilimento I.C.M.E.S.A. e sui rischi potenziali per la salute et per l'embiente derivanti da attivita'industriali (Legge 16 Giugno 1977, n. 357). Juillet 1978 (470 pages).

(32) Fiches toxicologiques. Recueil des fiches parues dans les cahiers de notes documentaires Institut National de Recherche et de Sécurité (I.N.R.S.).

(33) *Le Monde*, 16-17 juillet 1978.

(34) *Le Monde*, 13 novembre 1979.

(35) *Le Monde*, 14 novembre 1979.

(36) *Le Monde*, 17 janvier 1979.

(37) D. BURGESS, Detonation of a flammable cloud following a propane pipeline break: December 9, 1970, explosion in Port Hudson. United States Department of the Interior, U.S. Buro of Mines, 1973 (26 pages).

(38) *Le Monde*, 4 novembre 1978.

(39) *Le Monde*, 24 avril 1980.

(40) *Le Monde*, 25 avril 1980.

(41) Rapport de la Commission d'Enquête du Sénat, présénte par A. Colin Seconde session ordinaire 1977-1978, juin 1978, no 486 (289 pages).

(42) L'accident du Tanio. Centre de Documentation de Recherche et d'Expérimentation sur les Pollutions accidentelles des Eaux (C.E.D.R.E.), juin 1980 (29 pages).

(43) *Le Quotidien de Paris*, 14 mars 1980.

(44) P. EDDY, E. POTTER and B. PAGE, *Destination désastre*. Grasset, Paris 1976.

(45) *Flight International*, 23 janvier 1975.