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Historical analysis of accidents in the transportation of natural gas

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Abstract

The purpose of the present analysis is to determine the main features of accidents occurring in the transportation and distribution of natural gas (in a gaseous state). A survey of 185 accidents taken mainly from the database MHIDAS has been performed. Of these, 131 (70.8%) occurred in transport systems, 32 (17.3%) in process plants, 13 (7.0%) in storage plants and nine (4.9%) in domestic/commercial activities. The 131 accidents occurring in gas pipes were selected for further analysis. The data show that the most frequent accident was explosion (86 cases, 65.6%) followed by loss of containment (63 entries, 48.1%) and fire (56 entries, 42.7%). The cause of the accident was identified for 90 cases (68.7%). Of these, the most frequent causes were mechanical failure (39 entries, 43.3%), impact failure (37 entries, 41.1%) and human error (32 entries, 35.6%); of the specific causes, impact failures due to excavating machinery were especially numerous (21 cases, 23.2% of known causes). The consequences of the accidents, in terms of both human and economic losses, are assessed. Finally, some conclusions are given about the risks involved in natural gas transportation.

1. Introduction

Natural gas is currently one of the most widely used sources of energy, and its use is growing. The world consumption of natural gas (2170×10^{12} m^3 in 1994) has doubled from 1990. The proved reserves have continuously increased in the last years: $39\,400 \times 10^{12}$ m^3 in 1970; $76\,800 \times 10^{12}$ m^3 in 1980; $130\,200 \times 10^{12}$ m^3 in 1990; $148\,200 \times 10^{12}$ m^3 in 1994. These reserves would cover the actual consumption of natural gas

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during 60 years. Actually, natural gas covers 20% of energy consumption in the European Union.

As a fuel, it has several advantages which justify its wide use. Amongst them we can cite its ease of distribution at low pressures and, most important, its clean combustion characteristics; the flue gases contain practically no sulphur.

These two features have put natural gas in a privileged position both for the generation of electricity and as a domestic fuel. This has meant installing and maintaining complex piping systems to transport and distribute gas, a great deal of them located in highly populated zones. Due to these circumstances, accidents caused by the loss of containment of natural gas tend to involve substantial economic losses and a considerable number of victims amongst the population.

It is of great importance, therefore, to study the origin of, and the main features and consequences commonly associated with these accidents; such an analysis can lead to a very useful set of conclusions for improving safety measures and decrease the risks involved in the use of natural gas.

To carry out this study, the best approach is probably historical analysis, i.e. the systematic gathering and treatment of information concerning accidents occurring in gas transportation and distribution systems. This analysis should lead finally to a definition of the technical and organizational steps needed to reduce the probability of occurrence of accidents, and for the identification and improvement of protective measures to reduce the associated consequences. It could also be useful, in some cases, for the validation of the mathematical models used for the estimation of the consequences of accidents.

Gas pipes, traditionally made of steel or cast iron, have extensively been replaced by polyethylene tubing in recent years. Polyethylene pipe has many advantages: it is easier to install, has good mechanical properties and it is not corroded by damp soils. Thousands of kilometers of this pipe have already been installed and its use is still increasing.

This pipe is mostly installed underground, side by side with other utilities; one of these utilities is the electric network, which often follows gas ducts. Sometimes, these electric networks are very old, and prone to breakdowns. In certain conditions, the significant amount of heat released by such electric breakdown can increase the temperature of the subsoil considerably, thus affecting the polyethylene pipe. In spite of its good mechanical properties, this material is very sensitive to temperature, and a partial melting of the pipe wall can lead to a major gas leak.

Gas pipes can also be damaged by other activities: underground work, bull-dozers, etc. The effect will always be a loss of containment. If the gas release is rapidly detected, the situation can easily be controlled, but if the leak is not detected, the gas can follow preferential routes (for example, through sewer systems), accumulate in a confined space and form a flammable mixture. However, even if the leak is immediately detected, if the flow rate of gas release is high, an explosion could occur if the release is ignited. Taking into account that a considerable proportion of gas networks are installed in highly populated zones, the consequences of such an explosion could be severe. Although a number of circumstances must coincide to cause an explosion, the probability of it is not negligible and, in fact, such accidents occur from time to time.

This report describes the results of a historical analysis carried out on a sample of 131 accidents involving pipes in which natural gas was transported in a gaseous state. The main features of these accidents are described and conclusions are derived.

It should be taken into account that in this type of analysis several limitations must be considered, which can have an influence on the quality of the information used. In the case of the MHIDAS database, these limitations are related to the sources of information (based essentially on short papers in the technical literature rather than direct reports on each accident), the availability of enough data to fill the database, and the various possible interpretations of the accident scenario according to the information contained in the database. As some aspects of accidents are frequently not known, it is usual to find empty fields in the database. Furthermore, it must be taken into account that MHIDAS is not a database specifically devoted to natural gas.

2. Natural gas networks

As stated above, steel or cast iron gas pipes are gradually being replaced by polyethylene tubing. Iron and steel pipes, although protected with embedded tar ribbon, suffered many problems due to corrosion. In contrast, polyethylene is perfectly resistant to corrosion, even in waterlogged soils. Polyethylene was first used in the USA in 1965. It was introduced in Europe in 1968 (UK, Belgium and Germany). At the beginning it was only used for low or medium pressure (0.07 bar in the UK, 0.1 bar in Belgium); in 1978 France increased the pressure up to 4 bar and in Spain it is also used at this pressure. At present it is being used at pressures up to 7 bar (Belgium, UK).

The USA is the country which has the largest polyethylene piping network; in 1987–1991 alone they laid 97 189 km of network and 84 575 km of branches (house connections). The length of polyethylene networks in several countries can be seen in Table 1 [1]. In Europe, the country with the largest network is the UK, with an overall

Table 1
Length of polyethylene networks in various countries

Country	Main pipes length (km)	Branches length (km)
Canada	82315	62249
UK	65787	98000
Germany	40000	20000
France	28500	17000
Belgium	10582	4200
Holland	10000	9000
Hungary	9200	300
Japan	5800	3000
Australia	5500	8000
Denmark	3850	4000
Austria	3380	–
Spain	1650	–
Italy	1000 [a]	–
Finland	625	60

[a] Including branches.

length of polyethylene pipe of 164000 km approximately. It is followed by Germany, France, Holland and Belgium [2]. This information highlights the potential for a serious accident: the existence of thousands of kilometers of natural gas networks (polyethylene pipe) located mainly in highly populated areas, i.e. in zones with intense human activity.

3. Sources of information

The accident cases were taken mainly from the MHIDAS (Major Hazard Incident Data Service) [3] database, developed and managed by the Safety and Reliability Directorate (SRD) on behalf of the Major Hazard Assessment Unit of the UK Health and Safety Executive; some other accidents taken from the ESTRALL [4] database have also been included.

MHIDAS was selected for this study for two main reasons: firstly, because although it includes approximately 6000 incidents, fewer than other well-known accident databanks (FACTS, for example, had about 15 000 incidents when this analysis was carried out), the information contained in MHIDAS is generally more complete than that in other databases; and secondly, all the events registered are available on CD-ROM, which makes the treatment of data easier.

The MHIDAS database includes accidents from 95 countries, particularly from the USA, UK, Canada, France and India; it was created in 1986, but includes accidents that occurred even at the beginning of this century and is periodically updated. The ESTRALL database, created recently by the Chemical Engineering Department of the Universitat Politècnica de Catalunya, includes 140 accidents, occurring for the most part in Spain.

The survey for this study was made in 1995. At that time, the database on CD-ROM included 239 entries of accidents involving natural gas: 60 (25.1%) concerning liquefied gas and 179 (74.9%) involving gas. The ESTRALL database included six accidents involving natural gas (gas). The following sections concern these 185 incidents involving natural gas in a gaseous state.

4. Origin of the accidents

The origin is described in the MHIDAS database by two codes; the first one describes the general origin of the accident (transport, processing plant, etc.), while the second one

Table 2
General origin of accidents occurring with natural gas (gas)

Origin	Number of entries	Percentage
Transportation	131	70.8
Process plant	32	17.3
Storage plant	13	7.0
Domestic/commercial	9	4.9

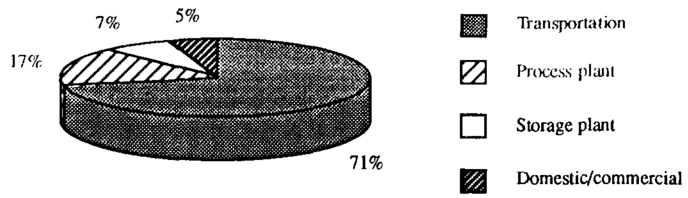

Fig. 1. Distribution of general origin of accidents (see Table 2).

describes in greater detail the circumstances surrounding the accident described in the first code (for example, in the case of transport, whether it was on a road or railway). Table 2 and Fig. 1 give the distribution of entries according to their general origin; this information was available for all the cases.

Approximately 71% of the accidents occurred during the transportation of natural gas, either by road, railway, ship, or by pipeline. Accidents in process plants are much less frequent (≈ 17%), as are those in storage plants (7%) and domestic premises (≈ 5%). The situation is significantly different from that found in the analysis of overall accidents in chemical plants and in the transportation of hazardous materials; a recent study based on 5325 accidents in chemical plants and in the transportation of hazardous materials [5] gave a contribution of 39% to transportation. Although these two statistical analyses are not strictly comparable due to the the different characteristics of their

Table 3
Specific origin of accidents

Origin	Number of entries	Percent of general origin	Percent of total
Transportation			
Piping	127	96.9	68.6
Pumps/compressors	2	1.5	1.1
Rail tank	1	0.8	0.5
Substation	1	0.8	0.5
Process plants			
Process piping	6	18.7	3.2
Pumps/compressors	4	12.5	2.2
Process equipment	2	6.3	1.1
Process tanks	2	6.3	1.1
Not specified	18	56.2	9.7
Storage			
Atmospherical pressure tanks	5	38.5	2.7
Pressurized tanks	2	15.4	1.1
Pumping	1	7.7	0.5
Not specified	5	38.5	2.7
Domestic / commercial			
Piping	4	44.4	2.2
Equipment with flame	1	11.1	0.5
Not specified	4	44.4	2.2

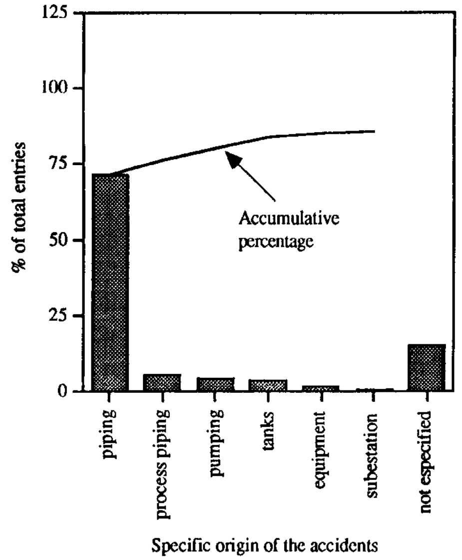

Fig. 2. Pareto chart for specific origin of accidents (see Table 3).

respective samples, it is interesting to observe that there is a significant difference; it must be attributed to the risk associated with large gas distribution networks, and also the size of these networks in comparison with process or storage plants.

With regard to the specific origin, Table 3 and Fig. 2 show the distribution of the main contributions to accidents in transportation, process plants, storage and domestic/commercial events. Only in 14.6% of the accidents was the origin not specified. The analysis of these data clearly shows the relatively high frequency of accidents in pipes: 127 amongst those occurring in transportation plus four in the domestic/commercial sector. As a whole, 70.8% of overall accidents studied in this survey took place in piping systems. In fact, six more accidents occurred in process plant pipes, but due to the different circumstances existing in those plants it seems better to study them separately from the aforementioned set. The remaining specific origins are far less numerous. Accidents originating in tanks (10 entries) and pumping systems (seven entries) are less frequent than those originating in pipes.

Taking all this information into account, from this point on, the analysis will be continued with relation to the 131 accidents occurring in natural gas pipes.

5. Distribution according to time

The date of occurrence of the accidents in pipes was known in 126 cases (96.2%); the CD-ROM version used had entries recorded up to July 1994 and ESTRALL had records up to April 1995. Therefore, decades back from 1995 (i.e. 1986–1995) were used to study the distribution, as a classification by natural decades (i.e. 1980–1990) would involve losing the information corresponding to recent years. Fig. 3 shows this distribution.

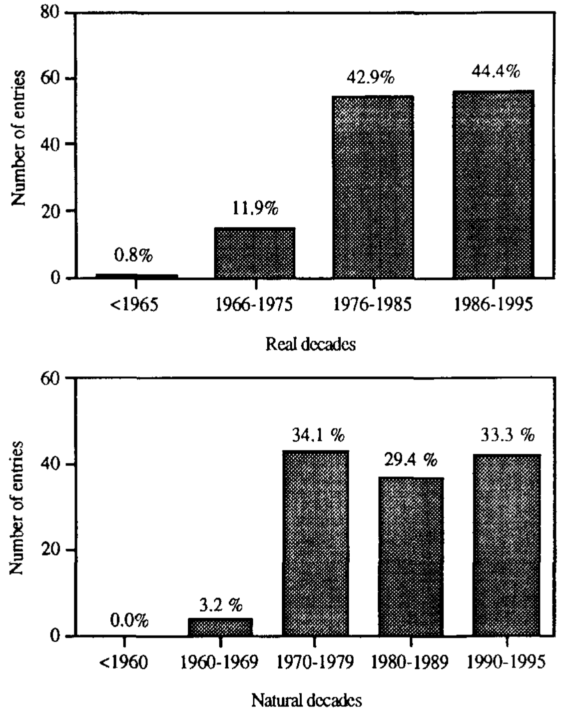

Fig. 3. Distribution of accidents according to time.

A significant increase in accidents registered can be observed from 1970 onwards. This increase may be attributed to two factors. Firstly, the consumption of natural gas increased in many countries from this time, with the consequent increase in length of the piping for transportation and distribution systems. Secondly, it can also be attributed to improvements in the reporting of accidents, and the difficulties of retrospective data collection.

6. Types of accident

The database considers four possible types of accident: loss of containment, explosion, fire and gas cloud. In all 131 entries, the type of accident is known. Their distribution can be seen in the first part of Table 4; because more than one of the types can exist in the same accident, the sum of the percentages is greater than 100. Three of the types—explosion, loss of containment and fire—have high percentages; in about two out of three accidents (65.6%) there was an explosion, while in almost half of the cases (48.1%) there was a loss of containment. Fire existed in 42.7% of the accidents; however, a gas cloud appeared only in three cases.

Table 4
Types of accident

Type	Number of entries	Percent of total
Explosion	86	65.6
Loss of containment	63	48.1
Fire	56	42.7
Gas cloud	3	2.3
Classification with exclusive categories		
Explosion + fire	40	30.5
Loss of containment	26	19.8
Explosion	26	19.8
Loss of containment + explosion	20	15.3
Loss of containment + fire	14	10.7
Loss of containment + gas cloud	3	2.3
Fire	2	1.5
Accidents with at least one of the following types of explosion		
Unconfined explosion	8	6.1
Confined explosion	6	4.6
Physical explosion	5	3.8
Not specified	67	51.1
Accidents with at least one of the following types of release		
Continuous release	38	29.0
Instantaneous release	1	0.8
Not specified	24	18.3
Accidents with at least one of the following types of fire		
Fireball	5	3.8
Flash fire	5	3.8
Jet fire	2	1.5
Not specified	44	33.6

Using a classification with exclusive categories, i.e. a distribution in which the sum of the percentages is 100, the highest contribution is that corresponding to accidents in which an explosion and a fire have occurred (40 entries, 30.6%). It is followed by "loss of containment" (26 entries, 19.8%) and "explosion" (26 entries, 19.8%). Loss of containment and explosion occurred in 15.3% of accidents (20 entries) and loss of containment and fire in 10.7% (14 entries). Fire alone has a lower frequency. This distribution can be seen in Fig. 4.

The type of explosion was not specified in most cases (67 cases, 51.1% of the total); for the cases in which it was defined, the contribution was 6.1% of the total (eight cases) for unconfined explosion, 4.6% of the total (six cases) for confined explosion and 3.8% of the total (five cases) for physical explosion. A similar situation was found for accidents involving fire, in which only 12 entries specified the type of fire.

Finally, for the accidents classified as involving loss of containment, only one was identified as an instantaneous release.

The analysis of these data showed that the method of coding the accident type in MHIDAS is somewhat lacking in accuracy. A detailed analysis of the accidents (going back to the description included in the database) led to the conclusion that all the cases

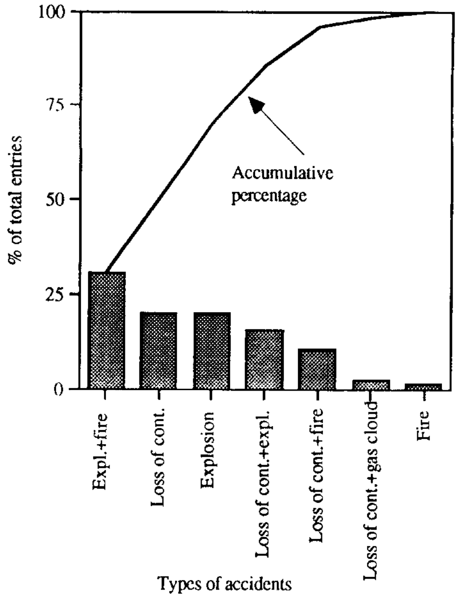

Fig. 4. Pareto chart for the types of accidents (see Table 4).

"fire + explosion" were really "explosion + fire", and all the cases "gas cloud + release" were actually "release + gas cloud".

7. Causes of the accidents

With regard to the general causes of the accidents, the database takes into consideration the following possibilities: human error, mechanical failure, instrument failure, services failure, external events and impact failure. Of the 131 accidents taken into account in this survey, only in 90 (68.7%) was the cause known.

The contribution of the various general causes has been summarized in Table 5. As one accident can be due to more than one cause, the sum of the percentages is again greater than 100. Three general causes show a sizeable contribution: mechanical failure (43.3% of known cases), impact failure (41.1%) and human error (35.6%); external events have a lower contribution (15.6%) and services failure is cited in only one case (electrical failure).

More than one cause was given for 31 accidents, and in 59 there was only one single cause. Of these, mechanical failure was the most frequent one (25 cases), followed by impact failure (19 entries) and external events (10 entries).

Accidents can be classified as having a single cause or more than one cause. Of those classified as accidents with mechanical failure, this was recorded as the only cause for 27.8% of the cases and in 15.6% it was associated with other causes. The corresponding figures for impact failure are 21.1% and 20%, respectively. A different situation is found

Table 5
Causes of the accidents

Cause	Number of entries	Percent of known
Mechanical failure	39	43.3
Impact failure	37	41.1
Human error	32	35.6
External events	14	15.6
Services failure	1	1.1
Accidents with one single cause		
Mechanical failure	25	27.8
Impact failure	19	21.1
Human error	4	4.4
External events	10	11.1
Services failure	1	1.1
Accidents with more than one cause		
Mechanical failure	14	15.6
Impact failure	18	20.0
Human error	28	31.1
External events	4	4.4
Services failure	0	0.0

in the accidents caused by human error; it was the only cause in 4.4% of the entries, while in 31.1% of cases human error was directly associated with another cause (as, for example, impact due to excavating machinery). This can be seen in Fig. 5.

The specific cause distribution can be seen in Table 6. Amongst the accidents originated by mechanical failure, the most frequent specific cause was corrosion (nine cases, 23.1% of general cause), followed by a leak in a coupling or flange (six entries, 15.4%), overpressure (five entries, 12.8%), relief valve failure (five entries, 12.8%) and

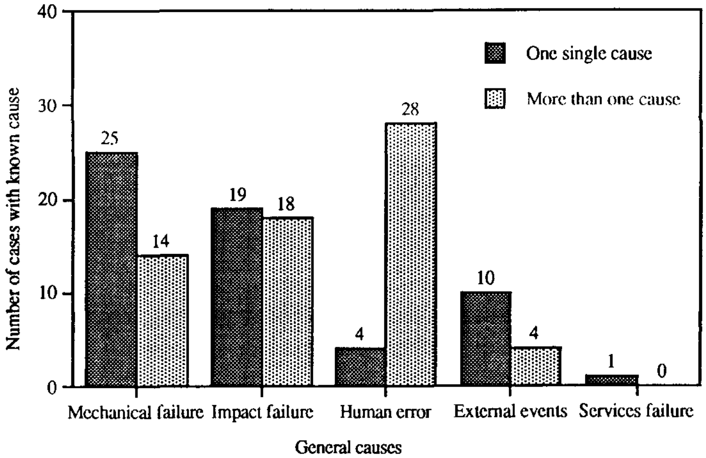

Fig. 5. Distribution of general causes of accidents (see Table 5).

Table 6
Specific causes of the accidents

	Number of entries	Percent general cause	Percent of known
Specific cause of accidents due to mechanical failure			
Corrosion	9	23.1	10.0
Leaking flange	6	15.4	6.7
Overpressure	5	12.8	5.6
Leaking valve	5	12.8	5.6
Weld failure	3	7.7	3.3
Stress	1	2.6	1.1
Overloading	1	2.6	1.1
Not specified	9	23.1	10.0
Specific cause of accidents due to impact failure			
Excavating machinery	21	56.8	23.3
Vehicle	5	13.5	5.6
Heavy object	5	13.5	5.6
Crane	1	2.7	1.1
Road accident	1	2.7	1.1
Impact ship–coast	1	2.7	1.1
Not specified	5	13.5	5.6
Specific cause of accidents due to human error			
General operations	9	28.1	10.0
Maintenance	2	6.3	2.2
Communications	2	6.3	2.2
Procedures	2	6.3	2.2
Construction failure	1	3.1	1.1
Installation failure	1	3.1	1.1
Coupling failure	1	3.1	1.1
Insulation failure	1	3.1	1.1
Management failure	1	3.1	1.1
Not specified	13	40.6	14.4 [a]
Specific cause of accidents due to external events			
Ground subsidence	4	28.6	4.4
Sabotage/vandalism	4	28.6	4.4
Flooding	2	14.3	2.2
Earthquake	1	7.1	1.1
Extreme temperatures	2	14.3	2.2
Not specified	1	7.1	1.1 [b]

[a] The sum these percentatges does not match that of Table 5, because there are two accidents with two specific causes for the same general cause (impact failure).
[b] The sum of these percentatges does not match that of Table 5, because there is one accident with two specific causes for the same general cause (human error).

weld failure (three entries, 7.7%); fatigue and overloading show the same contribution (one case, 2.6% each).

In the analysis of the specific causes included in the general cause "impact failure" and "human error" the sum of the percentages is greater than 100, because some accidents have more than one specific cause for the same general cause.

The distribution of the accidents with "impact failure" supplies interesting information. More than half of these accidents (56.8%) were caused by excavating machinery;

Table 7
Economic losses incurred as a result of the accidents

Losses	Number of entries	Percent of total
Between \$10000 and \$100000	1	0.8
Between \$100000 and \$1m	3	2.3
Between \$1m and \$10m	4	3.0
> \$10m	3	2.3

this specific cause is followed, with significantly lower frequencies, by accidents caused by vehicles (13.5%) and heavy objects (13.5%).

With regard to the accidents caused by human error, in 40.6% of the cases there was no information available on the type of error; for the rest, the most frequent source of errors were general operations (nine cases, 28.1% of general cause), followed by maintenance (two entries, 6.3%), communications (two entries, 6.3%) and procedures (two entries, 6.3%). Finally, for cases caused by external events, the most important contributions were those of soil subsidence (four accidents, 28.6% of general cause) and sabotage/vandalism (four entries, 28.6%), followed by flooding (two entries, 14.3%), earthquakes and extreme temperatures.

8. Economic losses

The economic losses incurred as a result of the accidents are only known in 11 cases (8.4%); the data are shown in Table 7. The small size of the sample does not allow a significant statistical treatment. Most of these accidents have economic losses between \$100,000 and \$10 million, and in three cases are greater than \$10 million. This shows that the economic losses in an accident of this type can be considerable. However, this information is somewhat lacking in accuracy, as there is an inherent difficulty in the comparison of economic data corresponding to different periods: inflation implies a continuous change in the economic cost of any given damage, and MHIDAS does not update the economic losses for each accident; the values are those obtained directly from the information source.

9. Human involvement in the accidents

As mentioned above, gas distribution networks are usually located in highly populated areas; the probability of there being victims if an accident occurs is therefore very high.

The consequences for people of the accidents can be classified into two main categories: number of deaths and number of people injured. This classification includes those accidents in which one of the two values (deaths or people injured) was greater than zero and the other was unknown, as well as those cases in which both values were known. Of the overall number of accidents (131), this information was known in 87 cases (66.4%); of those, in 69 accidents (79.3%) there were deaths or people injured and in 18 accidents (20.7% of known) there were neither people killed nor injured. In 44 cases (33.6% of total entries) this information was not specified in the database. This has been plotted in detail in Fig. 6(a) and (b).

Fig. 6(a) shows the distribution of the number of deaths, according to arbitrary categories (0 deaths, 1–10 deaths, etc.). In 26 cases (29.9% of known, 19.8% of the total) there were no deaths, while in 42 accidents (48.3% of known, 32.1% of the total) the number of deaths ranged between 1 and 10 and in eight cases (9.2% of known, 6.1% of the total) it ranged between 11 and 100. The maximum number of deaths was 106; this accident occurred in Taegu (Korea) in 1995, when an excavating machine that was working on the underground punctured a natural gas pipe and caused an explosion and fire [4].

With regard to the number of people injured, the data have been plotted in Fig. 6(b). In 20 accidents (22.9% of known, 15.3% of the total) there were no people injured, while in 38 cases (43.7% of known, 29% of the total) the number of them ranged between 1 and 10 and in 19 cases (21.8% of known, 14.5% of the total) the number of people injured ranged between 11 and 100. In two cases (2.3% of known, 1.5% of the total) the number of people injured was greater than 100. The maximum number of people injured in an accident was about 200.

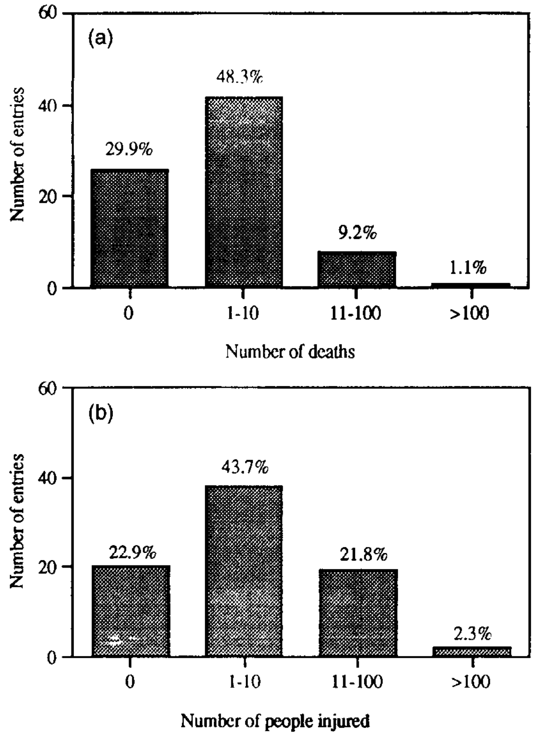

Fig. 6. Accidents according to the number of deaths and to the number of people injured (total known, 87 entries).

Table 8
Ignition source

Source	Number of entries	Percent of known	Percent of cases with ignition
Without ignition	21	58.3	–
Friction sparks	6	16.7	40.0
Naked flames	4	11.1	26.7
Electrical sparks	4	11.1	26.7
Hot surfaces	1	2.8	6.7

Therefore, a relatively high number of accidents caused death or injury; in 58.6% of known cases (39% of the total) there were deaths and in 67.8% of known cases (45% of the total) there were people injured. This must be attributed to the aforementioned fact that the gas pipes associated with these accidents are often located in highly populated areas. However, generally speaking, the number of deaths or people injured in these accidents is limited; i.e. an accident with 300 or more deaths, as can sometimes occur in process or storage plants, seems very improbable.

10. Ignition source

The database classifies the source of ignition at two levels: a general one and a more specific one. However, this information is known in rather few cases: in 95 accidents (72.5%), i.e. in about three out of every four cases there is no information on this subject. The information on the other 36 cases (27.5%) has been summarized in Table 8.

In 58.3% of the accidents for which information is available there was no ignition. In those in which there is information and there was actual ignition, the most frequent source of ignition were friction sparks (six cases, 40% of cases with ignition), followed by naked flames (four accidents, 26.7% of cases with ignition), electric sparks (4 cases, 26.7% of cases with ignition) and hot surfaces (one case, 6.7% of cases with ignition). Amongst the cases in which friction sparks were involved, in two cases they were produced by a tool, while in the other four cases the specific origin was not defined. When the source of ignition was naked flames, in one case they were from a boiler, in another case from a flare and in the other two cases the specific source was not known. For the electric sparks, in three cases they were caused by electric motors and in the fourth case this information was not known.

With regard to the delay time up to ignition, this information is only known in seven cases (5.3% of the total). In one case the ignition was instantaneous and in three cases the ignition time was up to 1 min; in one case this time was 2 min, and finally in two cases it was more than 1 h.

11. Discussion

The survey of 185 accidents occurring with natural gas (gas) has shown that most of them (70.8%) occurred in piping systems (transportation and distribution networks).

Amongst these 131 accidents, the most frequent type was explosion + fire (30.6%), followed by loss of containment (19.8%) and explosion (19.8%). Concerning the causes of the accidents, the most frequent one was mechanical failure (43.3% of known), followed by impact failure (41.1%) and external events (15.6%).

The survey of specific causes clearly shows that excavating machinery made the highest contribution (21 cases, 23.3% of known causes), followed by corrosion (nine cases, 10% of known) and leaking flanges (six cases, 6.6% of known).

It is interesting to compare these results with those obtained from similar studies previously published. A survey carried out on the failure of interstate natural gas pipelines in the USA (1950–1965) by the Federal Power Comission [6] gave 27.8% of known causes of failures as being due to excavating machinery, 19.3% due to corrosion and 18.9% due to weld failures. The percentage of accidents caused by excavating machinery has decreased slightly, according to these data. Nevertheless, this slight difference is not significant in these types of historical analysis, and could be due to poor recording of causal information. The most significant change is that found in accidents caused by corrosion, which have decreased from 19.3% in 1950–1965 to 10% in this work; this change is probably due to the extensive substitution of steel and cast iron pipes by polyethylene tubing. This is supported by the data published by Knowles et al. [7] on the accidents occurring in the UK over the period 1970–1977, which show 10.3% of known causes of events as being corrosion.

The decrease observed in the accidents caused by weld failures and coupling failures (18.9% of known and 6.5% of known, respectively, in the FPC study in 1950–1965) as compared to leaking flanges, weld failures and coupling failures (6.6% of known, 3.3% of known and 1.1% of known, respectively in this study) might also be attributed to the aforementioned substitution.

The distribution of accident cases according to time shows a rising trend. Although this is probably due to the increase in natural gas consumption, it could also be attributed to the improvement in access to information on acccidents which has taken place in recent years. Data over a wider period would be required to get a clear picture of this trend.

Finally, the survey has shown that in a high percentage of accidents there were victims (79.3%). If it is supposed that in those accidents for which information was not available there were no victims, then there were people involved in 52.7% of total cases. The most frequent number of deaths was in the range 1–10, as was the number of people injured.

While carrying out this historical analysis some difficulties were found because of the limited quality of the available information. To perform more reliable statistical studies, a more selective database would be required. Although the MHIDAS database has a good structure of fields, it is oriented to recording major hazards for all kind of substances and industrial sectors, not only natural gas networks. Taking into account the importance of natural gas and other similar fuels, a specific database could be very interesting. This database should be addressed to recording additional data relating to other fields such as reliability parameters, installation age, pipe material, source data (P, T, approximate amount involved, average source strength) and consequence data (type of damage at several distances).

Nevertheless, even taking into account the aforementioned limitations, this work gives interesting information which is not usually published for reasons of confidentiality.

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