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LIQUEFIED ENERGY GASES SAFETY: SOME CAUSE FOR CONCERN

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Liquefied energy gases (LEG's) such as propane, butane and ethylene, are now handled in large and increasing quantities both in the United Kingdom and abroad. Public hazard aspects of these gases are considered in this paper, focussing in particular on a number of major weaknesses that may currently be observed in the official control of public safety in the United Kingdom. A brief summary of the lethal properties and hazard potential of LEG's is also given, and, in a concluding section, an outline of research priorities necessary to remedy the deficiencies in the United Kingdom LEG hazard control policy discussed in earlier sections.

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Introduction

A familiar classification of the main sources of energy is into "conventional" and "unconventional" forms - coal, gas and oil belonging to the former group, and nuclear power and soft technologies such as solar, wind and wave power to the latter (Health and Safety Commission, 1978b). The label "unconventional" may suggest some degree of newness, unfamiliarity or uncertainty in respect of the reliability, large scale capability, or safety of certain energy sources, whereas "conventional" may correspondingly foster reassurance and familiarity on safety, reliability or large scale capability grounds. Nuclear power has come under intensive public scrutiny on safety grounds, and continual reassurances from industry have done little to appease the fears expressed, particularly in the light of occasional, some would say frequent, incidents involving various degrees of failure of nuclear technology (notably the major breakdown at Harrisburg, Spring 1979, and less dramatically, small radioactive leakages at Windscale and Hunterston, Winter 1978-79 to cite only a few incidents from the last six months). Public opposition and emotion is understandably aroused in the nuclear field because potential hazards are not confined to personnel within the nuclear industry itself but rather threaten the general public in a number of localities. This is apparently in contrast to hazards from conventional enegy sources, where risk is typically confined to industry personnel - rig workers and divers in the case of North Sea oil exploration, coalface workers in the coal industry. Does this mean that the public are safe as far as "conventional" energy is concerned?

In the case of liquefied energy gases (LEG's), ethane (ethylene), propane and butane, all major and useful biproducts from oil and gas separation and refining, and handled in large and growing quantities in the U.K. and abroad, it is increasingly clear that major public hazards are posed. In the U.K. this hazard has sometimes been recognised officially; for instance, planning permission for butane storage tanks at Flixborough has been turned down following the major incident there in 1974 (Department of Employment, 1975), and proposed new liquid gas facilities on Canvey Island are to be resited, following the hazard assessment report for that area (Health and Safety Commission, 1978a). However, apart from such isolated examples of precaution taken it can be argued that hazards posed now far outweight the safety measures adopted.

Concern about public safety can only increase when it is realised that official hazard assessments are usually not undertaken.

The U.K. attitude contrasts quite remarkably with the attitude in other advanced industrialised countries. One may legimately ponder the unfortunate likelihood of Britain awaiting a major disaster (such as the explosion on its way past a holiday campsite in San Carlos, Spain, September 1978, of a 40 tonne liquid gas road tanker, or a repeat of Flixborough, June 1974) before known hazards are officially fully recognised and appropriate safety standards implemented on a comprehensive basis throughout the country. The 1977 official British attitude is reflected in the statement (Scottish Development Department, 1978) that the largest liquefied energy gas berthing installation in the world, and associated gas fractionation plant (both proposed for the Edinburgh region) need not be regarded as major hazard installations.

With the reminder of the lethal properties of liquefied energy gases and of hazard incidents that have occurred in the past, it is instructive to contrast the approach to public safety adopted elsewhere in the world with that currently observed in Britain. In particular, an important objective below is to identify a number of major areas in which current British legislative control and overall hazard knowledge would appear to be seriously inadequate. Recommendations for urgent research priorities required to remedy the apparently weak position thereby exposed are given in a concluding section. The LEG facilities proposed for the Edinburgh region (described in the associated Public Inquiry Report issued by the Scottish Development Department, 1978) provide ready illustration of many of the criticisms offered below.

Some properties of liquefied energy gases

A straightforward summary of the physical properties of LEGs is included here in order to provide an adequate backcloth for public hazard considerations in later sections.

The substances in question are normally (at ambient temperature and pressure) gaseous, but are liquefied for transport and storage since this reduces their volume by between 200 and 600 times. They are maintained as liquids either by refrigeration or pressurisation (see Table 1).

Table 1. Some properties of liquefied energy gases (taken from General Accounting Office, 1978)

Property	Methane	Ethane	Propane	Butane
Boiling point	-263^0	-127^0	-44^0	31^0
Specific gravity	0.466 at -263^0	0.546 at -127^0	0.585 at -49^0	0.601 at 31^0
Vapour density at 32^0 (Air = 1.0)	0.555	1.04	1.56	2.04
Flash point	-306^0	-211^0	-156^0	-76^0
Auto-Ignition temperature	1004^0	950^0	871^0	806^0
Flammable limits (concentration)	5.3-15.0%	3.0-12.5%	2.2-9.5%	1.8-8.4%
Laminar Burning velocity	0.87 mph	0.92 mph	0.98 mph	1.03 mph
Gas-to-liquid volume ratio (Gas at 32^0, liquid at boiling point)	650	410	290	230

All temperatures in degrees Fahrenheit.

Hazard risk arises from the possibility of damage to and leakage from containing vessels, and the overall magnitude of the hazard posed clearly depends on the type and quantity of gas and on the geography of the locality. Thus the nature of nearby installations and infrastructure, the number of people in the vicinity - both industrial personnel and the general public - the prevailing weather conditions and the local terrain can all affect the behaviour of and risk posed by leaked gas. There are, however, a number of properties of these gases that apply universally.

Most of the gases of interest (notably ethane, ethylene, butane and propane) are heavier than air and therefore any escape will tend to hug the ground and not disperse upwards; this contrasts with methane (natural gas), piped via the national network for common use in industry and household appliances. In the case of the heavier gases referred to, any escape will be moved according to the prevailing wind, may be pushed uphill or downhill, and will penetrate any open buildings or underground grids, drains and gutters. Unless efforts are made to disperse any accumulation it can remain for a long time, with the possibility of ignition at a considerable distance from the source of leakage. It is these properties that make these gases so effective in modern warfare, notably the devastating fuel air weapons.

Gas leaked from a punctured container will clearly expand in volume (between two hundred and six hundred times) as it returns to ambient temperature and pressure. In contrast to the storage of other flammable substances, eg. petroleum (where in the absence of pressurisation or refrigeration puncture to the container will only involve leakage above the point of damage), potentially the whole of a given container may be leaked, and not just that above the point of damage.

An "empty" LEG container is still potentially dangerous since in this state the internal pressure is approximately atmospheric and, if the container is damaged or the relief valve is leaking or left open, air can diffuse into the cyliner and may form an explosive mixture with any gas remaining in the cylinder. Leaked gas will be diluted as it mixes with air, and in this state it is reaily capable of combustion - ethylene, for example, burns at concentrations between 10% and 2%. The fact that such small concentrations in air are combustible is partly why the gases in question are potentially so hazardous. Of probably equal significance, however is that the nature of the combustion is uncertain; it could be strong but even burning, or explosive burning with high overpressures in a ferocious and terrifying fireball, depending on the ignition source, the degree of mixing of gas and air within the cloud and the degree of confinement of the cloud. A very small proportion of the gas in air can give rise to an explosive mixture. A rupture of a gas tank resulting initially in intense but quiet burning can suddenly turn into an explosion (sometimes termed a BLEVE - a boiling liquid expanding vapour explosion) as the intense heat from the initial burning suddenly undermines the integrity of the container. This may happen even if the container in question has a pressure relief valve. It is this sudden behaviour that has led fire officers abroad not even to attempt to fight a blaze associated with leaking gas from a tank, but to concentrate instead on evacuating neighbouring areas. The resulting fireball from the explosion of 100 tons of ethylene (the typical load of a single train-wagon) can cause a third degree burn within three seconds to an observer standing a mile away (as in fact happened following the derailment of an LEG train in the United States).

In general the likely behaviour of anything but small volumes (greater than 5 tons) of leaked gas is unknown*; only small scale models have been tested in open atmospheric conditions with larger scale leakages restricted to theoretical analysis and computer simulation. Apart from this acknowledged uncertainty, there are significant differences in view between experts in the field on the nature of likely behaviour. The best course in the interests of public safety would appear to be to accept the most pessimistic of all reasoned views, but this attitude is apparently not echoed in the offices of public servants whose role it is to safeguard the public from undue risk.

Although combustion poses the mostly likely hazard, it would also be possible for a sufficiently concentrated gas cloud to cause suffocation, or, at subzero temperature, to freeze-dry lungs. The gas is colourless, and normally odourless unless odourised before distribution in order to enable detection by smell.

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*Note that even such a "small" spillage, when mixed with air in flammable proportions would be enough to fill more than 77 miles of 6-foot diameter underground sewer line.

Actual incidents and credible accidents involving liquefied energy gases

Liquid gas carrying road tankers have a capacity of up to 40 tons (typically around 30 tons in Britain). Their hazard potential was given such unfortunate and dramatic illustration in the incident at San Carlos in Spain, 1978, when a road tanker exploded on its way past a holiday campsite incinerating over 200 people. This accident could have been much worse if the gas had leaked and spread before igniting. No road accidents involving gas leakages have been recorded in Britain, though danger always threatens; for example at Easter 1979 an "empty" gas tanker left the road and embedded itself in the soft verges en route in the Edinburgh region - the locality was evacuated while the tanker was righted. Rather more significant than the statement that no LEG road hazard has materialised is to observe the rate at which the volumes now carried is increasing. Accident probabilities were naturally low in the past, with relatively small quantities being transported, but the recent increase in volumes carried brings with it an unwelcomed increased in the danger threatened.

There are no restrictions on routes taken by road tankers; they may freely traverse known accident blackspots, busy cities, and so on. Accidents involving road tankers, due to their sheer size, have typically resulted in more damage to other vehicles involved, but the possibility of a gas leakage, burning and/or explosion giving serious hazard threat for some distance from the source (in a rush-hour traffic jam, or on a congested motorway in the fog?) is always present. This is clearly recognised in the U.K. Health and Safety Commission (1976) report (paragraphs 47 and 48):

> "From incidents which have occurred, the possibility of a collision causing the failure of a cargo tank of a gas carrier cannot be ruled out. This could result in a massive escape of highly flammable vapour. The formation of a large vapour cloud could be attended by a massive explosion ... a considerable number of fatalities and injuries could result from such an incident depending when and where the accident occurred.
>
> "Much larger quantities are carried by rail - a typical LPG train consists of ten wagons each containing 60 tonnes of LPG. There is clearly the potential for a serious explosion since fire and explosion of any one wagon might involve the entire train resulting in a large large number of deaths depending when and where the incident took place." (Health and Safety Commission op cit., paragraph 46)

> "In Illinois (U.S.A.) a massive cloud of propane escaped from a train badly damaged by derailment. The train was carrying 800 tonnes of propane which, if the circumstances had been different, could conceivably have killed up to 1,000 people. In this particular incident, subsequent fires and explosions caused damage estimated at $3 million; yet no one was killed or seriously injured, although at least 1,000 of the people at risk were taken to a disaster centre."
> (Health and Safety Commission, 1976, paragraph 14)

The Illinois rail accident summarised here is presumably different from that cited in the General Accounting Office Report (1978), in which there were seven deaths, 349 injuries and $24 million of damage, with the explosion felt 45 miles away. Several other LEG rail incidents are also cited in this report.

> "There is in addition a considerable coastwise traffic in fuel by sea. The ships involved in this trade include foreign registered ships, and a detailed record of accidents is not available. It may reasonably be assumed that there are some fatalities in this traffice."
> (Health and Safety Commission, 1978, paragraph 44)

Accidents may happen in the open sea (a large gas tanker has apparently recently disappeared without trace) but of more immediate concern to the public are accident possibilities in estuaries and near coasts; vessels typically hold anything between 4,000 and 60,000 tonnes of refrigerated liquefied gas and the possibility of their involvement in a collision or running aground cannot be ignored. Major hazards threatened then include a massive and spontaneous explosion (comparable with that seen recently at Bantry Bay, Ireland - caused by sudden ignition of petroleum gas vapour), or a huge leak of gas which may drift and ignite at some distance from its source (35 miles is not a ridiculous estimate of how far such a cloud would drift, though typically it would find a much closer source of ignition). Even if no gas were to escape there is still the problem of how to maintain the integrity of refrigeration plant on a damaged vessel (without which the liquefied gas would boil), and of how to transfer the cargo from a tanker run aground (with no possibility of refloating until the next spring tide, six months hence?). A hypothetical incident involving a grounded tanker in the Forth Esuary is discussed in ADBJAG (1979a,b); the failure leading to this incident is an assumed loss of hydraulic power of one of the pilot tugs*.

*Following the publication of this report and comments from pilots that tugs do not loose power in this way, the first oil tanker to use the new Sullom Voe terminal in the Shetland Isles collided with the jetty, due to a loss in hydraulic power.

Gas handling and processing installations are a further source of hazard. Some spectacular incidents have occurred in the recent past; two modern gas fractionation plants (Qatar and Ab Qaig) have exploded within the last two years destroying all people and plants up to two miles from the explosion source and with damage reported as much as sixteen miles away. Fatalities here were relatively low due to their fortunate location in relatively unpopulated areas. However, elsewhere plants of similar design and operated by the same companies are located within cities, and more are planned for the immediate outskirts of built up areas (for example, those due for the Edinburgh region referred to in more detail below). A repeat of the Qatar or Ab Qaig explosion at one of the latter locations would give rise to a tragedy of unimaginable proportion. And make nonsense of the official 1977 statement that such plants need not be regarded as hazardous installations. The worst incident to date involving liquefied energy gases occurred in Cleveland, Ohio, in 1944, when a liquefied natural gas storage tank ruptured leaving 136 people dead and 77 missing. This accident virtually halted the use of LEGs in the United States for twenty years, and provided a fearful illustration of LEG hazard in populated areas. The U.K.'s worst incident, Flixborough 1974, though severe enough, occurred outside normal working hours, leaving the death toll well below its possible level.

The only available hazard assessment (ADBJAG, 1979a) for the proposed gas fractionation plant and berthing facilities in the Edinburgh region (the Shell/Esso Mossmorran/Braefoot Bay developments described in the associated Public Inquiry Report, Scottish Development Department, 1978) suggests that local villagers face a risk many thousand times the officially accepted risk level for the general public (a probability of death of one in a million a year - roughly the same as the probability of being struck by lightning), and inhabitants four miles away, for instance, would be exposed to more risk than that experience on average by face coal miners. Again these findings can contrast dramatically and with the official 1977 statement quoted in the introduction that these proposed LEG facilities need not be regarded as major hazard installations. Again, hazard is threatened by drifting gas which does not ignite at source; accidental releases of toxic gases which have not given rise to death or serious injury have been reported from abroad. In one case gas literally poured into a valley which was unpopulated; in another the escape occured on the downwind side of a town.

Finally it is necessary to point to the immediate position of liquefied energy gas facilities as prime targets for sabotage and terrorism.

Official safeguards in the handling and transporting of liquefied energy gases

The Health and Safety Executive (and associated with it, the Health and Safety Commission) is the main official body in the United Kingdom with what might be called a "watchdog" responsibility for safeguarding both the general public and industry personnel against inudstrial hazard. It prepares codes of practice on industrial safety and has powers to commission enquiries and hazard surveys, draft regulation on safety and ensure that any existing statutory controls are complied with.

Government departments directly concerned with various aspects of health and safety in relation to LEGs are the Departments of Employment, Environment, Transport, the Home Office and the Scottish Office; relevant reports appear from time to time (some of which are referenced below), calling largely on advice received by the Health and Safety Executive.

The main statutory controls relating to the handling and transshipment of LEGs in the United Kingdom are the 1928 Petroleum (Consolidation) Act, various orders made under the 1974 Health and Safety at Work (etc) Act, the 1972 Liquid Petroleum Gases and Highly Flammable Liquids Regulations, and the 1978 Hazardous Installations Regulations; further Regulations for the transport by road of dangerous goods are in preparation. Rather than summarising particular aspects of the existing controls, it is of greater interest to point out what appear to be a number of major and important deficiencies.

(1) Of the regulations which apply to installations, none are concerned with scrutinising for adequate safety precautions plans for as yet unbuilt facilities. Planning controls in relation to safety are thus effectively absent. It would not be enough, however, simply to introduce planning controls, it would also be necessary to ensure that sufficient expertise existed within the public sector (expertise in what would be a new area of planning control) in order for such controls to be appropriately implemented.

A prerequisite for adequate planning controls would be the preparation of official hazard survey reports for any proposed installations that could be designated "hazardous". Such reports are currently not usually required; instead the current policy in the United Kingdom is to proceed with relevant surveys on a piecemal basis - Canvey and Flixborough have each now been treated on this basis (the former only after significant public pressure, the latter following the explosion of the original plant there). Planning control will remain unsatisfactory, however, until a more comprehensive approach is adopted throughout the country. It should scarcely be necessary to point out that attempts to take short cuts on hazards early on in the planning process pave the way for expensive, perhaps tragic, delays at a later date. Adequate official hazard assessment can reasonably be argued for on efficiency as well as safety grounds.

The full Canvey Island hazard survey report (Health and Safety Executive, 1978) was in fact heralded as a major step forward in official hazard control policy, yet the government has refused to undertake a comparable survey for other potentially hazardous developments (notably those referred to for the Edinburgh region). The unofficial, privately sponsored hazard report referred to earlier (ADBJAG, 1979a) for the Edinburgh area has produced some alarming results, which the government can only answer through its own independent survey; and independent private consultants report has already verified the main findings of the ADBJAG report.

(2) A written hazard assessment is required for any existing designated hazardous installation (note, the previous point dealt specifically with proposed as opposed to existing installations). It is stipulated, however, that this hazard assessment should be prepared by the company who own/operate the installation since the Health and Safety Executive has insufficient resources to undertake the assessment itself. In an earlier discussion (Macgill and McDonald, 1979) this has been likened to motorists conducting their own M.o.T. tests, and prompts the following remarks: (i) it is difficult to be assured that the Health and Safety Executive has resources for a sufficiently full scrutiny of a given industry's hazard assessment when it is readily admitted that it is precisely due to lack of resources that the Health and Safety Executive could not attempt to prepare

the assessment in the first place; (ii) it is difficult to be convinced that since industries' primary interests are so different from those of the general public then their hazard assessment will be sufficiently free of their own bias. It would seem particularly appropriate to raise this question in respect of substances for which there is significant disagreement among experts about their hazard potential. Recent gas fractionation plant explosions abroad have involved modern facilities that had been designed to the highest standards (the plant at Qatar, for instance which suddenly exploded eighteen months ago, completely devastating the area up to a mile away, and causing damage to property sixteen miles away, had been operated for just two years). In the knowledge that Esso were partners in the Qatar plant, the following quotation further undermines confidence in inudstry's own hazard assessment:

> "Esso insist on safe operations or no operations, and they claim there are fewer safer places than one of their manufacturing operations." (Scottish Development Department, 1978)

(3) Certain installations which are officially regarded as being particularly hazardous, notably nuclear energy facilities and explosives plants, can only be operated under licence, whereby written codes of practice for these installations have to be seen to be obeyed and are enforceable by law. The accident record and hazard potential of LEG facilities suggests that these are of a comparable public risk status, and it would therefore seem reasonable to seek a comparable licensing system. A number of disadvantages of such a licensing system are raised by the Advisory Committee on Major Hazards (see Health and Safety Commission, 1976), though a different interpretation may see these as being advantages rather than disadvantages.

> "Firstly, that it usually calls for considerable technical manpower, both on the part of the Company to prepare the detailed technical submissions and on the part of the regulating authority to examine their validity. Secondly, any departure from the conditions of a license must be by permission of the regulating authority in the form of a legal approval or consent; this also takes up manpower. Thirdly, the system almost inevitably tends to transfer responsibility from the Company to the regulating authority."

(4) There is no regulation enforcing operating companies to inform the Health and Safety Executive of malfunctions within their plant, or minor actual hazard (that is, malfunctions, which under alternative, but still credible, circumstances may have led to loss of life or serious injury). This contrasts with proposed road regulations, where vehicle accidents and malfunctions have to be reported, due to their hazard potential, whether or not loss of life or serious injury resulted.

(5) There are no regulations that cover shipping on a comprehensive national basis. Individual port authorities each have their own practices, but there are no comprehensive guidelines applicable to all estuarine and coastal traffic in hazardous goods. Again malfunctions do not need to be reported, and the public is left with inadequate reassurance that appropriate safeguards are being implemented.

The Forth Ports Authority evidence at the Public Inquiry for the Edinburgh proposals (Scottish Development Department, 1977) suggested that most LEG vessels would move during hours of darkness, and there would be no interference with other shipping. This is intriguingly at variance with the practice in, for example, Boston harbour in the United States, where LEG vessels can only move under conditions of perfect visibility, calm sea, and when all other vessels within a radius of two miles have been brought to a halt.

(6) The increasing use of cross country pipelines for transporting hazardous substances has not come under the same degree of scrutiny as, for example, installations and road transport.

(7) The present Public Inquiry system through which planning proposals for new hazardous facilities must currently pass is unsatisfactory. Apart from it being left to objectors to question the degree of public risk involved (it was noted earlier in this section that official hazard assessments are not mandatory, neither are they normally undertaken), the government department(s) in charge of the ultimate decision are not bound to (and in practice, apparently do not) consider hazard evidence that may come to light after the closing date of the Inquiry. This would appear to be quite inappropriate in the case of industries in which new technology is continually being brought into operation; in which recent accident

records elsewhere in the world leave much to be desired, and for which the delay between Inquiry and decision may be one of several years.

> "Verbal reassurances from industry on safety and reliability still apparently carry more weight than all the evidence from recent incidents abroad (including many deaths and serious burns), or than precautions now taken as a matter of course elsewhere in the world."
> (Macgill and McDonald, 1979)

(8) Among the recommendations noted in the closing paragraphs of the official Flixborough Disaster Report (Department of Employment, 1975) is the following paragraph:

> "In any area where there is a major disaster hazard (existing LEG installations are officially recognised as posing such a hazard) a disaster plan for the co-ordination of rescue, fire-fighting, police and medical services is desireable. Although all services appeared to us (The Court of Inquiry) to work satisfactorily at Flixborough we were specifically asked to draw attention to this need. We suggest that the special committee should give consideration to it."

Evidence submitted at the recent Bantry Bay disaster inquiry would suggest that here, for instance, emergency plans were badly inadequate; it is not known how corresponding contingency emergency plans for areas in which LEG installations might operate; it is indeed doubtful whether they exist at all.

(9) It is remarkably easy to find statements in the literature (notably in official publications) pointing to the lack of information on the whereabouts of hazardous materials, on which routes (and in particular the nature of the routes) are used in their transshipment, on the number of near misses from disaster, and so on. Such a gap in official knowledge does nothing to foster reassurance that public safety is being adequately protected; it is apparently not even being monitored. Complacency is easily bred, and it is unfortunate that human nature will almost inevitably choose to wait for a major disaster before taking preventive action.

(10) It is also easy to find statements in the literature to the effect that the behaviour of gas clouds and associated unconfined vapour cloud explosions in ideal theoretical conditions is well understood, but understanding is immediately and seriously undermined in open atmospheric conditions. Although the Advisory Committee on

Major Hazards suggests that caution should therefore be exercised, in relation to the hazard potential of a given quantity of leaked gas the official *status quo* does not echo this view. Thus there is, for instance, no cordon of safety distance applicable throughout the U.K. to liquefied energy gas installations to separate such installations from built up areas. This is in marked contrast to the situation abroad, where in Holland, for instance, a distance of seven kilometres is now being observed for new gas fractionation plants and associated ship berthing facilities.

(ii) A brief case study of LEG facility proposals for the Edinburgh region* undertaken by the author earlier this year in conjunction with an undergraduate field course, gave ready illustration of many of the deficiencies outlined above - a Public Inquiry held two years ago with decision still pending. Hazard not officially considered a priority at the time, and only the barest of evidence therefore called for; verbal reassurances readily accepted. No cordon of safety considered necessary - Cowdenbeath (population over 10,000) within a mile of the proposed fractionation plant, villages of Dalgety Bay and Aberdour (each with a population 4,000) within a mile of berthing facilities; as mentioned earlier, the relevant cordon of safety in Holland is now seven kilometres. Estuarine hazard not the concern of the Health and Safety Executive - it is estuarine hazard potential that has (a) prompted Lothian Council (to the south of the Forth, and not otherwise concerned with the developments) to press for a re-opening of the Public Inquiry on safety ground, and (b) apparently prompted the South of Scotland Electricity Board to review the resilience of proposed Torness nuclear power station (miles away) to withstand an explosion either at the berthing facilities or in the Forth Estuary. An alarming catalogue of LEG accidents since 1977 has finally not, according to the Secretary of State for Scotland, been worth considering as relevant evidence; neither has the weighty General Accounting Office report into LEG hazard - the most thorough and comprehensive research document yet produced in this field.

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*A gas fractionation plant at Mossmorran, near Cowdenbeath, and associated ship berthing facilities at Braefoot Bay.

The three recommendations which open this report are the following:

- Future facilities for storing large quantities of LEG's should be built in remote areas.
- Facilities already in other than remote areas should not be permitted to expand in size or in use.
- Large quantities of LEG's should not be transported through densely populated areas unless delivery is otherwise impossible.

The considerations leading up to these and other recommendations include a much more detailed review of actual incidents and credible accidents involving LEG's than it has been possible to give in the relevant section above, and the interested reader is immediately referred to this report for more information.

Conclusions

The preparation of official advisory reports with respect to the public hazard posed by LEG's would appear to be gathering some momentum, but practical measures to be adopted are still remarkably lacking. Part of the problem may be readily identified in terms of lack of basic information and knowledge, though this alone would need to be supplemented by adequate techniques of hazard assessment in order for sufficiently well balanced and comprehensive planning guidelines to be put into practice. The following research strategy is suggested in order to begin to overcome the inadequate situation regarding LEG hazard control in the U.K. exposed in the above section.

The first priority is to assemble an information bank on various aspects of LEG handling and transshipment; some of this information should be readily obtainable, but some would require more exhaustive effort. The following five areas would seem particularly important ones in which comprehensive information is urgently required.

(i) On the main installations where LEG's are manufactured and stored, noting the quantities involved, various locational aspects of these installations, and any particular precautions that are observed which sites are designated for expansion; the location of proposed new sites.

(ii) On the transshipment routes followed and quantities involved – road, rail and sea; precautions observed (for example, are special routes taken to avoid accident blackspots, congestion or built up areas; is there interference with other traffic); which haulage/ shipping companies are involved (British/foreign).

(iii) A full catalogue of incidents and accidents involving LEG's, both in the U.K. and abroad, noting whether the full hazard potential materialised, and paying particular attention to precautionary recommendations made following any inquiries into these incidents.

(iv) To document any specific local planning practices that are observed; for example, individual Port Authorities may each have their own guidelines for shipping; local councils may similarly have individual codes regarding particular routes through towns.

(v) A continually updated review of the general behaviour of confined vapour cloud explosions, bearing in mind the marked divergence of opinion that is currently apparent among "experts" in this field.

A further major research area is that of quantitative hazard assessment. The existing methodology needs to be reviewed and consolidated, and here the much heralded Canvey report (Health and Safety Commission, 1978a) may be taken as a blueprint. Objections have been raised against using the Canvey study in this way, notably by parties (oil companies wishing to develop LEG sites) whose interests would not be very well served by full quantitative assessment of risk. Hazard assessments could, however, be carried out with respect to all LEG installations, and in addition, some meaningful assessment of transshipment routes. Quantification takes direct account of the physical probability of failure of individual pieces of equipment and containing tanks, the likely volume of release for a given type of failure, the probability of wind blowing in a particular direction, and so on. Results of any quantitative assessment must, however, always be complemented by qualitative appraisal. Actual hazard to materialise from any given type of incident will invariably have a large standard deviation due to the large number of variable factors involved – wind direction and speed, other weather conditions, daily/ seasonal population movements, congestion, uncertainty in the physical probability of equipment failure, and, not least, human error (85% of industrial and of shipping accidents are due to human error).

Finally, planning aspects need to be tackled directly. One may ponder the level of working knowledge of LEG hazard prevalent in various public offices in the U.K., particularly local councils, planners and Port Authorities. In a more constructive vein it would be useful to explore means by which the list of deficiencies in current planning and regulatory practices may be remedied. Considerable progress here may be achieved through an appraisal of planning controls adopted in other advanced industrialised countries such as the United States and the Netherlands where safeguards against public risk are considerably more stringent. This is not to suggest that international comparability is an important goal which should necessarily be aimed for, but rather to invite on open and thorough study of why public hazard practices in countries with similar economic and social values should be so different.

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