**ECONOMIC COMMISSION FOR EUROPE** **INF. 23**

**INLAND TRANSPORT COMMITTEE**

**Working Party on the Transport of Dangerous Goods**

**Joint Meeting of the RID Safety Committee and the Working Party on the Transport of Dangerous Goods**
**(Bern, 20-24 March 2006)**

# PROPOSALS FOR AMENDMENTS TO ANNEXES A AND B OF ADR

## Comments on document TRANS/WP.15/AC.1/2006/12 (France) Marking of Vehicles carrying dangerous goods packed in Limited Quantities

## Transmitted by the Government of the United Kingdom

The United Kingdom notes that France submitted the INERIS report contained in INF.4 of the current session of the Joint Meeting, to the 21st session of the UN of the United Nations Sub-Committee of Experts on the Transport of Dangerous Goods, where several countries questioned the assumptions and findings of the report and its conclusions, including the United Kingdom.

The United Kingdom would like to address some of the assumptions and conclusions of the report. To that end Annex 1 of this paper includes the INERIS report contained in INF 4 with detailed comments from the United Kingdom outlining our concerns.

In the view of the United Kingdom the INERIS report is fundamentally flawed, it is not an extensive or exhaustive study, rather it is a theoretical, paper based analysis of a limited number of dangerous goods in static storage sites, no tests in a transport scenario were carried out. The report does not carry out any practical tests, nor does it look at dangerous goods in transport scenarios.

The report takes as its starting assumption that there are no risks involved in the carriage of dangerous goods in limited quantities. This is a fundamentally flawed assumption - no one has said that limited quantity loads present no risk, but that there is evidence that LQ present significantly reduced risks in comparison to fully regulated dangerous goods loads - a view supported by the research, if not the conclusions, of the INERIS report. It is also worth noting that the INERIS report also appears to assume that limited quantity loads are provided with total exemptions from the regulations; this is misleading as there are packaging and marking requirements in place.

The report analysis is based on RID /ADR 2001 texts and therefore it is largely out of date, following closer alignment of RID/ADR texts with the UN model regulations. Thus large parts of the report and the conclusions are based on out of date practices and expired provisions.

The very limited scientific data used in the report is exclusively based on data in static sites; no data from transport incidents has been used or has been provided, to support the conclusions of the report. No doubt this absence of scientific data is largely due to the relative rarity of incidents involving dangerous goods in limited quantities.

The INERIS study also ignores the work which has been done in the context of Road Tunnels by the OECD/ PIARC group which concluded that limited quantities present a reduced risk and therefore could be excluded from restrictions on dangerous goods in tunnels.

The proposal in 2006/12 (France) cites the INERIS report as justification for changing the existing provisions, however, in the view of the United Kingdom both the report and the proposal fails to demonstrate how any of the proposed changes would reduce risk of accidents.

What is clear is that the French proposal, if adopted, would change the dangerous goods sector irrevocably. The downstream consequences would be that many carriers would refuse to carry limited quantities, forcing a shrinking in the number of carriers, increasing the price of transporting dangerous goods which would doubtless lead to an increase in undeclared and underground dangerous goods.

The enforcement difficulties would beyond doubt increase, it is entirely foreseeable that a carrier stopped with a load of 11 tonnes gross mass of limited quantity goods would be asked to prove to enforcement officials the accuracy of the figure; so in effect the French proposal would impose additional documentation on all loads and for no appreciable safety gain, no reduction in risk and as a result of no cost benefit analysis.

It is for all of the above reasons that the United Kingdom strongly opposes the French proposal and has serious doubts about the validity of the INERIS report on which that proposal is based.

**Annex 1**

**ECONOMIC COMMISSION FOR EUROPE** **INF.4E**

**INLAND TRANSPORT COMMITTEE**

**Working Party on the Transport of Dangerous Goods**

**Joint Meeting of the RID Safety Committee and the**
**Working Party on the Transport of Dangerous Goods**
**(Bern, 20-24 March 2006)**

# Study on the relevance of the system of exemption for the transport of hazardous goods packed in limited quantities

**Transmitted by the Expert from France**

***INERIS***
***INSTITUT NATIONAL DE L'ENVIRONNEMENT INDUSTRIEL***
***ET DES RISQUES***

# Study on the relevance of the system of exemption for the transport of hazardous goods packed in limited quantities.

FINAL REPORT

Ministry of Equipment, Transport and Housing.

DTT / MD

***Certification Division***

*FEBRUARY 2002*

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Mko-R1-337

# Study on the relevance of the system of exemption for the transport of hazardous goods packed in limited quantities.

Final report

Ministry of Equipment, Transport and Housing.

DTT / MD

**FEBRUARY 2002**

**M-A KORDEK**

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# INTRODUCTION

1. The regulations on the transport of hazardous goods, by whatever means, provide for the exemption from the majority of their provisions, in cases where the hazardous goods being transported are packed in limited quantities in combined packaging : indeed, the regulations on the transport of hazardous substances take the view that there is little or no risk for certain hazardous substances once they have been packed in limited quantities.

UK Comment = The report here makes an assumption that dangerous goods packed in Limited Quantities have no risk. This in the view of the United Kingdom is misleading as the Limited Quantities provisions acknowledge a reduced risk, not no risk, for carriage of such dangerous goods.

2. During the discussions which took place during the last biennial meeting of the UN Committee of Experts on the Transport of Hazardous Goods, several representatives of the authorities concerned expressed doubts about the safety of goods tranported under this system of exemption.

UK Comment = This reflects an historical view which does not take into account the changes made to the Limited Quantity provisions.

3. In France, summary analyses carried out on the occasion of recent events (accidents in tunnels) came to the conclusion that goods transported under this system of exemption could present not-inconsiderable risks in the event of an accident.

UK Comment = The OECD / PIARC risk modelling concluded that dangerous goods in Limited Quantities do not pose a significant enough effect to be included within the restrictions placed upon road tunnels.

There has also been no published data by INERIS or any other source, which shows that on the rare occasions there have been accidents involving transport units carrying Limited Quantities that they have contributed any significant affect to the accident.

4. A study has therefore been carried out at the request of the Ministry of Equipment, Transport and Housing – in a letter dated the 15th of June 2001 – which consisted of assessing the consequences of accidents involving loads containing hazardous goods packed in limited quantities in comparison with loads of the same overall size containing goods in cases that do not enjoy the system of exemption for limited quantities.

5. This study sets out to confirm whether or not the assumption that there is no risk in the case of a substance that has been classified as hazardous when it is packed in limited quantities is borne out by the evidence.

UK Comment = This paragraph is misleading as it gives the impression that the study involved practical tests and analysis in transport situations, which it does not.

It is misleading to say that there is an assumption that there is no risk involved in the carriage of dangerous goods in Limited Quantities. Rather it is that for goods in Limited Quantities there is a reduced risk. The United Kingdom is not aware of an assumption that has been made by dangerous goods experts that there is no risk associated with Limited Quantities.

6. This bibliographical study is not exhaustive. It describes examples in order to compare the risk and consequences between the following types of case :

- goods packed in limited quantities that enjoy exemption
- goods packed in large quantities that are subject to all the provisions of the regulations on hazardous substances.

UK Comment = It should be emphasised that this report is only a search and compilation of available literature mainly within the context of static storage facilities. The report does not cover any practical tests to address any transport issues.

# EXEMPTIONS RELATING TO THE TRANSPORT OF HAZARDOUS GOODS PACKED IN LIMITED QUANTITIES

7. This section sets out the exemptions relating to the transport of hazardous goods packed in limited quantities as given in the UN recommendations and in the ADR regulations on road transport.

UK Comment = The report can mislead in its use of the word "exemptions" for Limited Quantities. Rather it is a different set of provisions which apply for goods in Limited Quantities which do include packaging and marking requirements. The title of RID / ADR chapter 3.4 is also perhaps misleading in its use of the word exemptions. The other modes entitle their equivalent sections "Dangerous Goods in Limited Quantities".

8. In this study, the provisions for limited quantities laid down in the regulations on other means of transport have not been taken into account.

## 2.1 UN RECOMMENDATIONS :

9. A hazardous substance may be transported and exempted from the provisions relating to the transport of the specified substance simply by complying with the following provisions :

- Limited quantities :
  - the limited quantity applicable to each substance is specified in column 7 of the list of hazardous substances in section 3 of the UN recommendations,
  - for substances in classes 1, 6.2 and 7, no limited quantity is authorised. Some substances from other classes may also be banned for transport in limited quantities : the word "NONE" is then entered in column 7 of the list of hazardous substances.
- Packaging conditions :
  - Inner packages are placed inside appropriate outer packages. These packages must comply with other provisions relating to their construction. The gross weight of the case must not exceed 30kg.
  - The outer packages may consist of retractable or extensible covers if the inner package is not likely to break or be easily perforated. The gross weight of the case must then not exceed 20kg.

- In class 8, packaging group II, there is a specific provision : if the inner package is fragile (glass, stoneware, porcelain), it must be placed inside a rigid compatible intermediate package.

➢ Provisions to be complied with :
- The same case may contain different hazardous substances packed in limited quantities provided that these substances cannot react with one another in the event of a leak.
- These cases do not have to show any special labelling. It is not necessary to impose, inside a vehicle or a container, provisions for the separation of these hazardous substances.
- The words « in limited quantities » must be added to the description of the consignment.A new provision on labelling appeared in the revised twelfth edition of the UN recommendations (ST/SG/AC.10/1/Rev.12) :

- A lozenge-shaped label must be attached to the case showing the UN number of the hazardous substance that is being transported in limited quantities. If the case contains several hazardous substances, all the UN numbers must be shown.

Moreover:
- Hazardous goods packed in limited quantities and intended for personal use (packaging and distribution by retail sale) are exempted from displaying the official transport description and UN number on the packaging and they are likewise exempted from the requirements concerning the transport document.

## *2.2 ADR*

10. The European agreement on the international transport of hazardous goods by road (ADR) has transposed the exemptions for the transport of hazardous substances packed in limited quantities in the following way :

- A hazardous substance may only be transported and exempted from the provisions relating to that substance in accordance with the following provisions :
- the limited quantity applicable is specified for each substance in Table A "List of Hazardous Goods ". All hazardous substances have been gathered together into limited quantity categories called "LQX": the table below "Table 1"(section 2.4) shows the classes and packaging groups corresponding to each LQ category.
  Each LQ category specifies :

➢ the authorised weight for the inner package
➢ the weight for the outer package

➢ for substances in classes 1, 6.2 and 7, no limited quantity is authorised.
➢ Some substances from other classes may also be banned for transport in limited quantities. All these substances are shown by the code "LQ0" in column 7 of Table A "List of Hazardous Goods" : it should be noted that substances in class 4.2 are not exempted from the provisions of the ADR regulations whatever the quantity per inner package.

- So the provisions to be complied with are :

  ➢ For each LQ category, the nature of the outer package should also be shown.
  ➢ The marking of the case should be as follows :
    - if a single type of hazardous goods is being transported, the UN number is to be affixed, preceded by the letters UN

- if the case contains several different types of hazardous goods, the following information is to be affixed :
  - the UN numbers of all the different types of hazardous goods, preceded by the letters UN, or
  - the LQ letters, where LQ is an abbreviation of "Limited Quantities".
- These various items of information are to be entered on a lozenge-shaped label.

## *2.3 Différences between UN and ADR*

UK Comment = This section is out of date given the changes that have been incorporated into RID / ADR to harmonise with the UN Model Regulations.

11. In the ADR, an assessment of the risks has been made by specifying LQ categories, which take into account the hazards presented by the various classes and, within these classes by making a gradation according to the packaging group : in this way a limited quantity is laid down for the inner package and the outer package.

12. In the UN recommendations, a limited quantity has been specified for the inner package according to the class and packaging group, if there is one. As regards the outer package, the provisions apply whatever the class or packaging group.

13. For each of these two sets of regulations, splitting the hazardous substance into smaller amounts enables it to be exempted from the provisions on the transport of hazardous goods.

14. However, no information is required on the total load of hazardous substances per unit of transport, so it is possible to have large capacity loads of hazardous substances in packages enjoying exemption under the limited quantities system. Such a load could be the same size as a load containing packages of hazardous substances not enjoying exemption under the limited quantities system.

15. We have therefore devoted our attention to the effect of the total quantity of hazardous goods packed in limited quantities on fire and on the environment.

## *2.4 Comparison between the 'UN and ADR :*

UK Comment = This section is out of date given the changes that have been incorporated into RID / ADR to harmonise with the UN Model Regulations.

16. In the following table, the limited quantities laid down in the UN recommendations and in the ADR are compared :

- (1) : column 1 is the LQ category in the ADR,
- column (2) gives details of the class and packaging group relating to this particular LQ category,
- column (3) gives details about the physical state of the substance,
- column (4) sets out the limited quantities per inner package according to the ADR and the UN recommendations. The information in brackets, indicates the quantity per outer package according to the ADR.

- column (5), shows the splitting up into smaller quantities as determined from the values given in the ADR. This splitting up corresponds to the ratio of the limited quantity per outer package to the limited quantity per inner package.

**TABLE 1 :**

| LQ category in ADR (1) | Class, packaging group (2) | Physical state, comments (3) | Quantity : per inner package (per outer package) (4) | | Splitting up into smaller quantities (5) |
|---|---|---|---|---|---|
| | | | ADR | UN | ADR |
| LQ0 | 1, 7, 6.2 | No exemption | 0 | 0 | 0 |
| LQ1 | 2 | Gases * | 120 ml (30kg) | 120 ml | 250 |
| LQ2 | 2 | Gases** | 1 l (30 kg) | 1l | 30 |
| LQ3 | 3, I | | 500 ml (1 l) | 0 | 2 |
| LQ20 | 8, I | Liquid product n.s.a | 100 ml (400 ml) | 0 | 4 |
| LQ21 | 8, I | Solid product n.s.a | 500 g (2kg) | 0 | 4 |
| LQ29 | 9, II | 3 polyhalogenated products | 500 ml (2 l) | 1 l | 4 |
| LQ4 | 3, II | | 3l (12 l) | 1 l | 4 |
| LQ5 | 3, II | Alcoholic drinks 70% by volume | 5 l (X) | 1 l | X |
| LQ6 | 3, II | Vapour pressure at 50°C : 110 / 175 kPa | 5 l (20 l) | 5l | 4 |
| LQ7 | 3, III | | 5l (45 l) | 5 l | 9 |
| LQ8 | 4.1, II | | 3 kg (12 kg) | 0,5 kg | 4 |
| LQ9 | 4.1, III 6.1, III | Solid product | 6 kg (24 kg) | 3 kg | 4 |
| LQ10 | 4.3, II 5.1, II | Liquid product | 500 ml (30 kg) | 500 g | 60 |

Gases* : this category comprises non-flammable and non-toxic gases that only show a single hazardous property and toxic gases with other hazardous properties.

Gases** : this category comprises aerosols and low capacity receptacles containing gases which only possess a single hazardous property.

**TABLE 1 (continued)**

| LQ category in ADR (1) | Class, packaging group (2) | Physical state, comments (3) | Quantity : per inner package (per outer package) (4) | | Splitting up into smaller quantities (5) |
|---|---|---|---|---|---|
| | | | ADR | UN | ADR |
| LQ11 | 4.3, II<br>5.1, II<br>5.2 | Solid product<br>5.2 : solid OP of type D, E, F | 500 g<br>(30 kg) | 500 g | 60 |
| LQ12 | 4.3, III<br>5.1, III | Except UN 1396 : 4.3, II | 1 kg<br>(30 kg) | 4.3, III : 1 kg<br>5.1, III : 1 kg<br>UN 1396 : 500g | 30 |
| LQ13 | 4.3, III<br>5.1, III | Liquid product | 1 l<br>(30 kg) | 4.3, III : 1kg<br>5.1, III : 1 kg | 30 |
| LQ14 | 5.2 | Liquid OP of type B, C. | 25 ml<br>(30 kg) | 25 ml | 1200 |
| LQ15 | 5.2 | Solid OP of type B, C. | 100 g<br>(30 kg) | 100g | 300 |
| LQ16 | 5.2 | Liquid OP of type D, E, F. | 125 ml<br>(30 kg) | 125 ml | 240 |
| LQ17 | 6.1, II | Liquid product | 500 ml<br>(2 l) | 100 ml | 4 |
| LQ18 | 6.1, II | Solid product | 1 kg<br>(4 kg) | 500 g | 4 |
| LQ19 | 6.1, III<br>8, III | Liquid product | 3 l<br>(12 l) | 1 l | 4 |
| LQ22 | 8, II | Liquid product | 1 l<br>(4 l) | 1 l | 4 |
| LQ23 | 8, II | Solid product | 3 kg<br>(12 kg) | 1 kg | 4 |
| LQ24 | 8, III | Solid product | 6 kg<br>(24 kg) | 2 kg | 4 |

| LQ category in ADR (1) | Class, packaging group (2) | Physical state, comments (3) | Quantity : per inner package (per outer package) (4) | | Splitting up into smaller quantities (5) |
|---|---|---|---|---|---|
| | | | ADR | UN | ADR |
| LQ25 | 9, II | Asbestos, Castor-oil plant | 1 kg<br>(4 kg) | none | 4 |
| LQ26 | | | 500 ml<br>(2l) | | 4 |
| LQ27 | 9, III | Solid product | 6 kg<br>(24 kg) | None except UN 3077 : 5 kg | 4 |
| LQ28 | 9, III | Liquid product | 3 l<br>(12 l) | 5 l | 4 |

OP : Organic Peroxides.

A code LQ26 was specified in the ADR, but this code is not assigned to any substance listed in the ADR's Table A "List of Hazardous Goods".

17. It should be noted that :

- alcoholic drinks (70% by volume) (class 3, Packaging group II) are exempted below an inner package quantity of 5l, but there is no limitation on the outer package ; the UN lays down a lower limited quantity of 1l.
- substances in class 4.2 are not exempted from the provisions of the ADR no matter what their quantities,
- substances in classes 4.1, 4.3, 5.1, 6.1 and 9 whose packaging group is I are not exempted from the provisions of the ADR.
- depending on the physical state of the substance, whether solid or liquid, for a substance in the same class and the same packaging group, the maximum authorised quantity under the limited quantity system is always lower in the liquid state than in the solid state.
- In the ADR some substances will have a limited quantity for the inner package greater than that in the UN recommendations, but the package overall will contain a lesser quantity of hazardous substances than under the UN recommendations.

## risk analysis by classes of goods

### *the risk to the environment*

18. There can be a number of different types of risk to the environment, namely :
- air pollution,
- water pollution,
- toxicity for people intervening at the scene of the accident.

UK comment = It is not clear how toxicity for people is a risk to the environment. There appears to be a mix up of class 6.1 substances toxic to humans and what is a risk to the environment. No allowance or comparable analysis has been made to non-dangerous goods which could cause as much or more environmental damage.

19. As regards air pollution, this risk may arise when toxic fumes are given off from a fire: we have not studied this point, as in a ventilated fire the phenomenon of dispersion will limit this risk by comparison with the effects of the fire, which will be studied later in the report.

20. The system of exemption for hazardous substances in limited quantities is not applicable to the goods which come under class 6.1, Packaging Group I, « highly toxic substances". Consequently, the risk of a direct toxic effect for people intervening at the scene of an accident is substantially reduced.

21. We have concentrated more especially on the case of toxic substances which in the event of an accident may harm the environment and in particular the aquatic environment. Some substances are liable to accidental spillage and so the consequences of any such pollution need to be known. Splitting them up into smaller amounts should limit this risk. So we have studied a few examples of the effects of an accidental spillage of these products when packed in limited quantities.

22. The class mainly concerned by this risk is class 6.1, packaging group II (PG II = moderately toxic substances) and packaging group III (PG III = slightly toxic substances).

23. In the remainder of the study, we will analyse the risk according to the degree of toxicity of the substance :
- Moderately toxic substances, PG II,
- Slightly toxic substances, PG III.

## Class 6.1, packaging group II : moderately toxic substances

24. Goods that come under class 6.1 with a packaging group II are "moderately toxic substances". The maximum inner and outer packaging quantities are respectively: 500 ml for the inner packaging, and 2 litres per case, making a total of four bottles per case, when a liquid is involved.

25. In the following examples, we will study the effects on the environment of the spillage of a 500 ml bottle containing a 100% concentrated substance. From the authorised legal contents, we will calculate the amount of water which may be polluted by the accidental spillage of such a toxic product.

## Aniline

26. This substance bears the official description UN 1547, Aniline.

27. According to the European Directive on Classification, Packaging and Labelling, its EC classification (EEC Directive 67/548) is :
- N (hazardous to the environment)
- R50 (highly toxic to aquatic organisms).

28. A concentration that is without toxic effects on the aquatic environment (= PNEC) was put forward in the risk assessment carried out under (EEC) Regulations n° 793/93. It is set at 1.5 µg/l. Above this PNEC, it is assumed that adverse effects on the ecosystem appear.

UK comment = the authors of the report have chosen a substance which is not typical of a Limited Quantity substance. The vast majority of Limited Quantity products are for the end user in consumer quantities not industrial purposes. The PNEC is calculated to be the LC50 divided by a factor of 1000 to act as a safety margin to extrapolate from acute toxicity to chronic toxicity - this factor works only for risk assessment on the basis that there will be a regular discharge of the substance from the same point, this would not be the case for a one off spill. The PNEC is not a valid tool for single accidental spills.

***Volume of water contaminated :***

29. Assuming an accidental spillage into surface water (for example a lake), involving a single bottle containing 500 ml of the substance (i.e. about 500 g with a density of 1.022 at 20 °C), up to 333 350 $m^3$ of water can be contaminated simply by the effect of dilution. Assuming that all 4 containers (that is to say a complete case) break open, up to 1 333 350 $m^3$ of water can be contaminated.

UK comment = The assumption made that all 4 containers would break open, is not reflective of a real life situation. Practical experience within UK industry and UK test evidence shows that it would be extremely unlikely that all inner packagings would fail at one time.

30. A concentration without toxic effects on the working of effluent treatment plants was proposed in the risk assessment. It is set at 100 µg/l for municipal effluent treatment plants not adapted for aniline.

31. Assuming an accidental spillage into the sewers, substantial concentrations can build up at the entrance to the rainwater treatment plant. However, a certain amount of mixing with other liquid waste can be assumed in the settling and aeration tanks. In order to calculate the concentration in the aeration tank, the default values of 2000 m3/d (volume of effluent) and 7.8 hours (hydraulic retention time) proposed in the Technical Guidance Document on risk assessment for chemical substances (EC, 1996) for characterising a municipal effluent treatment plant can be used. [4]

32. Elimination by biodegradation in the aeration tank is not a valid hypothesis since the microorganisms will not have had time to adapt to the substance. The phenomena of adsorption on the activated sludge and volatilization could be taken into account, but can be regarded as negligible in the case of aniline.

UK comment = the default values above would be correct for a small town waste water treatment works for effluent when leaving a home, factory or hospital etc. However, this model was developed for effluent not one off spills as can occur in transport.

33. With 500 ml of the substance (i.e. about 500 g with a density of 1.022 at 20 °C), a concentration of 770 µg/l may be reached in the aeration tank. Assuming that all 4 inner containers break open, a concentration of 3080 µg/l would be reached. In both cases, an adverse effect on the working of the effluent treatment plant may therefore occur.

UK comment = The assumption made that all 4 containers would break open, is not reflective of a real life situation. Practical experience within UK industry and UK test evidence shows that it would be extremely unlikely that all inner packagings would fail. The conclusion on the concentration level which would reach the aeration tank, ignores the rapid biodegradation, chemical interaction with organic waste in the system, rapid adaptation of the micro flora to aniline etc that would occur, and therefore are not reliable or sound conclusions.

## Chloroacetic acid

34. This substance bears the official description, chloroacetic acid in solution, UN 1750 : this substance presents a subsidiary risk : the risk of corrosion. We were principally concerned with the risk of toxicity to aquatic environments.

35. According to the European Directive on Classification, Packaging and Labelling, its EC classification is :
- N (hazardous to the environment)
- R50 (highly toxic to aquatic organisms)

36. A concentration that is without toxic effects on the aquatic environment (= PNEC) was put forward in the risk assessment carried out under (EEC) Regulations n° 793/93. It is set at 0.58 µg/l. Above this PNEC, it is assumed that adverse effects on the ecosystem appear.

37. Assuming an accidental spillage into surface water (for example a lake), involving 500 ml of the substance (i.e. about 790 g with a density of 1.580 at 20 °C), up to 1 362 000 $m^3$ of water can be contaminated. Assuming that all 4 containers break open, up to 5 448 000 $m^3$ of water can be contaminated.

38. A concentration without toxic effects on the working of effluent treatment plants was proposed in the risk assessment. It is set at 1600 µg/l for municipal effluent treatment plants.

39. Elimination by biodegradation in the aeration tank is not plausible since the microorganisms will not have had time to adapt to the substance. The phenomena of adsorption on the activated sludge and volatilization could be taken into account, but can be regarded as negligible for chloroacetic acid.

40. With 500 ml of the substance (i.e. about 790 g with a density of 1.580 at 20 °C), a concentration of 1215 µg/l may be reached in the aeration tank. Assuming that all 4 containers break open, a concentration of 3645 µg/l would be reached. In this second case, an adverse effect on the working of the effluent treatment plant is possible.

UK comment = The assumption made that all 4 containers would break open, is not reflective of a real life situation. Practical experience within UK industry and UK test evidence shows that it would be extremely unlikely that all inner packagings would fail at one time. Chloroacetic acid degrades rapidly in the environment and will very quickly lose its biological activity on dilution. Like aniline, the risk assessment models set up for steady discharge from factories do not apply to the transport of dangerous goods.

## Class 6.1, packaging group III : slightly toxic substances

41. Goods that come into class 6.1 with a packaging group III are "slightly toxic substances". The maximum inner and outer packaging quantities are respectively :3 litres and 12 litres

## Trichloroethylene

42. This substance bears the official description, trichloroethylene, UN 1710.

UK comment = the authors of the report have chosen a substance which is not typical of a Limited Quantity substance. The vast majority of Limited Quantity products are for the end user in consumer quantities not industrial purposes.

43. According to the European Directive on Classification, Packaging and Labelling of hazardous substances, its EC classification is :
- R52/53 (noxious to aquatic organisms, may lead to harmful long-term effects)

44. A concentration that is without toxic effects on the aquatic environment (= PNEC) was put forward in the risk assessment carried out under (EEC) Regulations n° 793/93. It is set at 115 µg/l.

45. Assuming an accidental spillage into surface water (for example a lake), involving 3 litres of the substance (i.e. about 4395 g with a density of 1.465 at 20 °C), up to 38 200 $m^3$ of water can be contaminated. Assuming that all 4 containers break open, up to 152 800 $m^3$ of water can be contaminated.

UK comment = The assumption made that all 4 containers would break open, is not reflective of a real life situation. Practical experience within UK industry and UK test evidence shows that it would be extremely unlikely that all inner packagings would fail.

46. A concentration without toxic effects on the working of effluent treatment plants was proposed in the risk assessment. It is set at 1300 µg/l for municipal effluent treatment plants.

47. Elimination by biodegradation in the aeration tank is not plausible since the microorganisms will not have had time to adapt to the substance. The phenomena of adsorption on the activated sludge and volatilization could be taken into account. For trichloroethylene, an elimination by adsorption and by volatilization of 92% is estimated by the SIMPLETREAT model as proposed by EC (1996) [4].

48. With 3 litres of the substance (i.e. about 4395 g with a density of 1.465 at 20 °C), a concentration of 540 µg/l may be reached in the aeration tank. Assuming that all 4 containers break open, a concentration of 2160 µg/l would be reached. An adverse effect on the working of the effluent treatment plant is therefore possible in the second case.

UK comment = The assumption made that all 4 containers would break open, is not reflective of a real life situation. Practical experience within UK industry and UK test evidence shows that it would be extremely unlikely that all inner packagings would fail at the same time.

## Tetrachloroethylene

49. This substance bears the official description, tetrachloroethylene, UN 1897.

50. According to the European Directive on Classification, Packaging and Labelling of hazardous substances, its EC classification is :
- R51/53 (toxic to aquatic organisms, may lead to harmful long-term effects)

51. A concentration that is without toxic effects on the aquatic environment (PNEC) was put forward in the risk assessment carried out under (EEC) Regulations n° 793/93. It is set at 51 µg/l.

52. Assuming an accidental spillage into surface water (for example a lake), involving 3 litres of the substance (i.e. about 4870 g with a density of 1.623 at 20 °C), up to about 95 500 $m^3$ of water can be contaminated. Assuming that all 4 containers break open, up to 382 000 $m^3$ of water can be contaminated.

UK comment = The assumption made that all 4 containers would break open, is not reflective of a real life situation. Practical experience within UK industry and UK test evidence shows that it would be extremely unlikely that all inner packagings would fail at the same time.

53. A concentration without toxic effects on the working of effluent treatment plants was proposed in the risk assessment. It is set at 11 200 µg/l for municipal effluent treatment plants.

54. Elimination by biodegradation in the aeration tank is not assumed since the microorganisms will not have had time to adapt to the substance. The phenomena of adsorption on the activated sludge and volatilization could be taken into account. For tetrachloroethylene, an elimination by adsorption and by volatilization of 93.4% is estimated by the SIMPLETREAT model as proposed by EC (1996).

55. With 3 litres of the substance (i.e. about 4870 g with a density of 1.623 at 20 °C), a concentration of 494 µg/l may be reached in the aeration tank. Assuming that all 4 containers break open, a concentration of 1978 µg/l would be reached. An adverse effect on the working of the effluent treatment plant is unlikely in either case.

UK comment = The assumption made that all 4 containers would break open, is not reflective of a real life situation. Practical experience within UK industry and UK test evidence shows that it would be extremely unlikely that all inner packagings would fail at the same time.

## Conclusions on the risk to the environment

56. In the case of the two moderately toxic substances from packaging group II chosen above, risks to effluent treatment plants have been demonstrated for both of them. Probable contamination effects on large quantities of surface water have also been quantified (> 1 000 000 $m^3$).

UK Comment = The risks to the effluent treatment plants described above are purely theoretical based on the assumption that the contents of the Limited Quantity packages were poured directly into the water works not allowing for a dilution effect. If there is a risk - than logic would dictate a change in the Limited Quantity provisions to LQ0 (i.e. not permitted) for the particular goods mentioned above. But it is fundamentally flawed to use this research based on chemical supply risk assessment models to read across to transport. To accept the proposals in 2006/12 (France) would do nothing to remove the risk or improve the situation as described above as the risk to the environment would remain the same irrespective of documentation or marking requirements.

57. In the case of the two slightly toxic substances from packaging group III chosen above, risks to effluent treatment plants have been identified for only one of the substances. Probable contamination effects on smaller quantities of surface water have also been identified (< 1 000 000 $m^3$).

58. The above exercise needs to be repeated on a higher number of substances, but it is clear here and now that the spillage of even the small quantities connected with the limited quantities system is liable to have serious consequences on the aquatic environment, especially the moderately toxic substances from packaging group II.

UK comment = There is no indication that the proposals in 2006/12 (France) would substantially reduce the risk of accidents or reduce the number of spillages or lead to improvements in diagnosis of the spillage. Indeed consequences from larger non Limited Quantity packages spillages could be much higher.

59. These consequences are comparable to the effects of quantities close to 1000 litres of ecotoxic substances that are destined to be regulated in the context of the transport of hazardous goods. (LC50 <1mg/litre).

## *The "corrosion" risk*

60. No information about this risk was found in the literature.

UK comment = No data has been presented to indicate that there is evidence of a problem with dangerous goods carried in Limited Quantities.

61. In the UN recommendations, substances in class 8 with a packaging group II and III are the ones which can be exempted from the provisions of the regulations on transport when they are packaged in limited quantities.

62. On the other hand, the regulations on transport by land (ADR) authorise substances in class 8 with a packaging group I to be transported in limited quantities.

UK comment = RID / ADR no longer allows Class 8 Packing Group I in Limited Quantities, therefore the above statement is no longer applicable.

63. Even in limited quantities of 100 ml, which is the value for class 8 packaging group I, this quantity is sufficient to cause skin damage to any person touching a case containing a bottle of this substance which might leak or be broken : indeed, these substances act rapidly, destroying whole thicknesses of tissue within 60 minutes.

64. No precautions are likely to be taken when loading or unloading this case, since no warning will appear on it. In fact, it is not compulsory to affix information on the cases about the classification and labelling of their contents.

UK comment = The above statement is not true for ADR. The Limited Quantity provisions require marking of all Limited Quantity packagings with their UN number (3.4.4. (c) or letters "LQ"). Therefore the presence of dangerous goods will be clearly indicated.

65. For the substances in class 8 that belong to packaging groups II and III, this risk is smaller : these substances destroy skin tissues over a period of several days.

UK comment = This is a fundamental misunderstanding of the classification criteria, the observation period is over days, but the exposure period is within minutes and hours.

66. Except in the event of a problem during transport, principally during loading and unloading, any intervention will only be of short duration. However it is important to note that once it has begun, the destructive action on the tissues may continue even after the period of direct exposure ceases.

67. It is also important to remember that certain substances in this class 8 may present other subsidiary risks such as toxicity.

68. The analysis of this risk would then proceed as studied previously (see section 3.1).

### *The "fire" risk :*

69. Even though the scope of this study is limited to hazardous substances in the conventional sense of the term, an examination of the fire risk must go beyond the notion of substances that are generally considered flammable, as listed in class 2, 3 or 4.

70. In fact, the potential scale of a fire initially involving flammable hazardous substances in limited quantities will be conditioned by the combustibility of many other components as the scenario unfolds : packaging, outer packaging, materials from which the trailers are made, as well as the presence of fuel used by the tractor units (the tank may contain up to 1,500 litres).

UK comment = The above statement only confirms that combustible materials burn, which would also include furniture or vegetable oil. It does not demonstrate that dangerous goods and especially Limited Quantity packages are initiators of incidents.

71. However, we have concentrated more especially on studying the "fire" risk with regard to two classes for which the consequences of this risk are considerable :

- class 2 : and within class 2 we have devoted our attention more especially to a particular object, namely : aerosols. In fact, when these aerosols are designed as consumer goods, the quantity per aerosol is often the value corresponding to the limited quantity value: the last provision of the section on exemptions relating to the transport of hazardous goods applies for this type of substance.

UK comment = The above statement is incorrect. In practice an aerosol of 1 litre is very rarely used. The Aerosol Directive (75/324) stipulates a maximum content of 750ml. Even these large aerosols are very unusual with the vast majority under 450ml.

- class 3 : flammable liquids are also often packaged in limited quantities when they are then used as consumer goods.

## Class 2 : the example of aerosol dispensers [1]

## Description of aerosol dispensers :

72. Aerosol dispensers bear the official description "AEROSOL" and the UN number, 1950.

73. There are several types and they are distinguished by their classification code : this code represents the group of hazardous properties associated with the object.

74. These types of object are not subject to the provisions of the ADR if conditions LQ1 and LQ2 are satisfied :

-LQ1 : the maximum quantity in the inner package is 120 ml : the property that these aerosol dispensers have in common is their toxicity which is indicated in their classification code by their T letter and they have a classification code that contains several letters in addition to the T for toxicity.

-LQ2 : the maximum quantity in the inner package is 1 litre : these aerosol dispensers have a classification code containing a single letter which defines the hazard group to which they belong : asphyxiants A, oxidants O or flammable substances F but they are not toxic T.

## Description of the aerosols tested:

75. In order to estimate the effects and consequences of a fire involving aerosol dispensers stored in a storage area, fire tests were recently carried out by INERIS.

76. For our study, we repeated these tests and used them in the case of the transport of aerosol dispensers. Indeed this type of object is often transported on pallets in lorries. Therefore the behaviour of such objects in a fire in transit will be identical to that observed in the case of a fire affecting a storage area: indeed, the packaging is identical and is retained for storage after the transport stage.

UK comment = There appears to be some inconsistencies between the French and English texts. In the English text the tests were repeated for the INERIS report, but in the French text they do not appear to have done so. It is therefore unclear if the report is based upon test data or

a paper research exercise. No test data or comparison with a control has been submitted. However, what is clear is that INERIS have made an assumption that the goods will act in the same way in a fire in a storage facility to a fire in a transport situation. No test data or use of a control has been submitted to support this view.

77. Among the aerosol dispensers commonly to be found on the market, and therefore transported, are the following :

- Hair spray : capacity 360ml
- Deodorant : 200ml
- Insecticide : 500 ml

78. These aerosols come into the category of non-toxic aerosols. They belong to the LQ2 group : their overall capacity is well below that set out in the table.

79. The componants of these aerosol dispensers are often flammable products such as LPG, ethanol, butane, …..(since CFCs were banned).

UK comment = Since 1989 95% of aerosols have contained Butane or other flammable gases.

80. These aerosol dispensers are contained in cardboard boxes, which may be stacked on a pallet. The number of such dispensers in the boxes varies from 1 to a few multiples of ten.

81. One transport unit may comprise several pallets and therefore a considerable number of aerosol dispensers: the pallets may be arranged on two levels.

82. In these tests, the fire was started by setting fire to alcohol in tanks beneath each pallet at ground level: this type of scenario is similar to what could happen with a sheet of fuel leaking from the vehicle's tractor unit in the event of an accident followed by a fire.

UK comment = Limited detail on the type and results of the test has been supplied. The use of Alcohol in the test seems at odds with the transport situation, where a diesel fire would be a more likely occurrence, which of course has a higher flashpoint than alcohol and would be less likely to start a fire and less likely to sustain a fire. So the conclusions should not be drawn across from a storage scenario to a transport one.

83. During the transport stage, fire represents the main risk with this type of cargo.

## Their behaviour in the event of a fire :

84. During tests simulating a fire in a storage facility containing this type of object packed in cases, the following sequence of events took place :

- all the dispensers exploded, one after another over a period of several minutes,
- debris from the dispensers was hurled about,
- the flammable substances contained in the formulation burst into flames, in the form of a fireball which, at the height of the fire, was almost continuous above the seat of the fire.

UK comment = The scenario of a fire in a storage facility will not reproduce the same conditions or results as that of a transport scenario, for example there is unlikely to be a chimney effect in a transport unit, whereas there is likely to be one in a storage facility.

Experience within the UK of the 1.3 billion aerosols moved annually, has shown that it is very unlikely that all the aerosols would go at the same time, rather they would go one after another, a clear advantage of having limited quantity provisions rather than one large container.

The test configurations and the results obtained are shown in the following table : UK comment = No control was used within the tests and no comparison was made to how non dangerous goods like margarine or vegetable oil would behave.

| N° | Type of dispensers | combustion heat (MJ/kg) | Number of pallets | combustion energy 200kg/pallet | Mean flow value * KW/m2 | Total duration of the fire In seconds | Mean dimensions of the flames L = length, H = height, L = width |
|---|---|---|---|---|---|---|---|
| 1 | DME-based hair spray (360 ml) | 2.85 | 3 | 17100 | 10 | 200 | L = 9 m ; l = 3 m ; H = 7 m |
| 2 | DME-based hair spray (360 ml | 28,5 | 6 | 34200 | 18 | 250 | L = 11 m ; l = 4 m ; H = 12 m |
| 3 | DME-based hair spray (360 ml | 28,5 | 9 | 51300 | 40 | 240 | L = 13 m ; l = 5 m ; H = 15 m |
| 4 | LPG-based deodorant (200 ml) | 34 | 6 | 40800 | 30 | 270 | L = 11 m ; l = 4 m ; H = 12 m |
| 5 | Insecticide ( 500 ml) with 57% water and 36% LPG | 18 | 3 | 10800 | 4 | 240 | L = 9 m ; l = 3 m ; H = 7 m |
| 6 | Cleaning foam (500 ml) with 61% water and 7% butane | 7,5 | 6 | 9000 | 1,5 | - | The fire did not take hold |

* : maximum value of the mean thermal flow measured at a distance of 10m. 20/4

85. When a fire breaks out in a system containing several boxes and therefore several dispensers, it is characterised by a very rapid development and by an intense radiation of the flames : there is a succession of BLEVEs ( = Boiling Liquid Expanding Vapour Explosions). Each BLEVE corresponds to a single dispenser and gives rise to the appearance of a fireball measuring between 1 and 2 m in diameter, depending on the unit volumes involved. A BLEVE lasts less than 1 second.

86. At the height of the fire, BLEVE's are occurring at such a rate that several take place at the same time : the resulting fireball takes the form of a wall of flame the dimensions of which are proportional to how many BLEVEs occur at the same time.

87. The dimensions of this flame are found to be linked to the number of aerosol dispensers involved, and to the available combustion energy.

88. However, the scale of the thermal effects of this flame remains well below that of the fireball which would result from the instantaneous BLEVE produced by all the products contained in the dispensers : splitting up into smaller amounts and therefore the notion of limited quantities are justified as they make it possible to reduce the consequences of a fire.

UK comment = The United Kingdom fully supports this conclusion which endorses the reduced risk provided by carriage of goods in Limited Quantities.

## The thermal flow during a fire

89. From the time of the first explosion which occurs within slightly less than 1 minute after the start of the test, the mean thermal flow increases with instantaneous peaks of thermal flows of varying intensity.

90. The mean thermal flow reaches a maximum value at the height of the fire then this mean flow decreases as the fire diminishes in intensity. This thermal flow dies out as the explosions become more widely spaced out.

91. One of the parameters affecting this thermal flow value is the combustion heat of the product : the higher the combustion heat, the higher the thermal flow measured. (Table 2, section 3.3.1.3)

92. Moreover, the combustion heat is closely linked to the formulation contained in the aerosol dispensers : an aerosol dispenser which has a significant water content will have a lower combustion heat than an aerosol dispenser which only contains flammable constituents.

93. During tests in an unconfined environment, no excessive air pressure waves were produced.

## Conclusions about the fire risk posed by aerosol dispensers:

94. The effects produced by a fire involving aerosols in « limited quantities » (within the meaning of the standard regulations) are by no means negligible, although less

substantial than those generated by the total mass of the contents if they had been placed in a single container.

UK comment = The United Kingdom fully supports this conclusion which endorses the reduced risk provided by carriage of goods in Limited Quantities.

95. Indeed, the power of the fire, the radius of action of the flames and the debris hurled about would be likely to considerably impede the actions of the emergency services in the event of an accident.

UK comment = No comparison has been made to how non-dangerous goods would behave in the same scenario. The proposals in 2006/12 (France) would do nothing to remove this risk or improve the situation as described above.

96. The presence of outer packaging in cases where there is combined packaging has virtually no effect on the consequences of a fire.

UK comment = This conclusion contradicts the conclusion drawn on page 23, that outer packaging is indeed a factor.

97. Finally, in the case of aerosols whose contents have a low combustion heat, the consequences are attenuated.

## Class 3 : flammable liquids [2, 3]

98. Class 3 : flammable liquids as defined by UN recommendations are liquids, mixtures of liquids or liquids containing solids in solution or in suspension (for example : lacquers, paints, varnishes, etc,… excluding however substances that are classified elsewhere because of their other hazardous properties) which give off flammable vapours at a temperature not exceeding 60.5°C in a closed test (or 65.6°C in an open test).

99. They can be transported in limited quantities without applying the provisions of the ADR if the inner package has the following maximum quantity:

- for liquids assigned to class 3 and whose packaging group is I : 0.5 l for the ADR and "none" for the UN recommendations.
- for liquids assigned to class 3 and whose packaging group is II : 5 l or 1 l for the ADR and 1 l for the UN recommendations.
- for liquids assigned to class 3 and whose packaging group is III : 5 l for the ADR and 5 l for the UN recommendations : with the maximum quantity per case being 45 l for the ADR.

UK comment = The above information is outdated and therefore not relevant.

100. There are no tests mentioned in the literature that are specific to this class of substance in terms of packaging for transport. So, in order to assess these exemptions, we studied the results of fire tests on this class : these tests were carried out in order to assess fires affecting storage facilities containing pallets of these kinds of substances packed in various containers, whether stored in cardboard boxes or not and on the basis of the overall quantity.

101. These tests were carried out by several companies or bodies such as :

- Factory Mutual Research ,
- "National Fire Protection Research Foundation",
- "American Iron and Steel Institute",
- "Distilled Spirits Institute",

UK comment = The above tests were all carried out in storage not transport scenarios. It is not appropriate to assume the worst case scenario for storage and then apply it categorically to transport. Of the few road traffic accidents involving transport units carrying dangerous goods within the UK, within the last twelve months, there have been no incidents of significant damage or spillage.

in order to be able to issue recommendations for the storage of flammable and combustible products. We used the tables of results published by these companies in order to analyse them in relation to the fire risk as applied to transport.
The tests selected to be used in our study are those in which the fire – in the majority of cases – was uncontrolled even in the presence of sprinkler systems : indeed, in a transport unit, there is no prevention system (set of sprinklers) to limit any outbreak of fire.
So, the conditions and consequences which most closely resemble a fire in a transport unit are those applicable to the tests where no sprinkler system was used or where the fire took hold even with the use of a set of sprinklers.

## The test conditions

102. For our study, we only took into consideration the following parameters :
- the nature of the product,
- the type of container and its capacity,
- the outer packaging.

103. During these tests, the layout of the pallets and the siting of sprinkler systems installed for safety purposes (type of sprinklers and configuration,…) were also studied : this type of test serves to determine the optimum position and operating conditions of sprinkler systems in storage facilities.

104. The substances tested were :
- heptane,"HEPTANES", UN 1206, class 3, PG II,
- 99% isopropyl alcohol, "ISOPROPANOL", UN 1219, class 3, PG III
- Ethyl alcohol,"ETHANOL or ETHANOL IN SOLUTION", UN 1170, class 3, PGE II or III,
- paint thinner, "PAINT or SUBSTANCES SIMILAR TO PAINT", UN 1263, class 3, PG I, II and III.
- kerosene, "KEROSENE", UN 1223, class 3, PG III,
- a 50/50 water-alcohol mixture,"ETHANOL or ETHANOL IN SOLUTION", UN 1170, class 3, PG II or III,

The letters "PG" correspond to the Packaging Group.
The following capacities were tested :
- 1 gallon : 3.79 litres
- 5 gallons : 18.92 litres

- 1 quart : 0.95 litres
- 1 pint : 0.47 litres.
- 16 oz : 480 ml
- 8 oz : 237 ml

The containers were of the following kinds :
- metal receptacles (for large capacity cans (5 gals), the metal receptacles are fitted with a polyethylene cap)
- plastic cans,
- glass bottles.

Depending on the nature of the containers, the test fires were started up in different ways. This will be indicated for each substance tested.

## Tests on heptane :

105. The tables below show the tests carried out on this product in two different kinds of containers with different capacities.

106. Heptane is a substance that comes into class 3, PG II :
- the limited quantity per inner package is 1 litre both for the ADR and for the UN recommendations.

107. The fires for all these tests were started in the same way : about 40 litres of heptane were poured out and then set alight. Whatever the capacities used, all the containers tested were metallic.

### *Tests on containers governed by the regulations on the Transport of Hazardous Substances*

108. The first series of tests corresponded to an inner package size in excess of the limit which defines the limited quantity. This type of packaging must comply with the provisions of the regulations on transport.

109. According to these tests, it was found that :
- for tests S7 to S12 with the exception of S11, thanks to the sprinkler system, the fire was brought under control and there was no damage. These sprinkler systems came into operation between 35 and 40 seconds after the fire started.
- for test S11, when the same sprinkler system was installed, but for a larger overall quantity, as a result of the overall height of the pallets being higher, the fire was not brought under control.

110. Fires involving heptane, in containers of about 4 litres and making up overall quantities of about 600 to 6000 litres, were brought under control in storage facilities by means of sprinkler systems (which came into operation 40 seconds after the fire started) : in a transport unit however this type of safety device does not exist : it would not be possible to bring the fire under control since, as in test S11, the containers would burst open and allow the liquid to burn.Moreover, the coming into operation of the sprinkler systems is closely linked to the start of the fire : this indicates the speed of a fire involving this type of substance.

UK comment = these tests appear to be more about the effectiveness of sprinkler systems than carriage of limited quantities.

111. These tests clearly show the speed of a fire involving this type of substance and underlines the importance of regulations for these large capacities.

UK comment = This conclusion is in line with the principle of fully regulating in RID / ADR the larger volume of dangerous goods, however, the test showed nothing about Limited Quantities in transport.

***Comparison of the behaviour according to the packaging***

112. For tests S40 and S41, it was found that the bigger volume containers were less fire-resistant than those with a smaller capacity : in fact, the 0.95 l cans were less damaged than the 3.79 litre ones. Therefore splitting up this hazardous substance into smaller amounts helps to limit the effects : a value of 1 l for heptane represents the correct value.

UK comment = The United Kingdom fully supports this conclusion which endorses the reduced risk provided by carriage of goods in Limited Quantities.

113. In test 48, the sprinkler system came into operation after 2 minutes 47s : the 0.95 l containers at the top of the pyramid exploded even when the sprinkler system had started up. Even if the risk is reduced, it is still there, and so are the consequences.

UK comment = This in the view of the United Kingdom is misleading as the Limited Quantities provisions provide a reduced risk, not no risk, for carriage of dangerous goods.

***Effect of the outer packaging***

114. When one looks at the results of tests S13 and 15, the 20 litre cans were more heavily damaged as a result of a fire than the smaller capacity (5 litre) cans: the smaller capacity (5 litre) cans were packed in boxes, whereas the 20 litre cans did not have any outer packaging. These tests show the importance of the outer packaging in a fire (an extra barrier to the spread of the fire)

UK comment = The tests clearly show that the Limited Quantities provisions, which require an outer packaging and are of smaller size, would be more effective in a fire than the fully regulated packages.

***Effect of the material from which the container is made***

115. If we compare the behaviour of heptane in a fire when packed in plastic containers, we find that there was a tendency for the fire to spread, which was not the case when it was packed in metal containers : a sheet of liquid formed and then caught fire.

116. In test P6-2, 50% of the goods burned after the HDPE cans melted and allowed the heptane to escape. This phenomenon moreover was accentuated by the fact that this test was carried out on cans that had not been placed in any kind of outer packaging.

UK comment = The tests were not carried out in packaging that would meet the limited quantity packaging provisions which stipulate a requirement for outer packaging, therefore the test results would be misleading if read in the context of limited quantities, as the outer packaging would slow down the spread of the fire.

| REF. | NATURE OF THE CONTAINER | OUTER PACKAGING | TOTAL QUANTITY In litres | SUCCESS IN CONTROLLING THE FIRE | COMMENTS |
|---|---|---|---|---|---|
| P6-2 | HDPE jerrycan 5 gal (18.2 l) | None | 606 | FNC | The containers burned, melted and allowed the heptane to escape.<br>Even with sprinkler : 50% loss : |
| S7-3 | Metal container 1 gal : 3.79 l | Ordinary cardboard box | 606 | FC | Only the cardboard boxes burned.<br>The heptane was not involved. |
| S8-5 | Metal container 1 gal : 3.79 l | Ordinary cardboard box | 1817 | FC | Only the cardboard boxes burned.<br>The heptane was not involved. |
| S9-9 | Metal container 1 gal : 3.79 l | Ordinary cardboard box | 3634 | FC | Only the cardboard boxes burned.<br>The heptane was not involved |
| S10-11 | Metal container 1 gal : 3.79 l | Ordinary cardboard box | 5450 | FC | Only the cardboard boxes burned.<br>The heptane was not involved |
| S11-12 | Metal container 1 gal : 3.79 l | Ordinary cardboard box | 7267 | FNC | The cardboard boxes burned.<br>15 empty containers: burst open violently |

FC : Fire brought under control ; FNC : Fire not brought under control.

| | | | | | |
|---|---|---|---|---|---|
| S12-13 | Metal container,<br>1 gal : 3.79 l | Ordinary cardboard box | 6056 | FC | Only the cardboard boxes burned.<br>The heptane was not involved |
| S13 | Metal container,<br>1 gal : 3.79 l in cardboard box<br>5 gal : 18.92 l | Cardboard box<br><br>No packaging | 3331 | FNC | 5 gal container: bulging and emptying through melted PE cap<br>1 gal container: bulging and one container split open violently |
| S15 | Metal container,<br>1 gal : 3.79 l in cardboard box<br>5 gal : 18.92 l | Cardboard box<br><br>No packaging | 5299 | FC | 24 of the de 5 gal containers came open as a result of the PE cap melting |
| S40-11 | Metal container,<br>1 gal : 3.79 l in cardboard box<br>1qt : 0.95 l | Containers in secondary packaging: cardboard boxes | 4156 | Fire suppressed | None of the containers burst open. |

FC : Fire brought under control ; FNC : Fire not brought under control.

| | | | | | |
|---|---|---|---|---|---|
| S41-12 | Metal container,<br>1 gal : 3.79 l in cardboard box<br>1qt : 0.95 l | Containers in secondary packaging: cardboard boxes | 4550 | FNC | 3 of the (1 gal) containers broke open and 40 to 50 containers were damaged.<br>Three containers came open and 15 to 20 were leaking. |
| S48 | Metal container,<br>5 gal : 18.92 l<br>1 gal : 3.79 l<br>1qt : 0.95 l | No outer packaging | 757 | FNC | The 1 litre cans were placed at the top of the pyramid of cans: consequently, several cans would have broken open due to falling.<br><br>Several 0.95 l cans exploded even after the sprinkler system had come on (that is to say after 2 minutes 47s). |

FC : Fire brought under control ; FNC : Fire not brought under control.

UK comment = The above packages do not meet the packaging requirements laid down by the limited quantity provisions and in some cases the volume of dangerous goods far exceeds the volumes allowed under the RID/ADR limited quantity provisions.

## The case of isopropyl alcohol :

117. The tables below show the tests carried out on this product in two different kinds of containers with different capacities.

118. Isopropyl alcohol or isopropanol is a substance that comes into class 3, PG II or III :
- the limited quantity per inner package is 1l both for the ADR and for the UN recommendations : it is only classifed in packaging group II.

119. The fire was started using rolls of cellulose soaked in a flammable liquid (a few hundred ml) or with isopropyl alcohol (10 l) in tanks.

***Tests on containers which are subject to the regulations on the Transport of Hazardous substances***

120. The first three tests (P4, P5, P16) were carried out for containers whose capacity was greater than that below which exemptions for limited quantities are applicable. For these three tests, the overall quantity was similar. The parameter which varied was the outer packaging : only one type of packaging which was specifically fire-resistant made it possible to limit the damage : these tests were characterised by the formation of a sheet of liquid. It was also found in the case of the non-fire-resistant types of outer packaging that the fire very quickly became out of control in spite of the fact that the sprinkler systems had come into operation above the pallets.

UK comment = The above tests simulate what would happen in a storage facility, not a transport scenario. In a transport scenario, foam rather than water would routinely be used, which would have a different impact to that of water.

121. These tests showed the importance of special measures with regard to the packaging of these kinds of substances when they are transported in quantities in excess of the limited quantities.

UK comment = The above conclusion would equally apply to any combustible product, not just dangerous goods.

***Tests on containers which are not subject to the regulations on the Transport of Hazardous Substances***

122. Tests P32, P34 and P35 were carried out on low-capacity cans: 1 quart: 0.95 l. It was found that whatever the overall capacity, by bringing the sprinklers into operation very soon after the fire had started, it did not spread. It is therefore easier to bring a fire under control when small containers are involved as the sprinkler system helps to bring the fire under control.

UK comment = The United Kingdom fully supports this conclusion which endorses the reduced risk provided by carriage of goods in Limited Quantities

123. This leads us to conclude that in the case of storage facilities, these sprinkler systems are necessary in order to prevent a fire spreading due to sheets of burning liquid. However, transport units are not and cannot be fitted with sprinkler systems, so the spread of a fire will be difficult to prevent.

124. Compared with larger capacity containers, flammable liquids packed in small containers help to slow down the effects of a fire, as there is less flammable substance involved. However this comment is true in the case of storage facilities fitted with sprinkler systems.

125. In a transport unit, this effect will be reduced, principally because of the absence of sprinkler systems : the spread of a fire involving class 3 goods will be reduced if they have been packed in limited quantities, but the task of bringing the fire under control will be just as difficult as in the case of a transport unit carrying unlimited quantities.

UK Comment = The conclusion drawn does not follow from the above summation. The tests show that where goods are packed in limited quantities there is a reduction in the speed of the fire which in turn endorses the reduced risk provided by carriage of goods in Limited Quantities.

126. Moreover, for tests P36, P37 and P38, it was found that for the same overall capacity of flammable liquid, reducing the capacity of the containers helped to reduce the losses in a fire affecting a storage facility : this was achieved by bringing a sprinkler system into operation very quickly (1 minute 30 seconds) over the area that was on fire. In this case where a fire involves such substances, the sprinkler system is of great mportance: any delay in switching on the sprinkler system results in increased losses and there is time for a sheet of flammable liquid to form.

127. In the case of a fire in a transport unit, under such conditions, it is inevitable that a sheet of burning liquid will form.

UK Comment: There is a lack of scientific data to support the view that a sheet of burning liquid form.

128. The advantage of packing such flammable substances in limited quantities is to reduce the size of the blazing sheet and therefore help to prevent the fire spreading. Another factor which limits the spread of a fire is the overall quantity involved.

UK Comment = The assumption that there will be a limit to the spread of a fire in relation to the volume of dangerous goods has some logic, but this in itself makes the case for limited quantities. The proposed changes in 2006/12 (France) will do nothing to limit load sizes, improve the safety or reduce the risk of carriage of limited quantities.

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| REF. | NATURE OF THE CONTAINER | OUTER PACKAGING | TOTAL QUANTITY In litres | SUCCESS IN CONTROLLING THE FIRE | COMMENTS |
|---|---|---|---|---|---|
| P4-8 | Plastic can - HDPE,1gal | Cardboard box: 4 pallets stacked to a height of 4 cardboard boxes. | 1635 | FNC | 55% of the fuel burned.<br>In less than 2 minutes 30 seconds, the burning liquid began to affect the environment. |
| P5-1 | Plastic can – HDPE,1gal | Cardboard box coated with paraffin. | 1438 | FNC | Less than one pallet burned. |
| P16 | Plastic can – HPDE 1gal | Fire-retardant cardboard box | 1453 | FC | No significant sheet of liquid even though 114 cans were damaged (sprinkler system first came on after 17 minutes) |
| P32 | Plastic can – HDPE 1 pint | cardboard box | 2907 | FC | 14 boxes damaged by the fire: that is to say 76 litres of alcohol consumed..<br>Sprinklers came on after : 56 s. |
| P34 | Plastic can – HDPE 1 pint | cardboard box | 2736 | FC | 1 box damaged by a burning can.<br>Sprinklers came on after 25 s |
| P35 | Plastic can – HDPE 1 pint | cardboard box | 684 | FC | 20 boxes damaged : 95 litres consumed<br>Sprinklers came on after 54 s |
| P36 | Plastic can – HDPE 1 pint and 1 gal. | cardboard box | 5928 | FNC | 32 boxes damaged<br>Sprinklers came on after 1 minute 09s |

FC : Fire brought under control ; FNC : Fire not brought under control.

| | | | | | |
|---|---|---|---|---|---|
| P37 | Plastic can HDPE 1 gal | cardboard box | 4195 | FNC | 17 boxes damaged that is to say 238 cans burned.. |
| P38 | Plastic cans HDPE 0.47 and 0.95l+ | cardboard box | 4013 | FNC | 20 of the 1 gal and 15 of the 1 pint boxes burned : 190 burned.<br>The fire began to spread in less than 1 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | minute 30s. |
| P39 | Plastic can<br>HDPE 1 gal and<br>1 quart | cardboard boxes | 5518 | FNC | 359 boxes damaged : 2691 l burned producing a sheet with a diameter of 10.7 m.<br>The sprinklers came on after 2 minutes 10 s. |

FC : Fire brought under control ; FNC : Fire not brought under control.

## Other class 3 substances

### *Paint thinner :*

129. This substance bears the description: "PAINTS or SUBSTANCES SIMILAR TO PAINTS", UN 1263, class 3 with three possible packaging groups. In these tests P1, P2 and P3, we do not know to which packaging group these substances are assigned.

130. These tests were carried out with 3.79 litre capacity cans. The overall quantity was found to be either high (1,600 litres) or lower (600 litres). Even with the use of sprinklers, the fire was intense and a sheet of liquid formed. The fire burned intensely over this sheet of liquid with flames reaching a height of between 3 and 4.5 m for an overall quantity of 600 l.

131. The HDPE cans were unable to withstand the heat of the fire and melted allowing the paint thinner to escape and catch fire, thus spreading the flames.

UK Comment = the above test was carried out in a storage facility, not a transport scenario. Therefore the results should not be used out with the context in which they were obtained.

### *Kerosene*

132. This substance bears the official description "KEROSENE", UN 1223, class 3, PG III. The exemption for limited quantities applies to containers not exceeding 5 l.

133. Test P15 was carried out using 0.47 litre capacity bottles. Tests involving the use of fire-retardant material were carried out. The bottles were surrounded by a nylon cylinder and the resulting units were placed in fire-retardant cardboard boxes. The fire was not spread by the liquid sheet formed by the 322 damaged bottles : this sheet did not spread beyond the test zone.

### *Ethyl alcohol*

134. This substance bears the official description, "ETHANOL or ETHANOL IN SOLUTION", UN 1170, class 3, PG II or III.

135. A test P10 on ethyl alcohol was carried out using 237 ml capacity plastic bottles. It was found that the fire engulfed the entire pile of pallets and the fire gradually intensified, but no sheet of liquid was formed.

136. When this substance is in solution with water, it bears the official description, " ETHANOL or ETHANOL IN SOLUTION", UN 1170, class 3, PG II or III.

137. Tests were carried out on this product when packaged in glass bottles: for tests G2 and G4, it was found that the bottles were unable to withstand the fire and started to explode as soon as the fire began : a sheet of burning liquid was formed.

Moreover, it was found that the damage with this type of glass container was also more substantial :  a large part of the cargo was destroyed.

| RÉF. | PRODUCT | NATURE OF THE CONTAINER | OUTER PACKAGING | TOTAL QUANTITY In litres | SUCCESS IN CONTROLLING THE FIRE | COMMENTS |
|---|---|---|---|---|---|---|
| P1-2 | Paint thinner | Plastic can HDPE, 1gal | cardboard box | 681 | FC after 6 minutes with sprinkler. | Containers distorted, melted, empty, as a result of intense sheet of flames. Flames reached a height of 3 to 4.5 m and the diameter of the sheet was 3.66 m. |
| P2- | Paint thinner | Plastic can HDPE, 1gal | cardboard box | 681 | FNC | intense sheet of flames (measuring 9.1 m in diameter) + sound of containers breaking open |
| P3- | Paint thinner | Plastic can HDPE, 1gal | cardboard box | 1635 | FNC | intense sheet of flames |
| P10 | Ethyl alcohol (>50%) | Plastic-8oz (237 ml) aerosol | cardboard box | 545 | FC | The fire slowly got bigger with a single sprinkler: the pallets were engulfed in flames produced by the burning product, but there was no sheet of liquid. |
| P15 | Kerosene | Plastic can HDPE, 1 pint + nylon cylinder | Fire-retardant cardboard box | 1 022 | FC | 51 boxes and 322 containers were damaged: as a result there was a sheet of burning liquid in the test zone. No spread beyond this zone.. |
| G2 | Ethyl alcohol +water(1/1) | Glass bottle : 0.76 l | cardboard box | 3997 | FC | 85% damaged<br>1 min 40 : the bottles began to break open.. |
| G4 | Ethyl alcohol +water (1/1) | Glass bottle : 0.76 l | cardboard boxes | 34474 | FC | sheet of liquid measuring 6.1 m in diameter + bottles broken open : 54% damage.. |

FC : Fire brought under control ; FNC : Fire not brought under control.

## Conclusions about class 3 substances :

138. These tests were carried out to determine the behaviour of flammable liquids in storage facilities. However the test samples were also representative of the sort of amounts that are transported, and the packaging materials concerned are also used for transporting such substances. The tests involved both containers covered by the « limited quantities » exemptions and also ones not covered by this scheme.

UK Comments = The tests conducted in storage facilities, often used packaging that was in excess of the limited quantity volume, not in accordance with the type of packaging allowed with dangerous goods in larger amounts than allowed under the limited quantity provisions.

139. Important lessons can therefore be learned from these tests for the transport of flammable liquids.

140. It emerged that the flammable nature of these substances brings a real danger of a self-perpetuating fire, no matter what the type of container or quantity per container.

141. The spread of a fire can be slowed down by splitting up the flammable liquids into smaller volumes, but the choice of what kind of container to use is very important.

UK Comment = this conclusion supports the principle of limited quantities which only allows small volumes of dangerous goods to be put in quite prescriptive packagings.

142. However, a fire involving these kinds of substances usually develops so rapidly that it is difficult to contain it : indeed, in all the storage facility tests, the sprinkler system was triggered right from the moment the fire first started.

143. It was found that this class of substances burns quickly and intensely.

144. The problem which has to be overcome with these substances is the formation of a sheet of liquid, as the containers are perforated or burst open one after another, since there is a danger that this will spread the fire.

145. Moreover, although it does have an effect, splitting up these flammable liquids into small-capacity containers does not always limit the consequences of a fire in a satisfactory manner. In certain cases (for example p5-1 and p38 with isopropyl alcohol) it proved easier to bring the fire under control in the case of containers which did not come within the « limited quantity » scheme.

146. Lastly, in several cases, the fire could not be brought under control even after the automatic sprinkler systems came into operation.

UK Comment = in a transport scenario involving limited quantities it is unlikely that the fire would develop so rapidly, or that there would be the development of a sheet of liquid.

147. Of course the seriousness of the consequences and the scale of a fire involving the formation of a sheet of flammable liquid are linked to the total quantities involved.

UK Comment = Therefore the conclusion must logically be to support the continued use of limited quantities which by their definition have a smaller amount of dangerous goods per package.

# ANALYSIS BY TYPE OF CONTAINER

## *The containers for aerosol dispensers*

### Description

148. The aerosol cans mentioned in section 3 were of the following types :

- tin plate cans with 3 components : 1 cylindrical body + 1 bottom + 1 dome-shaped top to which the valve is attached,
- aluminium cans cast in one piece, to which the valve is attached.

### Their fire resistance

149. As a fire begins to take hold, each dispenser is affected by a BLEVE which initially involves the receptacle (or can) bursting open. However, depending on the kind of dispenser involved, there are differences in the way it bursts open and in the amount of debris.

### Tin plate cans

150. These cans consist of a cylindrical body, a bottom and a dome-shaped top to which the valve is attached.

151. When they are involved in a fire, these cans break open in the area where the body is attached to either the bottom or the dome-shaped top.

152. As a result of breaking open in this way, the liquefied and overheated gases contained in the can are suddenly vaporised. It is the pressure associated with this vaporisation which causes debris to be hurled about :

- The dome-shaped top or the bottom only weigh a few grammes, and so these kinds of debris cannot be hurled very far.
- Debris consisting of the cylindrical body of the containers, because of its shape, seems to be helped on its way by a thrust similar to that required for propelling a rocket.
- The distances which may be travelled by this second type of debris vary since they depend on the angle of the axis of the dispenser to the horizontal at the moment when it bursts open : however, during the tests, instances of this type of debris being hurled up to a distance of about 100 metres were observed.

## Aluminium cans :

153. These cans consist of two components only : the aluminium body which is cast in one piece and the valve which is attached to the circular opening.

154. This kind of can may burst open in the area where the valve is attached, but usually in a fire it simply explodes, with the wall of the can being torn to pieces and the possible formation of small items of debris.

155. During fire tests on this type of can, the geometry of the debris was such that there was no rocket effect and the maximum distances over which the debris was hurled were well below 100 m.

156. During tests, it was found that the heat of the fire was sufficient to cause the aluminium to melt.

## Choice of an aluminium or tin plate can

157. In both these cases, very few dispensers escape undergoing a BLEVE during a fire : those that do are dispensers which receive a mechanical blow from a neighbouring dispenser which has exploded. This impact has the effect of hurling them sufficiently far away (10 to 20 m) to remove them from the intense radiation of the flames, but the impact may also be sufficiently violent to rupture their walls so that they lose their contents more or less rapidly, in the form of a jet of liquid and/or gaseous product which may or may not be on fire.

158. These dispensers, which correspond to the latter case and which lose their burning contents could be of an incendiary nature. This property will be confined to a short distance (no more than 20 m).

### *CONTAINERS FOR CLASS 3 SUBSTANCES*

159. During the tests shown in the tables in section 3, the following containers were tested :

- metal tins with a capacity of 1 quart (0.95 litres), 1 gallon (3.79 litres), and 5 gallons (18.92 litres). In the case of the large capacity (5 gal) tins, they were fitted with a polyethylene cap.
- high density polyethylene plastic cans with a capacity of 1 gallon (3.79 litres), 1 pint (0.47 litres) and 1 quart (0.95 litres).
- 0.76 litre glass bottles.

## metal containers :

160. This type of container often has a polyethylene cap on the 3.79 litre capacity containers : this orifice will serve as a safety valve for the product which is

heating up inside the tin : the heat will cause it to melt and thus prevent pressure building up inside the container.

161. Out of all the tests reported here, in only one or two was there a violent rupturing of the metal container. No test reported the formation of a blazing sheet of liquid which caused the fire to spread.

### plastic containers :

162. In all cases, the cans – regardless of their capacity – burned and melted, allowing the liquid inside to escape and form a sheet of liquid which caught fire and could cause the fire to spread.
163. In the majority of cases, nearly 50% or more of the storage capacity was burned. It was also found that limiting the overall quantity of product did not help to reduce the risk : indeed, in the case of plastic cans, the result was always the same, regardless of the overall quantity involved.
164. In the case of plastic cans, the capacity of which varied, the test results always showed that a sheet of liquid formed which then caught fire and therefore heightened the risk of the fire spreading.
165. Moreover, according to some tests [3], under certain conditions, plastic containers were heard to explode, even though plastic normally tends to melt : this indicates that there was a build-up of pressure in the container before the fire burnt the plastic.

### Glass containers :

166. The majority of the goods packed in glass containers were broken : over 50% in fact. Moreover, glass containers were heard to explode due to the rise in pressure inside them. In certain cases this then led to the formation of a sheet of burning liquid.

## The behaviour of plastic bottles containing flammable liquids in a fire

167. Class 3 products are packed in very thick polyethylene (PE) plastic bottles or polyethylene terephthalate (PET) plastic bottles.

168. The behaviour of these two types of bottles in a fire is very different when subjected to the same levels of heat :

- PET bottles : the heat increases the pressure within the bottle which then splits open : the product inside can then escape. The liquid will then catch fire and form a sheet of flames which spreads the fire up to a distance of 4 m from the position of the bottle.

- PE bottles : the heat causes these bottles to melt and form a bubble above the surface of the liquid. On the surface of this bubble, a hole is formed through which the liquid can escape : the fact of the product boiling does not bring about a rise in pressure inside the container. However, the vapours from the liquid above the hole may catch fire.

169. The nature of the plastic used to make the container for a flammable liquid is very important: it can help to spread the fire by allowing the burning liquid to escape.

### Conclusions about the choice of container for class 3 substances

170. These substances must be transported in limited quantities within the authorised values. The following recommendations could be made:

- The optimum level of safety is achieved when a metal container fitted with a plastic cap is used : in the event of a fire, this cap will melt thereby allowing the flammable liquid to be evacuated without forming a sheet which would spread the fire to neighbouring areas. Moreover, this would help to prevent a rise in pressure by allowing the product to evaporate through the orifice.
- The consequences are more severe when a plastic container is used : in the event of a fire, a sheet will form which will spread the fire
- The most unfavourable case is that of glass containers : because of the rise in pressure inside the container, the latter explodes, with the danger of solid debris and burning liquid being hurled about.

## PROPOSED IMPROVEMENTS TO THE SYSTEM OF EXEMPTING HAZARDOUS SUBSTANCES FROM THE NORMAL REGULATIONS WHEN TRANSPORTED IN LIMITED QUANTITIES

171. Whatever the risks studied, whether to the environment, from corrosion or from fire, packing hazardous substances in limited quantities does not do away with the risk, although splitting them up into smaller amounts can limit the consequences of an accident.

UK Comment = There has never been an assumption that limited quantities removes all risk. However, this conclusion that splitting up the goods into smaller amounts limits the consequences is the basis for the limited quantity provisions which the report actually endorses.

172. However, there is no simple relationship (for example of proportionality) between the extent to which a load of hazardous substances is split up and the seriousness of the consequences of an accident which may happen to this load.

173. The consequences – as measured from the tests studied – are substantial : hazardous good`s transported under the « limited quantities » system cannot be regarded as harmless in safety terms.

UK Comment = The claim that the consequences are "substantial" has not been put into context eg by comparing with the same amount of dangerous goods in a single receptacle that is subject to the full requirements and which is involved in a spillage or fire. There has never been an assumption that there is no risk, rather that the risk is significantly reduced under the limited quantity provisions.

174. So the posting of warning signs indicating that the transport unit is carrying hazardous substances is the least that should be required in order to make anyone who may come into contact with these substances whilst they are being transported from their source to their destination, as well as the emergency services in the event of an accident, aware of the dangers they present.This could be adjusted to the total quantity carried in the load

UK Comment = There has been no justification shown that such warnings would:

(a) reduce the likelihood of an incident occurring,

(b) reduce the severity of the incident or

( c) contribute to the alleviation of the consequences of any incident that may occur.

Nor has the report demonstrated with any statistical data that there is currently any evidence of any problems with the use of the limited quantity provisions.

175. Studies should be carried out on the minimum regulations required for inner packaging materials:

-plastic caps for metal containers filled with flammable liquids

-more severe limitations on, or (in certain cases), a complete ban on glass containers

176. Substances in packaging group I should not be allowed exemption under the limited quantities system (this comment is only applicable to the RID/ADR).

UK Comment = the study is out of date with the current requirements for limited quantity packaging provisions which goes into some detail as to what packaging is required.

## References

1 - "Caractérisation du phénomène d'incendie dans un stockage de générateurs d'aérosols", J.Chaineaux, December 2000.

2 - Directory of fire tests involving [the] storage [of] flammable and combustible liquids in containers, Schirmer Engineering Corporation, 2nd edition, October 2000.

3 - "Flammable liquids in drums and smaller containers", Factory Mutual Engineering Corporation, Loss Prevention Data, 7.29, September 1989.

4 - CE (1996) Technical Guidance Document in support of commission directive 93/67/EEC on risk assessment for new notified substances and commission regulation (EC) No 1488/94 on risk assessment for existing substances. European Commission. Office for Official Publications of the European Communities, Luxembourg, 1996