ANALYSIS AND DESIGN OF TYPE B PACKAGE TIE-DOWN SYSTEMS

C. Phalippou, C. Tombini, L. Tanguy

Commissariat à l'Energie Atomique (France)

I - INTRODUCTION

Radioactive material transport packages are designed to retain their ability to prevent any unacceptable risk in connexion with the products being transported, whether this be under normal transport conditions or under accident conditions.

To this end, they must be able to withstand various regulatory tests of a mechanical and heat-related nature, among which figure:

- a drop from a height of 9 metres,
- a drop of one metre onto a punch,
- being subjected to fire at 800°C for thirty minutes.

These tests are cumulative in nature to simulate an accident, and their results must be recorded in a safety report corresponding to the model of the package.

Irrespective of the means of transport (road, rail or air), regulations governing the transportation of dangerous materials make no specific provision for package tie-down conditions.

In order to analyse the incidence of tie-down conditions as a cause of road accidents and to advise carriers on methods of calculating the risk, the French Atomic Energy Commission (CEA), within the framework of a research contract financed by the European Community, conducted a survey into road accidents in which B type packages were involved. After analysis of the survey results, the CEA then conducted reduced scale tests on representative models to establish design rules for tie-down systems. These rules have been the subject of various publications and have at last resulted in the production of a software aid to the design and monitoring of tie-down systems. This document states the various stages involved in this work and the way in which the ARRIMAGE software is arranged.

II - SURVEY INTO ROAD ACCIDENTS

The French Atomic Energy Commission and the Belgian company Transnubel have surveyed various European authorities responsible for the carriage of radioactive products in order to

discover the nature of the role played by package tie-down system in road accidents which occurred in those particular countries.
British, French and Swedish statistics on accident configuration analysis have been collated in Table 1.

Direction of impact	GREAT BRITAIN	FRANCE	SWEDEN
Head-on	58%	58%	50%
Side-on	12%	27%	41%
Rear-on	26%	8%	9%
Overturn	4%	7%	___

TABLE 1

Figure 1 gives the distribution of accident configuration established from the statistical data of several countries.

This survey has showed that the most frequent accidents could be split into two categories:

- front-on impacts where the lorry strikes an obstacle or another vehicle,
- side-on impacts where the package is struck by another vehicle carrying a heavy load which hits the package, occasionally perforating its exterior wall.

The distribution of accidents in terms of their velocity at the moment of impact is given for Belgium, France, Germany and Sweden in Table 2. Figure 2 gives the average distribution as obtained from data collated from several countries.

V (km/h)	Belgium	France	Germany	Sweden
$V<50$	54.5%	45.5%	61.2%	40%
$50<V<80$	45.5%	52%	37.4%	53%
$80<V<100$	0	2.5%	1.4%	3.5%
$V>110$	0	0	0	3.5%

DISTRIBUTION OF ACCIDENTS AS A FUNCTION OF THE SPEED OF THE VEHICLE AT THE MOMENT OF IMPACT

TABLE 2

In the majority of these accidents, the drivers brake and reduce the velocity of their vehicle significantly before impact. It is for this reason that the average velocity of the vehicles at the moment of impact is only of the order of 50 km/h.

In many accidents the tie-down system of the package is either partially or totally destroyed. After the crash, the package may strike the lorry cab and then rolls a certain distance away from the vehicle.

It is important to calculate the tie-down system:

- to ensure that the package does not crush the lorry cab in the case of a head-on crash,
- to limit the damage due to piercing of the container wall and ensures that the crash does not alter the leaktightness of the containment vessel in the case of a side-on crash,
- and to ensure that the container remains close to the vehicle in all cases.

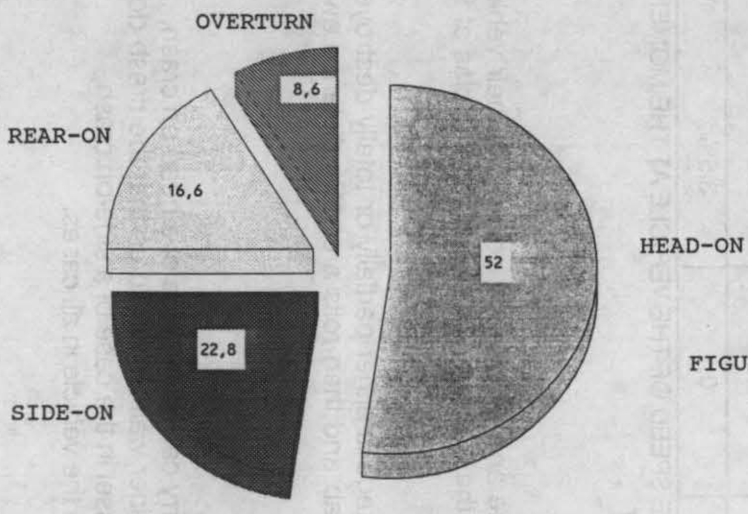


FIGURE 1

DISTRIBUTION OF ACCIDENTS AS A
FUNCTION OF THEIR CONFIGURATION

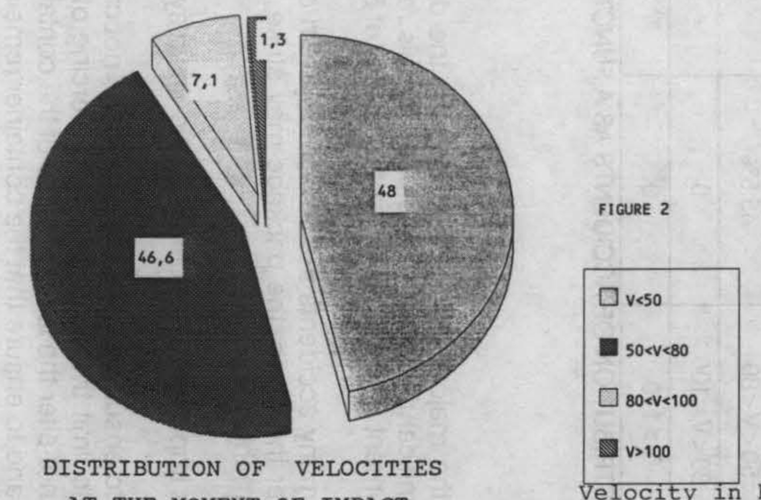


FIGURE 2

DISTRIBUTION OF VELOCITIES
AT THE MOMENT OF IMPACT

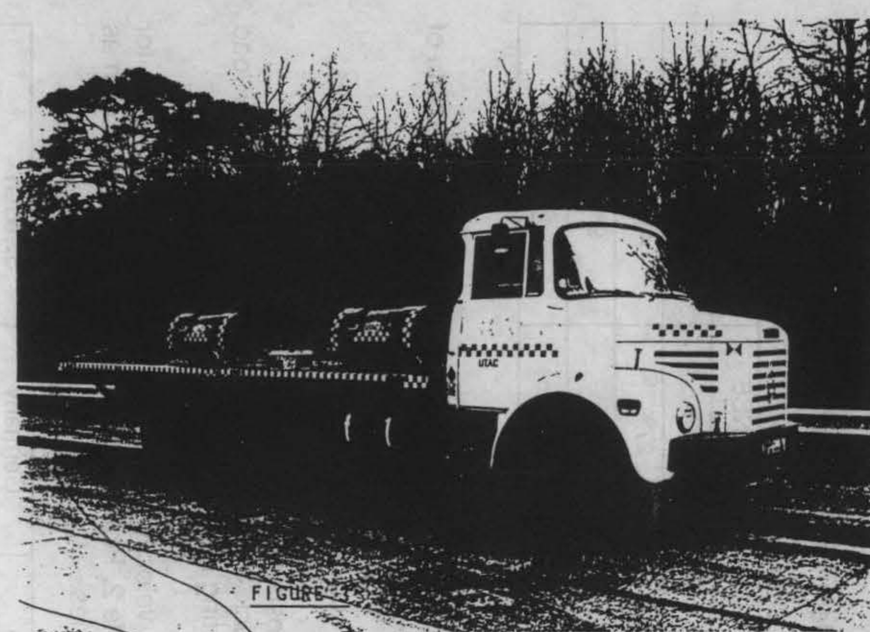
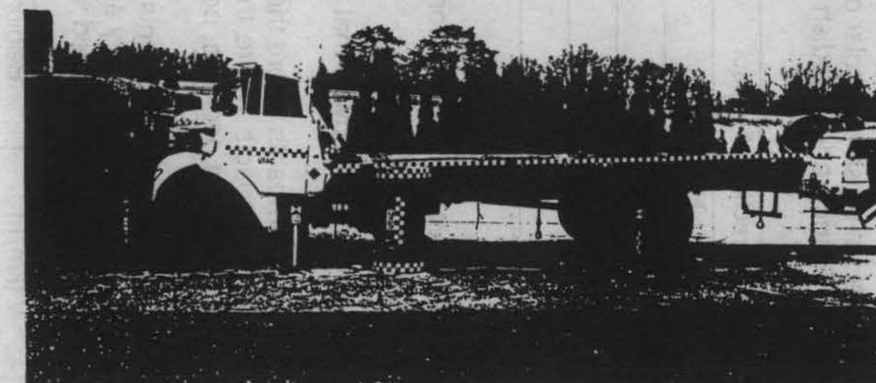


Fig 3

Fig. 4



III - ACCIDENT SIMULATION

In order to test the strength of various types of tie-down system, the CEA has conducted, in collaboration with Union Technique de l'Automobile et du Cycle (UTAC), a test campaign intended to test various types of tie-down systems on a model road vehicle.

During testing, the lorry was simulated by a mobile platform on which was fixed a type B package weighing approximately one ton (see Figure 3).

During head-on accident simulation, this platform was impacted against an indeformable block at a speed of 50 km/h (see Figure 4)

Side-on accidents were simulated by a punch impacting the side of the package.

During each of the tests, crash accelerometers measured deceleration on the platform and on the container.

Various sorts of direct linkages were tested, including webbing, chains and slings, but also various other tie-down systems in the presence or absence of chocking.

IV - DESIGN RULES FOR TIE-DOWN SYSTEMS

Analysis of the tests has made it possible to establish four design or mooring verification criteria for tie-down systems:

- a geometric criterion linked to the possibility of tying down the package on the platform of the lorry,
- a head-on crash behaviour criterion,
- a side-on crash behaviour criterion,
- a rigidity criterion intended for comparing the strength of the package wall and the strength of linkages during a side-on crash.

IV.1 - Modelling of the tie-down system

Type B packages are generally of cylindrical form and are stowed horizontally (with the cylinder generatrix parallel to the centreline of the lorry) or vertically (with the package stood on its end). The packages are fixed onto the lorry platform with linkages of the straight sling type, cables or webbing; chocks which are secured to the lorry platform are occasionally used to increase rigidity in the case of head-on crash.

IV.2 - Geometric criteria

Geometric criteria were developed to take into account the habits of carriers and to make the assembly as rigid as possible by making the linkages work as best as they possibly could in each of the accident scenarios.

Six criteria were adopted:

- the lateral distance between the edge of the platform and the package must be greater than 0.30 m,
- the tie-down points on the package must be above the centre of gravity of the package,

- the total length of the linkage must be at least equal to a minimum length because of the geometry,
- the angle between the straight linkages on the platform and the longitudinal axis must be below 45°,
- with horizontally positioned containers, checks must be made to ensure that the linkages do not rub against the walls of the package.

IV.3 - Head-on crash behaviour criteria

The resistance of the tie-down system to a head-on crash must be sufficient to resist the forward acceleration at the moment of impact.

According to this theory, the container fixed on the platform of the lorry is likened to a mechanical system with one degree of freedom of the sprung mass type. The acceleration measured during the tests on the lorry platform are applied to the input of this system and the response of this system is calculated. Then the maximum acceleration which the straight linkages must withstand is deduced. In the case of chocking, the head-on crash resistance criterion will consist in evaluating the resistance of the chocking alone without taking into account the straight linkages.

IV.4 - Side-on crash criteria

In the case of a side-on crash, the following design criteria have been retained:

- the straight linkages located on the impact side must break under the crash,
- the straight linkages located on the side opposite the crash must not break in order for the package and the lorry platform to remain attached.

For the calculations, the projectile is likened to an object weighing three times more than the package.

IV.5 - Rigidity criteria

Type B packages are designed to remain leaktight after falling onto a punch from a height of 1 metre. As a corollary of this, we have retained a further criterion in the design of the tie-down system. It is intended to guarantee that the strength of the straight linkages always remains below the strength of the package wall to perforation.

In practice, the maximum cross-section of the linkages is calculated in order for them to rupture during a side-on crash of the same force as that which came into play during the regulatory perforation test.

V - THE ARRIMAGE SOFTWARE PACKAGE

Verifying these design criteria is not always easy. In order to simplify this process we have introduced these rules in a software package which can be used on an IBM-compatible microcomputer.

This software package is written in Quick Basic and makes heavy use of the graphics capabilities of microcomputers. It comes with a database of straight linkages (cables, slings, chains etc.), which makes it possible to design or check a tie-down system without having to refer to "paper" documents.

V.1 - Software organisation

The software is divided into several modules for the processing or collection of data. Figure 5 shows an organisational chart of the theory behind the software. The database of straight linkages can be modified or up-dated by the user. It is compatible with available database management formats such as DBASE. The design module proceeds to design a tie-down system by following a certain series of steps, hence the time needed for the calculations. The time taken by these calculations can be reduced considerably if there is an arithmetic coprocessor present.

V.2 - An example of it in action

By way of an example, we present the verification of the tie-down system of a type B container on a lorry platform. The container in question weighs 1300 kg, is cylindrical in shape with a diameter of 0.8 m, and is secured by four steel chains. Tables 3, 4, 5 and 6 show screen dumps of the data tables relating to the straight linkages, the package and the tie-down system. Tables 7, 8 and 9 the recommendations suggested by the software.

SCHEMATIC DIAGRAM
OF "ARRIMAGE" SOFTWARE

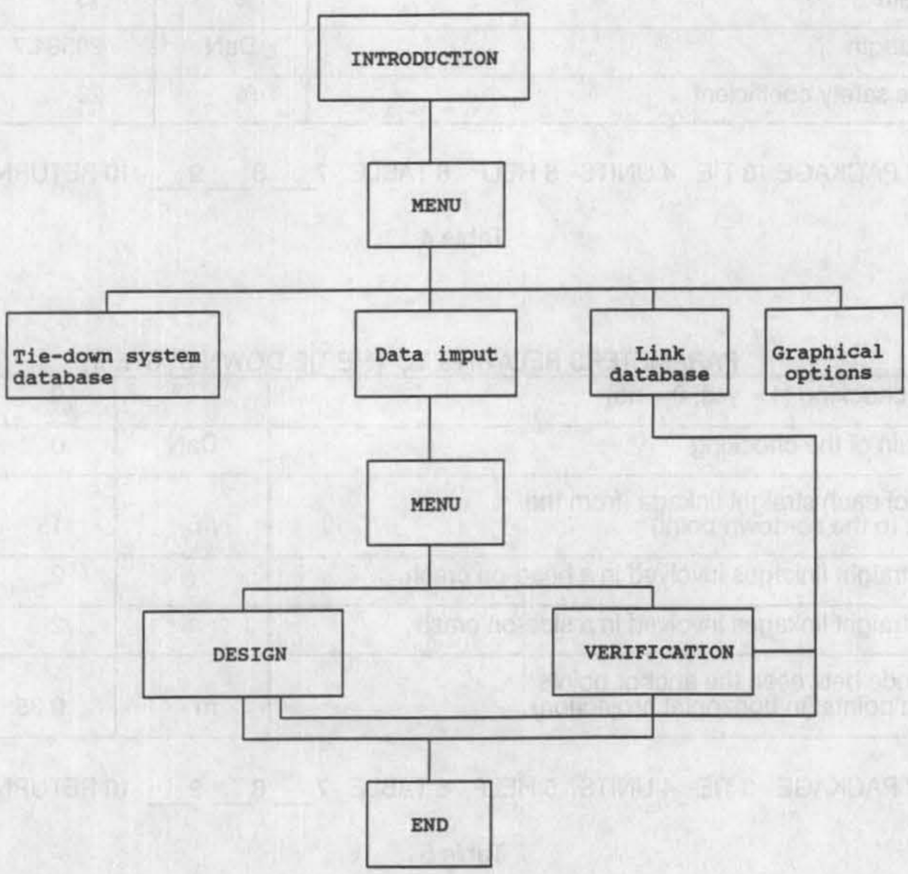


FIGURE 5

CEA PARAMETERS RELATING TO THE PACKAGE

Total mass	kg	1300
Container diameter	m	0.8
Height of the centre of gravity	m	0.35
Height of the tie-down points	m	0.6
Distance between the tie-down points	m	1.2
Penetration by a punch 150 mm in diameter for a drop height of 1 m	mm	20

1 LINKAGE 2 PACKAGE 3 TIE 4 UNITS 5 HELP 6 TABLE 7__ 8__ 9__ 10 RETURN

Table 3

CEA PARAMETERS RELATING TO STRAIGHT LINKAGES

Type of straight linkage (See key 4 code)	Code	CHA1
Diameter of the tie or width (according to type)	mm	14
Cross-section of resistance	mm^2	3007.876
Young's modulus of elasticity	Pa	2E+11
Indeformable length	m	0.65
Breaking strain	%	15
Breaking strength	DaN	20584.7
Inverse of the safety coefficient	%	20

1 LINKAGE 2 PACKAGE 3 TIE 4 UNITS 5 HELP 6 TABLE 7__ 8__ 9__ 10 RETURN

Table 4

CEA PARAMETERS RELATING TO THE TIE-DOWN SYSTEM

Presence of chocking (1= yes, 0= no)		0
Breaking strain of the chocking	DaN	0
Total length of each straight linkage (from the anchor point to the tie-down point)	m	15
Number of straight linkages involved in a head-on crash		2
Number of straight linkages involved in a side-on crash		2
Lateral distance betweeen the anchor points and tie-down points (in horizontal projection)	m	0.35

1 LINKAGE 2 PACKAGE 3 TIE 4 UNITS 5 HELP 6 TABLE 7__ 8__ 9__ 10 RETURN

Table 5

CEA PARAMETERS RELATING TO THE TIE-DOWN SYSTEM

Maximum distance between the tie-down points	m	1.39282
Maximum longitudinal distance between the anchor points	m	1.2
Minimum lateral displacement between the anchor points and the sides of the platform	m	0.2

1 LINKAGE 2 PACKAGE 3 TIE 4 UNITS 5 HELP 6 TABLE 7__ 8__ 9__ 10 RETURN

Table 6

MONITORING OF THE TIE-DOWN SYSTEM
GEOMETRIC CRITERIA

The lateral distance between the package and the edge of the platform is equal to 0.50 m, and therefore complies with the recommendation which specifies a minimum distance of 0.30 m.

The tie-down points on the package are located at 0.25 m above its centre of gravity, which complies with the general anti-tip regulation.

[Press a key to continue]

Table 7

VERIFICATION OF THE TIE-DOWN SYSTEM
HEAD-ON CRITERIA

NOTE: The straight linkages alone are only able to withstand a deceleration of 5.2 g. during head-on impact, whereas the recommendation specifies a minimum value of 43.3 g., in compliance with the primary vibration mode of 9.1 hz.

[Press any key to continue]

Table 8

VERIFICATION OF THE TIE-DOWN SYSTEM
RIGIDITY CRITERION

Straight linkages have a cross section of 3.1 cm» in accordance with the recommendation, which specifies a maximum value of 114.38 cm».

(This is to allow the tie-down system to free the package before the perforation effect causes damage to the package greater than that recorded during the punch 1 m drop test)

[Press any key to continue]

Table 9

Session 28:

UF6 PACKAGING

Chairman : M. Ingman
Co-Chairman : S. H. Park
Coordinator : K. Hirai