Measurement of the Acceleration Undergone by the Trunnions of Irradiated Fuel Transport Flasks During Normal Use

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I. SCOPE

Spent fuel casks are generally transported in horizontal position, tied down to the conveyance frame by their handling trunnions. These trunnions have therefore to be designed to resist not only handling forces but also those resulting from cask tiedown. In particular they must resist maximum forces, but also repeated forces of lower value which may induce damage by fatigue. It is the task of the designers to show that these requirements are met. It is also necessary to evaluate the maximum flaw size allowable and for this the designers have to perform a crack propagation analysis.

There is a further specific requirement: the package designers must know the dynamic forces undergone by the handling and tiedown components as precisely as possible: maximum forces as well as, for fatigue and/or crack propagation analysis, the number of cycles as a function of force intensities the flask will undergo during its life.

Many experiments have been performed using various modes of transport and different kinds of flasks. Unfortunately, up to now they have failed to provide the designers with the necessary values previously mentioned. In most cases, spectral analysis was performed after the measurements and, although the analysis gives a good view of the general vibrations undergone by the flask, it is not of easy use for the designers. In other cases full records are available on tape, but these are also difficult to use (and to process) due to the time necessary for reading them.

In order to collect directly usable data, NUCLEAR TRANSPORT LIMITED and TRANSNUCLEAIRE have developped equipment which simultaneously measures accelerations in the three axis of the trunnions and computerizes the signals.

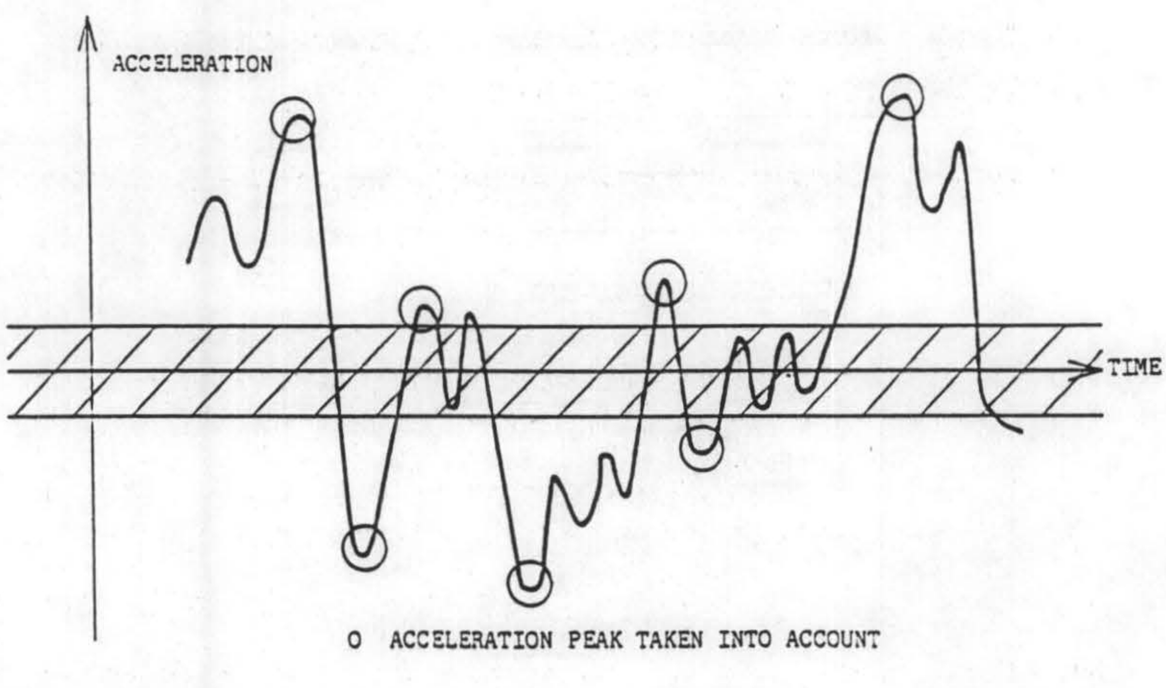
II. BASIC PRINCIPLES OF THE EQUIPMENT

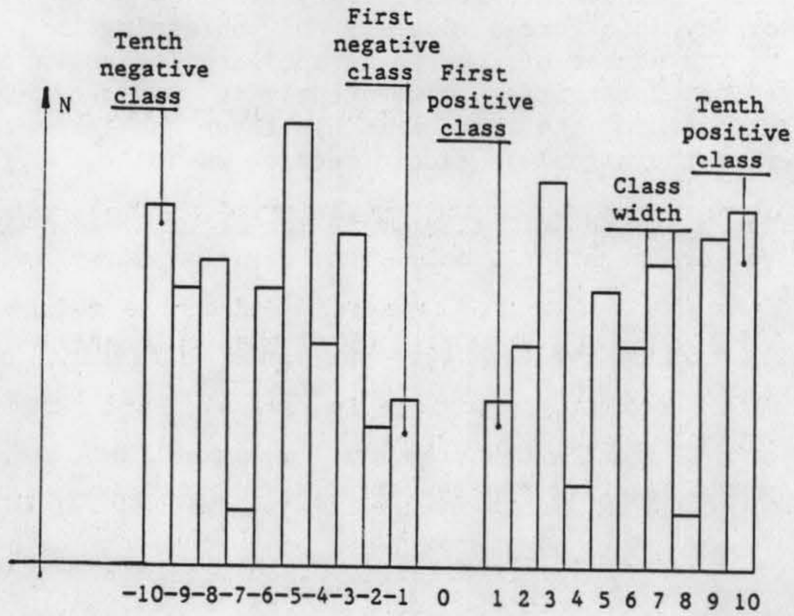
As explained above, it is necessary to know the intensity and number of dynamic forces. One way of obtaining this data is by recording the number of cycles of acceleration as a function of acceleration intensities. Consequently it was decided to measure accelerations in the three axis by three accelerometers and to computerize the signal in each direction as follows:

a) During a period of time where acceleration has a given sign (positive or negative), only the maximum value is taken into account.

b) All maximum values are put into different classes and computerized.

c) To avoid parasite measurements (background noises), the first positive and negative classes are not computerized.

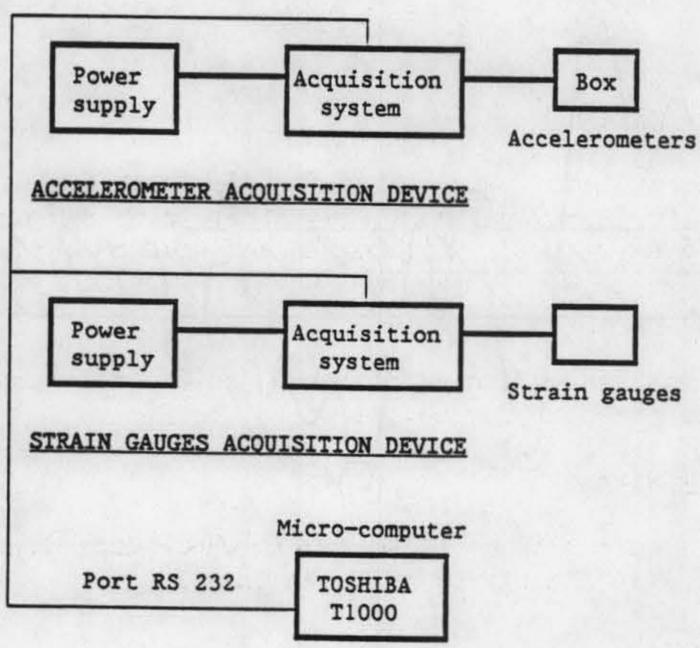




N . number of peaks in a given class

III. TECHNICAL CHARACTERISTICS OF THE SYSTEM

1) General description of the acquisition data system



2) Outline of the software

Before each measurement campaign, it is necessary to enter the following parameters:

- date and time
- ranges of classes
- acquisition duration for each histogram (between 1 and 256 minutes).

The software developped and implemented to the system works as following:

At the beginning the system measures and stores values recorded on chanel 1 (V1), then on chanel 2 (V2), then on chanel 3 (V3).

When the measurement is complete it reverses back to chanel 1 and operates the following sequences:

a) Measures the value of the new signal on chanel 1 (V'1).

b) If the sign of V'1 is different from V1, it stores in the class corresponding to V1 one unit more on the class counter, and keeps V'1 in its memory.

c) In the other case, the absolute value of V1 and V'1 are compared and only the greater value is stored.

When it is finished similar sequences are operated on the other chanels during all the measurement period.

3) Capacity

3.1 Accelerometer

Three accelerometers are fitted (one for each direction) and allow a range from -100G to +100G. They are servo-accelerometers efficient even with low frequencies and static accelerations.

3.2 Strain gauges

Three strain gauges can be attached to the relevant areas of the trunnion or tie-down device.

3.3 Memory size

All measures are stored in RAM memory whose capacity allows for the storage of 1440 histograms for each chanel.

3.4 Histogram

The range of the twenty classes available are suitable to a specific software.

Ten classes are reserved for negative values and ten classes for positive values.

The extreme classes are open, ie. they can store all values under previous classes.

3.5 Communication

The acquisition data system is equipped with a serial RS 232 port which allows for the setting up, via a portable micro-computer, of all parameters of the internal software and the collecting of all stored data.

3.6 Power supply

The system is connected to batteries which allow an autonomy of fifteen days of continuous working.

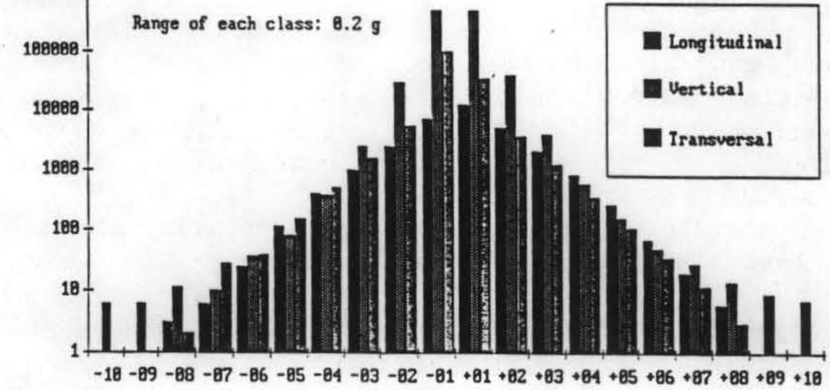
3.7 Acquisition measurements limits

The system has been successfully checked with signals having frequencies higher than 40 Hz.

IV. CAMPAIGN OF MEASUREMENTS

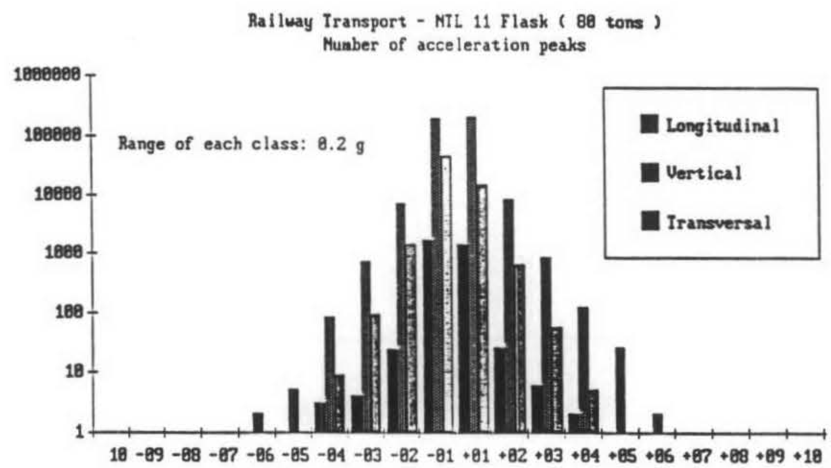
To date road and rail measurements have been performed. They show that this data system is easy to use and reliable.

The first transport concerned NTL 8/3 flask and was made during a road transport between La Hague and Tihange (Belgium). The full distance was 1600 Km. Highest and more numerous acceleration peaks are observed in vertical direction. In this direction they never exceed 2.2 g. In other directions they do not reach 1.8 g.



The second one was performed during a railway transport between Valognes (station near La Hague) and Wurgassen (West Germany). The full distance was 2360 Km. Level and number of acceleration peaks are quite lower than in the previous case. Maximum accelerations are as follows:

- Vertical: 1,4 g
- Longitudinal: 1.0 g
- Transversal: 1,0 g.



V. TEST RESULTS UTILISATION

One may use experimental results as follows for fatigue and/or crack propagation analysis:

Step 1. In each direction, transformation of histograms in tables of numbers of cycles ± x g: for each value of x, the maximum value corresponding to classes +x or -x is taken into account.

Step 2. Combination of vertical and longitudinal acceleration peaks with numbers compatible with previous numbers of vertical and longitudinal cycles.

Step 3. Calculation of forces on trunnions for each type of cycle.

Step 4. From results of an elastic stress calculation (by finite elements method or "by hand" and taking into account stress concentration factor) for a given load, calculation of range of stress for each cycle.

Step 5. Evaluation of fatigue damage d (for instance, using ASME method, $d = \Sigma di = \Sigma ni/Ni$ with ni number of cycles or range of stress i and Ni allowable number of cycles of range of stress i values of Ni being tabulated in curves).

Step 6. Crack propagation analysis, using for instance Paris' law ($da/dN = \alpha \Delta K^{\beta}$ with K is the stress intensity factor and a the size of the defect).

An example of points 1 to 3 is given hereafter with data issued from railway transport.

<u>Step 1</u>

Range of acceleration		±1.4g	±1.2g	±1.0g	±0.8g	±0.6g	±0.4g
Number of accel.	Vertical	2	26	124	886	8222	204174
	Longitudinal	0	0	3	6	26	1750

<u>Steps 2 and 3</u>

Acceleration combination	Vertical (g)	±1.4	±1.2	±1.2	±1.2	±1.0
	Longitudinal (g)	±1.0	±1.0	±0.8	±0.6	±0.6
Force on one trunnion (m.g)		±0.61	±0.58	±0.50	±0.42	±0.39
Number of cycles		2	1	6	19	7

Acceleration combination	Vertical (g)	±1.0	±0.8	±0.6	±0.6	±0.4	±0.2
	Longitudinal (g)	±0.4	±0.4	±0.4	±0.2	±0.2	±0.2
Force on one trunnion (m.g)		±0.32	±0.28	±0.25	±0.18	±0.14	±0.11
Number of cycles		117	886	747	7475	204174	00

- g: gravitational force
- m: mass of the packaging
- forces due to vertical accelerations are supposed acting on four trunnions
- forces due to longitudinal acceleration are supposed acted on two trunnions.

VI. CONCLUSION

A new acceleration acquisition system has been developped. Its use will provide informations about the forces the flasks undergo and their number. As shown in the paper, its use is very easy.

Further campaigns of measurements should corroborate the data issued from the first campaigns. Others will be necessary for other modes of transport (road transport for NTL 11 flask), for handling and other flasks. Thus it will be possible to define, in a data bank, typical couples (acceleration/number of accelerations) for each flask and each situation (sea, railway and road transport and handling). This data will constitute a basic data bank for the designer.

Other campaigns of measurements are planned, using strain gauges instead of accelerometers to approach actual stress peaks more accurately for a given point.

It can be seen from the measurements that the maximum accelerations measured during routine transports are much less than those which are generally taken into account for the trunnion design.