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Column Sentry® kinetic energy absorption test

Introduction

Column Sentry ® (the "Device") is a patented, engineered, device designed to absorb a large percentage of the kinetic energy accumulated by material handling equipment as they accidentally impact structural columns found in buildings such as warehouses. These devices are manufactured by Sentry Protection Products, Lakewood, Ohio, USA.

The device is roto-molded using LLDPE (linear low-density polyethylene). It comes in 2 symmetrical halves that are strapped around structural (steel) columns, forming a protective cylinder. Each half is an airtight shell.

Weighing approximately 34 kgs, the Device's diameter is 64 cm, its height is 104 cm.

AplusB has been commissioned by Sentry Protection to perform energy absorption test and calculations on a particular **Column Sentry®** model.

Test Configurations

- Location: Sentry Protection Products facilities, Ohio, USA
- Material handling equipment: 10,000 lbs. forklift truck
- Structural Steel “H” column protected: 14" x 14" - bolted to floor and anchored to roof stell structure
- Speed of fork lift truck at impact: 7 mph

Objectives of Test

1) Estimate the percentage of kinetic energy dissipated by the device as it absorbs a percentage of the kinetic energy accumulated by the fork lift truck (FLT)

2) Estimate the Percentage of kinetic energy absorbed by the air enclosed in each half device, as it is compressed as a result of the forklift colliding with the device

Observations

1. Under axial impact, the device's outer shell is uniformly crushed and moves in by 17.5 cm

2. Under impact, the device does not crack, thus increasing the air pressure inside the shell

Column Sentry ® kinetic energy absorption

Description

Mechanically, the device dissipates the kinetic energy and decelerates the FLT from 0 to 7 mph in "a fraction" of a second, over a distance of 17.5 cm. The device's mechanical properties should be somewhere between those of a block of stainless steel (infinite rigidity - incapable of absorbing any energy and thus transmitting all the kinetic energy to the steel column it protects) and those of a huge balloon (no rigidity - requires a great distance to slow the FLT down to 0 mph).

Notes

- 7 mph - 3,129 m/sec
- 10,500 lb = 4.750 kg
- **Kinetic Energy** is created when a moving weight acquires speed.
- **Energy** is the ability to do **Work**
- **Work** is done when a force causes an object to move. It is measured by the
- product of the force and the displacement in the direction of the force.
- **Work is expressed in foot-pounds or Newton-meters.**
  Thus, as it decelerates to a dead stop, and looses its energy, the FLT's kinetic energy is transformed into a) work that will deform and heat the device's shell, b) work to compress the air trapped inside the shell, c) work to deform (slightly) the steel column and make noise ; the remaining energy is restituted to the FLT as it "bounces" back. The shell recovers its shape (partially) causing the FLT to acquire speed away from the column
- Energy and Work are expressed in Joules or ft.lb., or several other units.

Test Results and Calculations

- Initial volume of half shell = 1/2 cylinder - 1/2 rectangular parallelepiped
- $((1/2(\text{Pi} \times 0.60^2)/4\times1.00)) - (1/2\ (0.25^2 \times 1.00)) = 0.141 - 0.0313 = 0.109\ m^3$ or 109 liters or 6,671 in^3
- ·Final (approx). volume of half shell after impact = (1.00 x 0. 125 x 0.35) = 0.044 m^3 or 44 liters.
- Pressure inside the device before impact = 1 atmosphere
- Pressure inside the device after being crushed to approx. half its original size:
  1 atmosphere x 109/44 = 2.47 atmosphere
- Thus increase in pressure: is 1.47 atmosphere or 21.60 lb/in^2
- After impact, the resultant force from increased inner pressure is thus:
  21.60 lb/in^2 x 42 in x 23 in = 20,865 lbs

Kinetic Energy of a 4 750 kg FLT at 7 mph:

$E_k = 1/2\ mv^2 = 1/2 \times 4\ 750\ kg \times (3.129\ m/sec)^2 = 23{,}252$ Joules or 17,708 ft-lb (work sufficient to lift a 17,708 lb weight up one foot)

This energy is capable of doing work equivalent to a force being displaced.

<u>Sentry Column@ kinetic energy absorption</u>

In our situation, the FLT, in impacting the device, moves forward about 0.175 m. Thus the force derived from the kinetic energy is 23 252 Joules/0.175 m or 132,870 kg or 298 000 lbs.

<u>The increase in air pressure inside the device accounts for 20 865/298 000 or 7%</u> of the <u>impact absorbing capacity of the device.</u>

Percentage Energy absorbed by the Device

Column Sentry® - Tests

- Given that the loss of energy accumulated by a body may be measured by the work it performs as it loses its energy, we measured the rolling friction of the FLT in its idle configuration: 392 lbforce or 200 kgforce or 1,962 Newtons
- We measured the distance traveled by the FLT in the course of "rebounding" as it came to a stop: 5 ft (1.50 m)
- The energy restored to the FLT is thus: 1,962N x 1.5 m = 2,943 Joules
- Since the kinetic energy of the FLT was initially 23,352 Joules, the percentage of **kinetic energy absorbed** by the Device (ignoring heat dissipation and noise) is approximately: (1 – 2,942/23,352) x 100 = **87%**

We realize that this is an approximation; nevertheless the results corroborate what "common sense" indicate.

Numerical Equivalents

Joule is expressed in the kilogram, meter, second system (mks)
1 ft-lb = 1.35 Joules
1 atmosphere = 14.7 lb/in^2
1 mile/hour = 44.7 cm/sec 1 kg = 2.205 lb