Variable Acceleration Profiling and Characterization of S&A Escapement Mechanisms

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Rotary Tables

Standard tool in the measurement of escapement mechanism arming distance

- Capable of applying long duration acceleration loads
- Related to tactical performance through escapement theory
  - Devices assumed to be distance measurement mechanism
  - Distance = $\frac{1}{2} at^2$
- Commonly used as part of escapement device acceptance tests
Standard Rotary Tables Limitations

• Not all devices follow escapement theory to the desired accuracy
• Fails to provide data on setback lock release
• Difficulty in indexing from specific event (e.g., setback lock release)
• For M427 family of devices, biases rotor towards the arm position
• Incapable of applying variable G loads
40G Acceptance Testing
Constant Acceleration Acceptance

- Acceptance test calls for a constant 40G stimulus be applied to the mechanism
- Setback weight is held until rotary table is at speed
- Weight is released and the mechanism is timed
- Acceptance determined via times in specification
Device Arming Under Constant Load
Effect of Load on Arming Distance

![Graph showing the effect of load on arming distance for different units. The graph plots arming distance (ft) against acceleration (Gs) with three units represented: Unit 24 (black diamonds), Unit 11 (purple squares), and Unit 23 (green triangles). The data is courtesy of Action Manufacturing.]
Device Arming Under Constant Load
Effect of Load on Arming Distance

Load affects arming distance by as much as 10%
Programmable Rotary Tables

• Allow the user to input desired positional coordinates and time history
• Resulting program can more accurately reproduce the tactical environment acceleration history
• Microphone allows for timing of critical events, such as environmental lock release
Programmable Rotary Tables
Limitations

• Inertia of device under test must be sufficiently small to allow table to track desired profile
• A tangential load is imparted to the device as table changes velocity
• Longer arm length is desirable for reduced error, but is limited by motor torque
Programmable Rotary Table

Table: ADRT-100-85'
Arm length: ~3.5”
Test item weight: ~.11lbs

High speed camera
Device under test
Photo detector
Ballast

Distribution Statement A: Approved for Public Release
Device Under Test

- Testing was conducted on the M427 S&A
- Part of Navy’s 2.75 inch rocket system
- Setback Weight extracts around 15 to 20Gs
- Mechanism arms: 1.13 to 1.37 sec (or 817-1218 feet of rocket thrust)

Safe

Armed
Programmable Table Replication of Tactical Acceleration Environment

- Load (Gs) vs. time (s)
- Impulse error: 0%
- Distance error: 0.3%
- Rocket @ 150°F vs. table output
Acoustic Trace from Device Armed on Rotary Table

Setback Weight extracts
\[ t = 44-47 \text{ms} \]

Table stops
\[ t = 1.062-1.065 \]

Table start
\[ t = 0 \]

Device arms
\[ t < 1.035 \]

Setback weight and arming events can be timed via a microphone
Setback Weight Instrumentation

Time to Extract Setback Weight: Microphone Data

10 Devices, each tested twice

Device and test method repeatable
Tangential Acceleration Effects

- Device static position in fixture was adjusted such that timing test was performed with setback weight at 12, 3, 6, and 9 o’clock positions.
Tangential Acceleration Effects

- Device timing consistent for a given orientation: <20ms (36’)

- Device timing varied based on change in initial orientation: <53ms (95’)

- Devices in 12 o’clock armed 30 – 60ft faster than in 6 o’clock position (44’ expected from inertial effects)

- Devices in 3 and 9 o’clock distances varied depending on device, up to 70’ (0’ expected from inertial effects)
Instrumented Rocket Tests

- Device to be spun in the lab using constant 40G and programmable rotary table tests
- Devices will be flown on instrumented rocket tests
  - Record arming time during flight
  - Record rocket acceleration history
- Provide correlation between field and lab simulation
Summary

- Programmable rotary table has sufficient frequency response to replicate acceleration environment for fuzing applications
- Provide additional insight into mechanism status during deployment
- Alternative acceptance test, and in some cases more accurate, compared to the constant 40G test