SNOW ENGINEERING CO. WICHITA FALLS, TEXAS	ENGINEERING REPORT REPORT X ORDER	NUMBER 1738	REVISION
TITLE **FRDS - PLC Enclosure Vibration Isolation System**	BY CS / CHK'D VT DATE 6/12/2006	MODEL AT802F/AT802AF SERIAL All PAGE 1 OF 11	

Overview

The shock loading seen by the FRDS PLC enclosure during aircraft maneuvers has become much more pronounced on amphibious versions of the aircraft. Long term vibration is starting to cause problems with some of the components located inside the PLC enclosure on all models.

A shock mount system to isolate the PLC enclosure from the aircrafts vibration and maneuvering loads has been developed. The purpose of this report is to provide details on the development of the FRDS shock mount system.

References

Item	Document	Company
1	061P500-D – FRDS Enclosure Assembly Drawing	Trotter Controls, Inc.
2	1050-0033 – Plate, Airframe Support	Trotter Controls, Inc.
3	1050-0034 – Plate, PLC support	Trotter Controls, Inc.
4	1050-0038 – Bracket, Stabilizing	Trotter Controls, Inc.

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Objectives

-Design and build a shock mount system using readily available components due to time constraints
-Provide as much isolation from aircraft vibration as is possible
  -Isolation from long term high frequency vibrations (10 Hz & above)
  -Isolation form short term, low frequency (high G) impact loads
  -Soft over travel limits for excessive hard shock impacts
-Compare the performance of the existing shock mount system with the new shock mount system
  -Plot isolation characteristics of existing shock mount system
  -Plot isolation characteristics of several prototype systems and compare to existing shock mount system
-Address integration & field service related issues
  -Must fit the existing available envelope
  -Must be easy to retrofit onto existing aircraft
  -Must be reasonably light
  -Must be reasonably economical and use parts that we can get quickly
  -Must reduce the time and effort required to install & remove the PLC enclosure from airframe
-Isolate the PLC from vibration effectively but survive excessive G loading without failing

Solution

The isolation system utilizes a dual spring rate system where very soft wire rope isolators have a low spring rate are using in conjunction with higher spring rate elastomer bumpers to limit the PLC maximum travel limits.

The design uses 10 Enidine compact wire rope isolators between the PLC and airframe mount. These isolators allow long travel for low frequency G loading as well as provide good damping characteristics for vibration isolation. For retrofit systems, an additional plate is mounted to the PLC to make installation of the system in the field easier. For production systems, only one plate is required since the isolators can be mounted directly to the airframe.

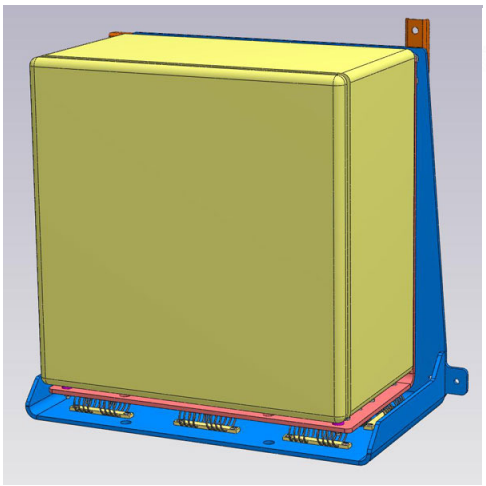
Very soft elastomer (sorbothane) bumpers were incorporated into the design to absorb shocks caused by excessive G loads. When the wire rope isolation system bottoms out, the soft elastomer bumpers limit the travel while providing shock absorption & good damping characteristics.

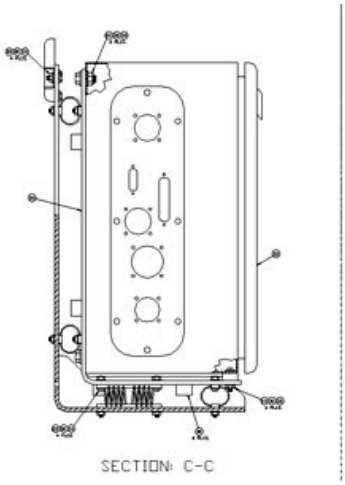
Initially it was planned to have 2 configurations of the system. A 'field retrofit' configuration for upgrading old PLC systems to the new shock mounts and a 'production' configuration in which all isolators attached directly to the PLC chassis. These two configurations are described below. It was later decided to do away with mounting the isolators directly to the PLC so only one configuration is in use. After this decision there were modifications to the 2 mounting plates to save weight and complexity, this revised design is mentioned below as

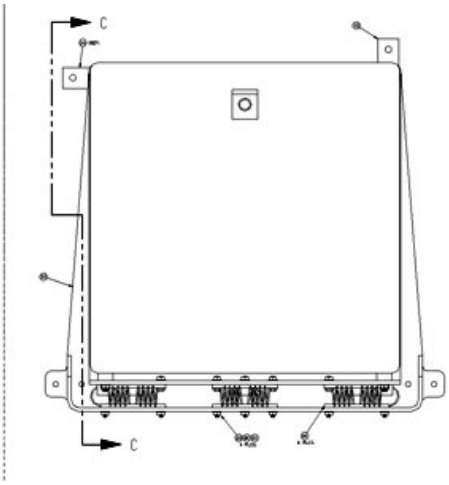
Field Retrofit Configuration

For field retrofit units, an additional plate (not used for new units) was used to mount the isolators to the PLC enclosure as opposed to mounting the wire rope isolators directly to the enclosure. Only 2 bolt holes need to be drilled in the bottom of the enclosure, the 4 existing bolts are used on the back. The PLC enclosure can now be removed by unbolting 4 (accessible) bolts at the bottom of the assembly and 2 bolts at the top. All the bolts are now moved out from behind the PLC enclosure to much more accessible areas making the PLC much easier to service.

Also, as an added benefit because the enclosure and shock mounting plates are removed as an assembly, the enclosure is shock mounted during shipment of the unit. New systems will be shipped to Air Tractor with the shock mount system already installed.







Production Configuration (OBSOLETE)

For new production units only one support plate (1050-1033) is required since the wire rope isolators will be mounted directly to the PLC enclosure. Functionally, the production and retrofit configurations are identical but the elimination of the un-needed plate will reduce overall weight slightly and represents a modest cost savings.

Production Configuration (CURRENT)

The new production units will now use a mounting scheme very similar to the 'Field Retrofit' configuration mentioned above. There were slight design changes made to this system.

-Mounting plates were made thinner and cut outs were added to save weight

-1050-0038 stabilizing brackets were removed and integrated into 1050-0033 mounting plate

Isolation System Details

Part Number	Manufacturer	Description
1050-0033 – Plate, Airframe Support	Trotter Controls	Plate to mount the vibration system to the airframe
1050-0034 – Plate, PLC support	Trotter Controls	Plate used for retrofit PLC enclosures to minimize vibration kit installation labor & effort
WR2-600-10-A	Enidine	Primary suspension system used to isolate the PLC
30-V10Z59-FB0807550	Sorbathane	Secondary suspension system used to limit over-travel
To Be Assigned	Air Tractor	Small support tubes to attach support plate to airframe similar to existing tubes used to support the PLC mount plate

After testing several part numbers and configurations of isolators we found the WR2-600 to be the best for both vibration isolation and shock loads. Each isolator has a working limit of 20 pounds. From conversations with the manufacturer, the breaking strength of the isolators is many times the working load. We expect the breaking strength to be 10 times the working load of 20 lbf or higher.

The isolators were sized as follows:

PLC weight = 40 lbf

Working Load Vertical force = 3.5 G's X 40 lbf = 140 lbf

The following configuration was used:

- 6 isolators on the bottom of PLC @ 20 lbf working load each in the vertical direction
- 4 isolators on the back of the PLC @ 20lbf working load each in the lateral direction

We assumed that the stiffness of the 4 isolators in the non-preferred direction was approximately 25% or 5 lbf per isolator.

Isolation Force Available $_{\text{Working Range}}$ = 6 x 20 lbf + 4 x 0.25x 20 lbf = 140 lbf

The wire rope system will bottom out for excessively high G loads. A secondary soft stop system was implemented to provide end of travel limits as well as additional damping. Sorbothane bumpers were picked because of very good

vibration dampening and shock absorption. We picked a very soft durometer material to aid in impact loads should the PLC enclosure try to bottom out in extreme situations.

Five soft sorbathane bumpers are used to limit downward travel of the wire rope system and to keep the two support plates from crashing together in the vertical direction. Vertical travel in the upward direction is limited by the wire rope geometry since they can only extend a certain amount.

Four sorbathane bumpers are used to keep the two support plates from crashing together in the lateral direction. Lateral travel in the opposite direction is limited by the wire rope geometry since they can only extend a certain amount.

Each sorbathane bumper has a working load of 8 lbf each and can withstand more than 40 lbf each without damage to the bumper. This system provides added stiffness to the suspension system at the end of travel limits.

Estimated Load Ratings

We expect the system to withstand loads in the following ranges:

Table 1 ~ Estimated isolation system G load ratings.

Maximum Working Load (vertical):	3.0~3.5 G's
Maximum Working Load (lateral):	2.0~2.5 G's
Maximum Peak Loads with no damage to bumpers (vertical):	8~10 G's
Maximum Peak Loads with no damage to bumpers (lateral):	6~8 G's
Maximum Peak Loads with no damage to wire rope system (vertical):	10~20 G's
Maximum Peak Load with no damage to wire rope system (lateral):	8~16 G's

Note: All peak loads are estimated. No peak load data is available from manufacturers. Static testing is required to validate the ultimate strength of the isolation system in each axis (X, Y, & Z).

Testing

Test Fixture

- A shaker table was built using a variable speed motor with an offset weight mounted to the shaft to induce vibration as the motor shaft rotates.
- A very stiff mount plate (having the shaker motor) was suspended using soft elastomeric rubber material. The motor can be operated at various speeds to excite the stiff shaker platform at various frequencies.
- The PLC & shock mount system was then mounted to the shaker table.
- An accelerometer is mounted to the PLC enclosure to measure the actual acceleration of the PLC assembly
- An accelerometer is mounted to the stiff shaker table platform to measure the excitation acceleration
- An inexpensive data acquisition system was used to measure and plot the acceleration of the shaker table and the PLC enclosure to measure the vibration characteristics

Data acquisition Details

The following equipment was used for the data acquisition system:

Accelerometers:

Crossbow P/N: CXL10LP3 +\- 10G
One mounted to shaker table, One mounted to PLC enclosure

USB DATA ACQUISITION SYSTEM:
Measurement Computing P/N: USB1208FS

Software:
Measurement Computing: DaisyLAB

Computer:
Windows XP based computer

Configurations Tested

The following configurations were tested:

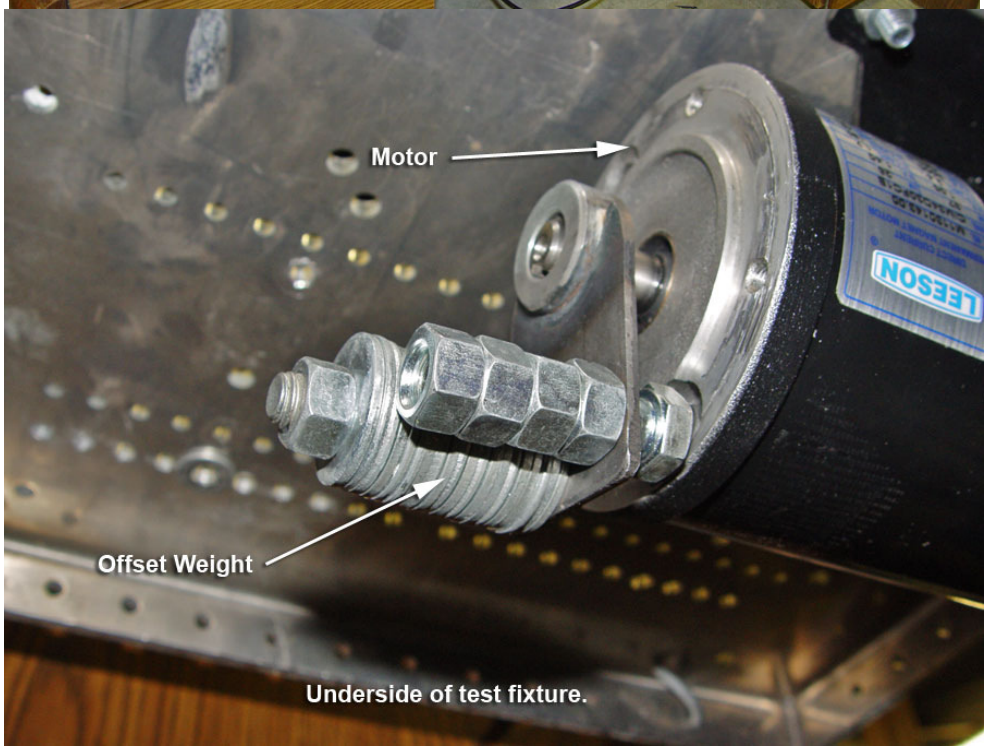
- Existing PLC shock mount system
- Several prototype shock mount systems
- The final shock mount configuration

Test Procedure

Each shock mount system was tested using the following method:

- The PLC & shock mount system was mounted to the shaker table
- The speed of the DC motor was set to a given frequency
- The magnitudes of the acceleration for the shaker table and the PLC enclosure were recorded
- The steps above were repeated for a variety of frequencies so that a plot of the isolation systems performance versus frequency could be generated.


Vibration Plates are suspended by rubber elastomers.
Motor with offset weight.


Motor
Offset Weight
Underside of test fixture.
LEESON

Vibration Test Results

Results Summary

The ratio of the PLC enclosure acceleration amplitude divided by the shaker table acceleration (excitation) is shown in Figure 1. The following can be seen from the figure:

- The old vibration isolation system amplifies shaker table vibration for all frequencies above around 5 hertz.
- The old vibration isolation system amplifies shaker table vibration at 12 Hz by 200%.
- The new vibration isolation system attenuates shaker table vibration at all frequencies.
- The new vibration isolation system transmits less than 20% of shaker table vibration at 12 Hz.
- The new vibration isolation system is 800% more efficient than the older system at a frequency of 12 Hz.

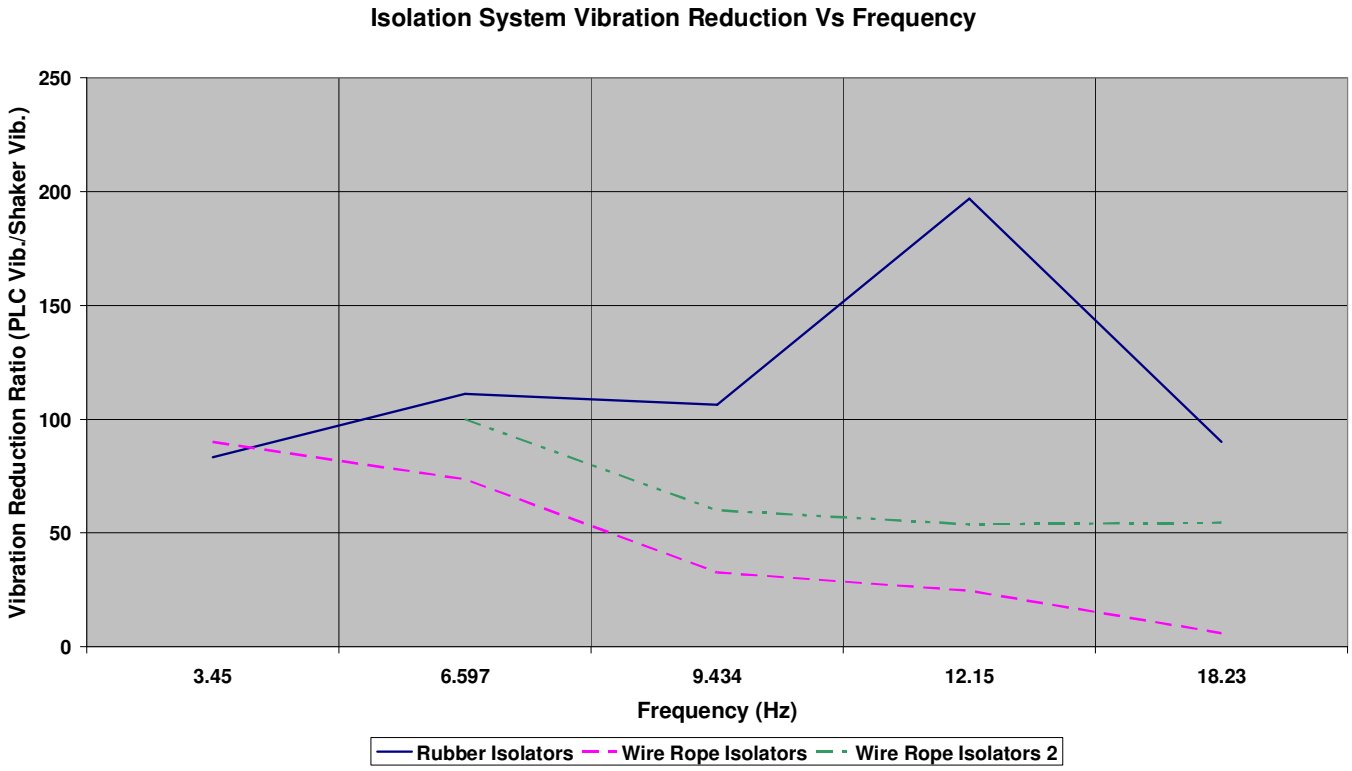


Figure 1 ~ Vibration reduction in percent versus frequency for the original and new vibration isolation systems. "Wire Rope Isolator 2" is a test of the 2nd lighter weight rev of the mounting plates.

Actual Data (Old Isolators)

The input acceleration caused by the shake table is plotted along with the output acceleration measured on the PLC enclosure versus time. This data was taken in the Z (vertical) direction at a shaker table frequency of 20 Hz.

The small amplitude (blue) signal represents the acceleration of the shaker table. The larger amplitude signal is the acceleration of the PLC enclosure.

Comparison of the amplitudes of the two signals shows that the old rubber mounts amplify the acceleration imparted to the PLC enclosure by the shaker table.

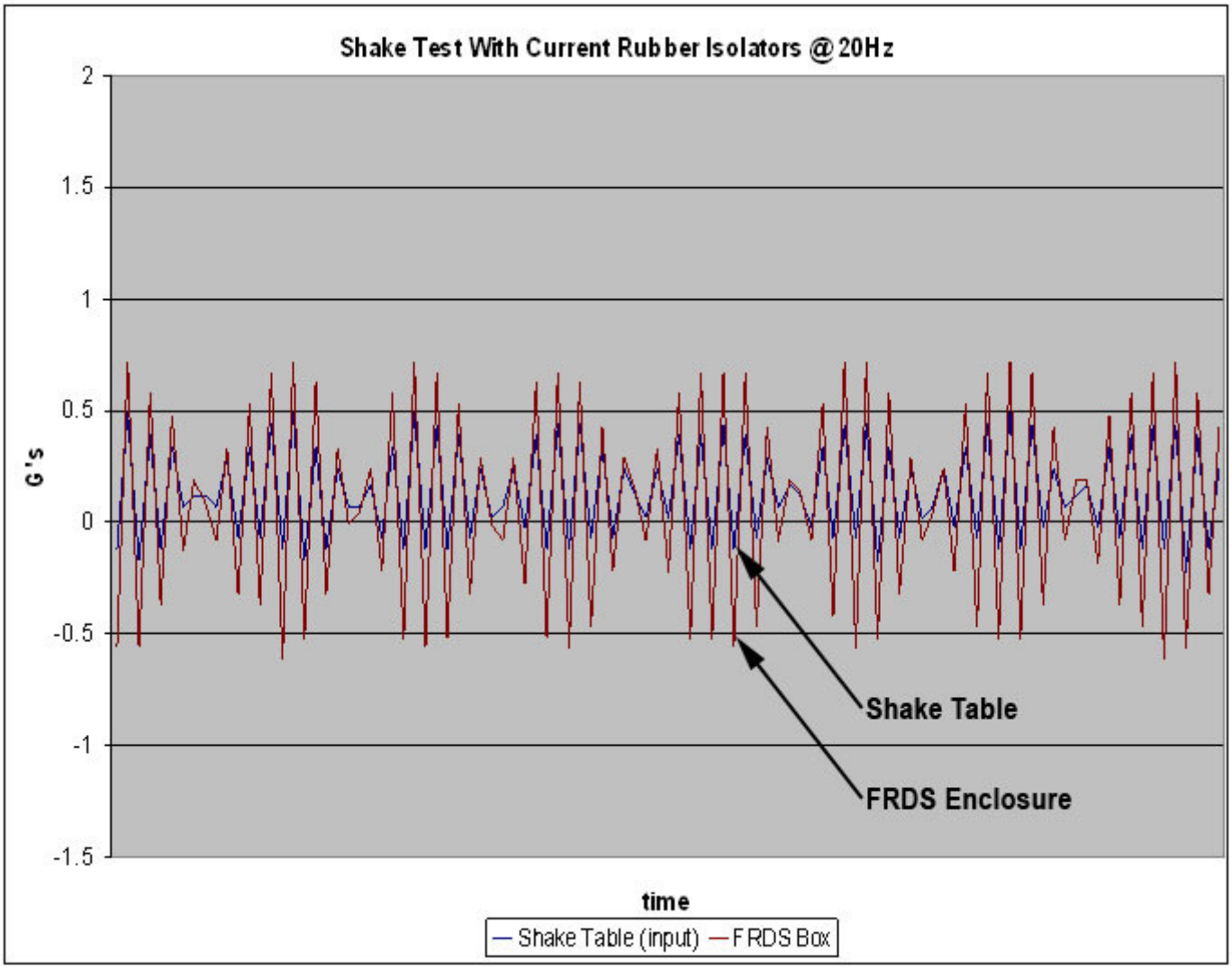


Figure 2 ~ Acceleration Vs. Time for the shaker table and old isolation system @ 20 hertz.

Actual Data (New Isolators)

The input acceleration caused by the shake table is plotted along with the output acceleration measured on the PLC enclosure versus time. This data was taken in the Z (vertical) direction at a shaker table frequency of 20 Hz.

The large amplitude (blue) signal represents the acceleration of the shaker table. The smaller amplitude signal is the acceleration of the PLC enclosure.

Comparison of the amplitudes of the two signals shows that the new isolation system significantly attenuates the acceleration imparted to the PLC enclosure by the shaker table.

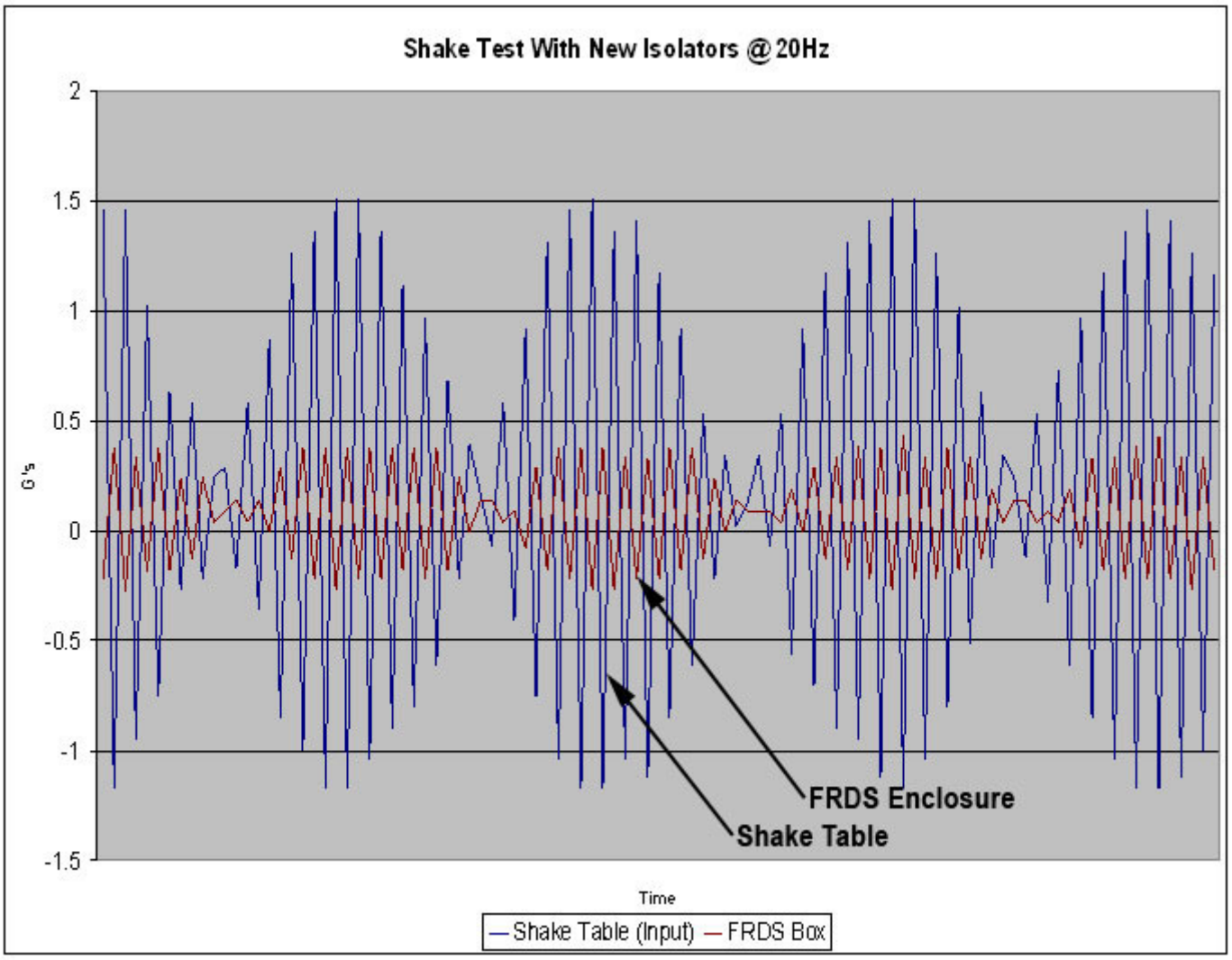


Figure 3 ~ Acceleration Vs. Time for the shaker table and new isolation system @ 20 hertz.

Summary and Conclusions

We feel that the new isolation system will serve to minimize damage to industrial quality PLC components caused by long term vibration. In addition, it provides a very soft suspension system will mild end of travel stops for reduction of excessive shock loads such as those seen in the Fire Boss configurations.

The design meets the following objectives:

- The system isolates the PLC enclosure as much as 800% percent better than the older existing system
- Soft over-travel limits are incorporated to handle excessive G loads
- The system fits within the same envelope as the existing system
- The system is removed and shipped with the PLC Enclosure so the shock mount system can be used during shipping
- The PLC enclosure is now much easier to install and remove
- The system was designed using readily available aircraft quality wire rope isolators
- The system is easily retrofitted to older aircraft using an additional plate to mount the isolators to the PLC enclosure (avoids full disassembly of the PLC enclosure)

Recommendations

- We recommend that the system be statically tested to verify survival of high G loading
- Two configurations should be used.
  - Production configuration uses only one plate to mount system in the airframe (this plate is the same for both configurations). The wire rope isolators are mounted directly to the PLC enclosure in this configuration.
  - Retrofit configuration uses an additional plate mounted to the back of the PLC enclosure to mount the wire rope isolators. This avoids having to remove all components from the PLC enclosure in the field.
- On new production units, we would like to provide the PLC enclosure with the shock mount system already attached to the PLC enclosure. This allows shipping of the unit with the shock mount system active.
- We recommend powder coating the isolation plates to match the PLC enclosure for enhanced corrosion resistance and so that operators will remove the PLC and isolation system as a single unit.