

# **BALLISTIC TESTING OF AGED NIEDNER RIFTS CONDUIT**

**INTERIM REPORT  
TFLRF No. 431**

by  
**Bernard R. Wright  
Scott A. Hutzler**

**U.S. Army TARDEC Fuels and Lubricants Research Facility  
Southwest Research Institute<sup>®</sup> (SwRI<sup>®</sup>)  
San Antonio, TX**

for  
**U.S. Army TARDEC  
Force Projection Technologies  
Warren, Michigan**

**Contract No. W56HZV-09-C-0100 (WD15–Task 5)**

**UNCLASSIFIED: Distribution Statement A. Approved for public release**

**December 2012**

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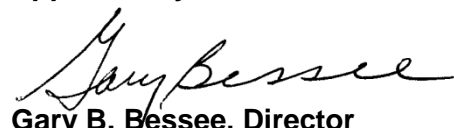
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Approved by:



**Gary B. Bessee, Director  
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<b>13. SUPPLEMENTARY NOTES</b>					
<b>14. ABSTRACT</b>  Two sample reels of Niedner Rifts Fuel Hoses were tested for resistance to ballistic penetration from hand-held or shoulder fired weapons. These hose samples had been tested for fuel supply testing several years ago. The question to be answered was, has several years storage after exposed to fuel affect the integrity of the hose. Ballistic tests were conducted as one phase of total testing, including pressure and flow resistance.					
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## EXECUTIVE SUMMARY

Two reels of naturally aged Niedner RIFTS conduit were available for testing at Fort Lee, Virginia. Both reels contained approximately 500 feet of hose with a manufacturing date of July 2005. The Niedner conduit was part of a previous RIFTS testing program at Southwest Research Institute (SwRI). Since manufacturing, the hose had been exposed to diesel fuel as well as outdoor environmental conditions. Due to the aged condition of the hose, TARDEC requested ballistic impact testing be conducted to determine whether there were any detrimental effects on the performance of the hose. Testing was conducted to evaluate the effects of small arms/shoulder fired weapons on pressurized hose sections. Three hose positions were tested, including approximately 90°, 45°, and longitudinally. Weapons used in this testing were: cal-308, cal-223, and 9 mm Pistol.

## **FOREWORD/ACKNOWLEDGMENTS**

The U.S. Army TARDEC Fuel and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, Texas, performed this work during the period December 22, 2010 through February 21, 2012 under Contract No. W56HZV-09-C-0100. The U.S. Army Tank Automotive RD&E Center, Force Projection Technologies, Warren, Michigan administered the project. Mr. Luis Villahermosa (AMSRD-TAR-D/MS110) served as the TARDEC contracting officer's technical representative. Mr. David Green, and Mr. Eric Sattler, of TARDEC served as project technical monitors.

The authors would like to acknowledge the contribution of the TFLRF technical support staff along with the administrative and report-processing support provided by Dianna Barrera.

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## **1.0 INTRODUCTION AND OBJECTIVES**

### **1.1 INTRODUCTION**

Two reels of naturally aged Niedner RIFTS conduit were available for testing at Fort Lee, Virginia. Both reels contained approximately 500 feet of hose with a manufacturing date of July 2005. The Niedner conduit was part of a previous RIFTS testing program at Southwest Research Institute (SwRI). Since manufacturing, the hose had been exposed to diesel fuel as well as outdoor environmental conditions. Due to the aged condition of the hose, TARDEC requested ballistic impact testing be conducted to determine whether there were any detrimental effects on the performance of the hose. Arrangements were made to ship the hose reels to SwRI for testing.

### **1.2 OBJECTIVE**

The purpose of this testing was to evaluate the effects of small arms/shoulder fired weapons on pressurized hose sections. Three hose positions were tested, including approximately 90°, 45°, and longitudinally. Weapons used in this testing were: .308 caliber, .223 caliber, and 9 mm.

## 2.0 SPECIMEN PREPARATION AND INSPECTION

### 2.1 RECEIPT OF NIEDNER RIFTS HOSE

The two reels of hose delivered to SwRI from Fort Lee are shown in Figure 1. The hoses were soiled but appeared to be in otherwise good condition.



Figure 1. Niedner Hose Reels as Delivered to SwRI

## 2.2 HOSE SECTION PREPARATION FOR BALLISTIC TESTING

A standardized procedure was prepared to provide a repeatable means of installing the couplings to the ends of the Niedner conduit sections. Conduit sections were approximately six feet in length. One end of the conduit contained a fitting to adapt to a nitrogen cylinder. The procedure to prepare the conduit was as follows:

- 1) Cut the Aramid jackets and bladder lining equally across one side of the conduit section and trim any excess Aramid yarns.
- 2) Apply lubricant to both the inside of the conduit section (bladder) and to the exterior mating surface of the shank.
- 3) Insert the shank into the conduit section leaving a 1-inch gap between the flange face and the end of the conduit. This will allow for sufficient space for the connecting collar.
- 4) Lightly bolt two sets of collars together with three bolts each, forming two collar halves.
- 5) Align the two collar halves together around the ridged end of the inserted shank. Be sure to align the ridges on the collars with the ridges on the inserted shank. Also ensure that the tapered side of the collars is facing the length of the conduit section.
- 6) Lightly bolt the two collar halves together on one side only then clamp the other side of the two collar halves together using the C-clamps and tighten until that side can be lightly bolted together.
- 7) After all bolts have been inserted, gradually tighten all bolts equally to 60 ft-lbs. Make sure to maintain equal spacing between collars and then attach a lock nut to each bolt.
- 8) Prepare one end of hose coupling to accept a water hose bib and valve to couple to the nitrogen cylinder that is used for pressurizing the hose to a typical operational pressure, approximately 550 psi.

### 3.0 BALLISTIC TESTING

#### 3.1 SUPPORT EQUIPMENT

Support equipment for the ballistic testing included the following:

- Two cameras:
  - Real-time with recording device
  - Hi-speed with recording device
- Weapons mount – support to insure weapon accuracy and repeatability

#### 3.2 PROCEDURE FOR BALLISTIC TESTING

The procedure use for the ballistic testing was as follows:

- 1) Prepare conduit as described above.
- 2) Set up the plumbing for the nitrogen to pressurize the conduit.
- 3) Fill the conduit with water and purge as much air as practical from the conduit.
- 4) Close the inlet and exit water lines.
- 5) Increase nitrogen pressure on the conduit at a continuous rate, to the desired pressure, approximately 550 psi.
- 6) Visually examine the conduit and take photographic records.
- 7) Lay hose section on level ground and check for proper pressure.
- 8) Position firearms to allow impact at three different angles (45°, 90°, longitudinally)
- 9) Perform testing using three types of ammunition:
  - .308 Caliber - ball ammunition
  - .223 Caliber - ball ammunition
  - 9 mm pistol
- 10) Insure that all personnel are protected from possible shrapnel or deflection of projectile.
- 11) Wait until “all clear” is announced by range control - personnel should approach hose section with caution because it is still under pressure.
- 12) Record photographic documentation of impact.

#### 4.0 RESULTS OF BALLISTIC DAMAGE

The results of the different ballistic rounds used in the ballistic testing series are shown in Table 1. It was the intent to use three different energy and size rounds that simulate typical calibers used in the military service and varied in size and weight of bullets.

In addition to the shot direction and caliber, documentation of ballistic impact was recorded on penetration at impact point, and then whether the bullet exited the opposite side. It was determined that only the larger caliber slug penetrated both sides except for the longitudinal test. The longitudinal test of the .308 caliber bullet had two impacts at the same impact point and only then did penetration occur.

**Table 1. Aged Niedner Rifts Conduit Ballistic Testing**

Caliber	Round-Grade	Shot Direction	Penetration	Side 1	Side 2	Comments
.308	130	90°	✓	✓	✓	
.308	130	45°	✓	✓	✓	
.308	130	Longitudinal	✓	✓	✗	Required 2 shots
.223	55	90°	✓	✓	✗	
.223	55	45°	✓	✓	✗	
.223	55	Longitudinal	✗	✗	✗	
9 mm	115	90°		✓	✗	
9 mm	115	45°	✓	✓	✗	
9 mm	115	Longitudinal	✗	✗	✗	

#### 4.1 DISCUSSION OF IMPACT DOCUMENTATION

##### *.308 Caliber, 90° Impact*

Post impact inspection indicated that penetration had occurred and the slug had exited on the opposite side, as shown in Figure 2.



Figure 2. .308 Caliber, 90° Impact

*.308 Caliber, 45° Impact*

Post impact inspection indicated that penetration had occurred and the slug had exited on the opposite side, as shown in Figure 3.



**Figure 3. .308 Caliber, 45° Impact**

*.308 Caliber, Longitudinal Impact*

Post impact inspection indicated that only after the second impact at the same point did penetration occur but did not exit the opposite side of the hose, as shown in Figure 4.



**Figure 4. .308 Caliber, Longitudinal Impact**

***.223 Caliber, 90° Impact***

Post impact inspection indicated that penetration had occurred but did not exit on the opposite side, as shown in Figure 5.



**Figure 5. .223 Caliber, 90° Impact**

*.223 Caliber, 45° Impact*

Post impact inspection indicated that penetration had occurred but did not exit on the opposite side, as shown in Figure 6.



**Figure 6. .223 Caliber, 45° Impact**

*Caliber 223, Longitudinal Impact*

Post impact inspection indicated that penetration had not occurred following impact, as shown in Figure 7.



**Figure 7. .223 Caliber, Longitudinal Impact**

***9 mm, 90° Impact***

Post impact inspection indicated that penetration had occurred but did not exit on the opposite side, as shown Figure 8.



**Figure 8. 9 mm, 90° Impact**

*9 mm, 45° Impact*

Post impact inspection indicated that penetration had occurred but did not exit on the opposite side, as shown in Figure 9.



**Figure 9. 9 mm, 45° Impact**

***9 mm, Longitudinal Impact***

Post impact inspection indicated that following impact, penetration had not occurred, as shown in Figure 10.



**Figure 10. 9 mm, Longitudinal Impact**

## 4.2 HOSE LINER EXTENSION

It was noted while the hose sections were being prepared for testing that the inner liner randomly extended beyond the Aramid jacket of the 6 ft sections of hose that were to be used in the ballistic testing. Figure 11 shows approximately a 1½ –2 inch extension beyond the Aramid jacket. This was not easily explainable since this was only a 6 ft piece of hose cut with a horizontal band saw. There were still several sections that had not been tested. Figure 12 shows a distinct random expansion in sections of hose that came from the same hose reel. It was theorized that this hose expansion, with both ends clamped on the end coupling, demonstrates the theory of hose bunching, preventing the fuel from being pushed through to empty the hose prior to placing in on the reel.



**Figure 11. Niedner Rifts Conduit Liner Extending 1½-2” beyond the Aramid Jacket**



**Figure 12. Niedner Rifts Conduit Liner from Same Reel with Random Expansion**

## 5.0 SUMMARY AND CONCLUSIONS

The need to perform ballistics testing to document the mode of failure of a high pressure hose surfaced during the development of the Rapidly Installed Fluid Transfer System (RIFTS) program. Whenever the Inland Petroleum Distribution System (IPDS) has been deployed, fuel pilfering has been an ongoing issue. One common method of pilfering fuel from the IPDS has been to place an over clamp with a tapping port around the aluminum pipe sections used in the IPDS. Once the clamp is in place, a self tapping spigot is used to penetrate the pipe and remove fuel. It is highly probable that the IPDS pipeline has been tapped when the system was operating at working pressure. This method of pilfering fuel has not resulted in any catastrophic failures in the IPDS pipe and most likely poses only minimal risk to the person tapping into the pipe

Because the Niedner hose is a flexible layflat hose that is operated at a high pressure, it is not possible to assess the risk of creating an unsafe condition or causing catastrophic hose failure from a single point penetration, such as small arms fire or attempting to tap into the hose to pilfer fuel, by making a direct comparison to the IPDS pipe. It is not known what mode of failure a high pressure hose would experience if an individual attempting to pilfer fuel installed some type of over clamp around the hose and tapped into the hose. TARDEC determined ballistics testing provided a safe method of obtaining valuable data regarding the mode of failure a single point, or double point in the case of ballistics fire, penetration would create in the Niedner high pressure hose.

In the majority of RIFTS system deployment scenarios, a high pressure hose will be laid along the side of existing roadways. There will be many situations when personnel will be either working around or passing in close proximity to the high pressure hose. Such situations will occur as personnel travel along the roadways adjacent to the high pressure hose and when inspecting the hose for leaks and overall hose condition. In the theatre of operation there will be an ongoing risk that the hose will be damaged by ballistics impact. Documenting the mode of failure through this testing will be critical to ensure the safety of personnel who work in close proximity to the hose.

Most hoses, including the Niedner hose, are designed to fail in the weft yarns at burst pressure. This design technique ensures that a burst failure results in a tear in the longitudinal direction in the hose. This design technique prevents the hose from separating into two sections when it fails which prevents the hose from whipping around as could happen if the hose was to experience a failure and separate into two sections at operating pressure.

TARDEC performed ballistics testing on the Niedner Hose to determine and document that the mode of failure when the hose is penetrated by small arms fire. The mode of failure documented in this report shows that it is consistent with the design parameters of the hose. All ballistic penetrations resulted in a small puncture in the hose. This testing did not show any evidence that the hose would experience a catastrophic failure resulting in complete tearing of the hose into two separate sections when penetrated by small arms fire.

A review of the test results indicates that the most important parameter in determining if the hose will be penetrated by small arms fire is the angle from which the projectile was fired. Even the 55 grain, 223 caliber projectile fired at a velocity of approximately 3000 ft/sec penetrated the hose test specimen from 90 degrees and 45 degree angles. It should also be noted even the 130 grain, caliber 308, when fired longitudinally, did not penetrate the hose until a second impact was fired. It should also be noted that only the heavier slug penetrated both sides of the hose.