Propane-Oxygen Car Bomb Rapid Assessment Report

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1 Introduction

This report presents the preliminary results of a quick-look test effort to determine the viability and lethality of a car bomb described in the Spring 2014 issue of Inspire magazine. This effort was conducted for the National Counter Terrorism Center (NCTC). This is an abbreviated report limited to the preliminary results and a brief discussion. A more detailed report will be authored upon completion of the test program.

The car bomb as described in the Inspire article consisted of a 20 *lb* commercial propane tank similar to what is available at HomeDepot or Lowe's home improvement stores, see Figure 1.

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Figure 1: Typical 20 lb propane tank used in this study

The propane from one of these tanks is vented until 3 bar (43.5 $psig$) of propane remains and then an additional 9 bar (130.5 psi) absolute of oxygen is added to the tank for a total pressure of 12 bar (188.5 $psig$). An improvised initiator is then constructed from a POL[1] x $^1/_4\,in$ hose barb fitting, a lightbulb (with leader wires), ground match heads, and epoxy. The top of the lightbulb is broken off and filled with ground match heads and sealed with tissue. The lamp is then inserted into the POL x $^1/_4\,in$ hose barb fitting with the lightbulb wires extending out the hose barb. The hose barb is then filled with epoxy to prevent the propane-oxygen mixture from leaking around the leader wires. The fitting is then attached to the POL valve on the tank. The article recommends that a minimum of 6 similarly modified tanks be placed next to each other in a vehicle. Each improvised initiator is then wired in parallel to a 12 v battery with a switch controlling the explosion. The article specifies 3 switch types depending on the method of initiation: a manual switch for martyrdom, a timer, and a radio frequency switch[1].

To determine if this propane tank bomb was feasible, a series of tests were designed to address the following questions:

1. Is the propane-oxygen recipe a viable explosive mixture?
2. Will the flame from the improvised initiator propagate through the POL valve into the tank interior and result in an explosion?
3. Will the flame from the improvised initiator propagate through an overfill protection device (OPD) valve into the tank interior and result in an explosion?

[1] Prest-o-Lite (POL) valve. A fitting used exclusively for flammable gases. Easily identified by the notches in the hex of the fitting. All POL fittings are tightened by turning counter-clockwise. POL valves are no longer authorized for use within the United States (April 2002) having been replaced by the required Overfill Protection Device or OPD valve.

4. What is the peak overpressure and impulse generated by the car bomb and using this data what is the TNT equivalency?
5. With the calculated TNT equivalency, at what range will there be a 50% probability of a death from fragmentation?

2 Preliminary Results

NCETR has conducted 4 propane-oxygen tests in this program to date. All 4 tests have resulted in violent explosions producing high velocity fragmentation. These shots have confirmed that regardless of the valve[2] type or initiator[3] used in these tests the propane-oxygen recipe explodes and will rupture the tank.

Figures 2 and 3, from test shots 1 and 3, show high velocity fragments moving away from the explosion and are typical of all 4 test shots. Table 1 is a summary of the preliminary fragment speeds from shots 1 and 3. The fragment speeds summarized are based on high speed video analysis, without correction for fragment direction. To minimize speed errors only fragments that visually appeared to track perpendicular to the camera axis were measured. The final report will utilize videogrammetry software that will allow the tracking of the fragments in 3 dimensions and will give more accurate results.

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[2] Test 1 used a 3/4 *in* pipe nipple and tee, Tests 2 and 3 used POL valves, and Test 4 used a OPD valve.

[3] Test 1 used a RISI SQ-80 thermite igniter, Tests 2-4 used the improvised lightbulb and ground match head igniter described in the Inspire article.

Figure 2: Shot 1 explosion and fragmentation of the tank 135 ms after initiation

Figure 3: Shot 3 explosion and fragmentation 19 ms after initiation

Shot	Direction of Fragment Movement	Time (ms)	Distance (m)	Fragment Velocity (m/s)
1	Tank to right 5 ft stake	4.33	1.29	298
1	Tank to left 5 ft stake	4.50	1.43	318
1	Tank to right 10 ft stake	10.33	3.02	292
1	Tank to left 10 ft stake	10.67	3.45	324
3	Tank to right 5 ft cone	4.00	1.24	310
3	Tank to left 5 ft cone	4.83	1.48	306
3	Tank right 10 ft cone	9.00	2.68	298
3	Tank to left 10 ft cone	9.83	3.00	305

Table 1: Shots 1 and 3 fragment speeds

Overpressure was measured on Shot 3 and Figure 4 is typical of the overpressure and impulse (shaded area under the pressure-time curve) collected. Figure 5, shows the overall test setup for shot 3 and the location of the pressure transducers relative to the charge.

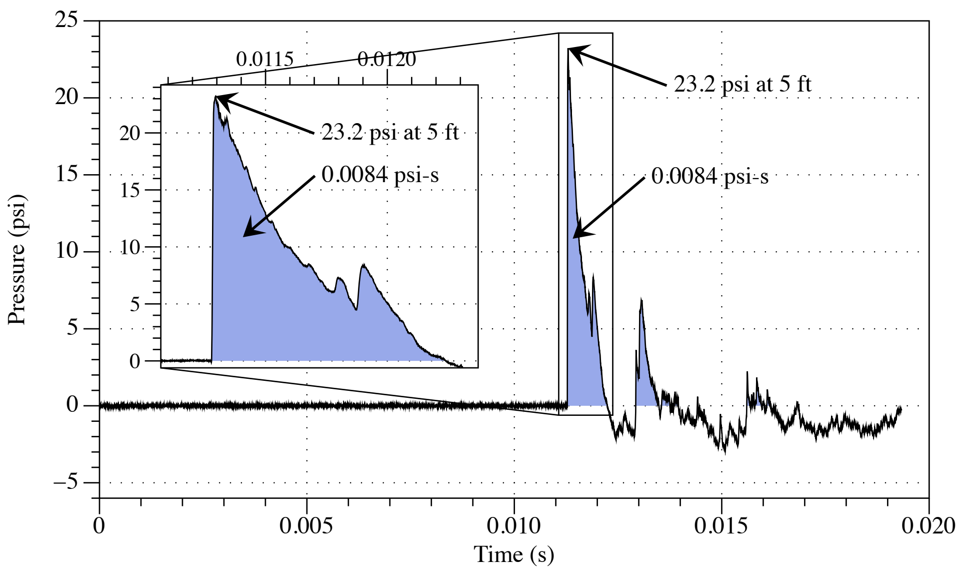

Figure 4: Overpressure data for shot 3 - X-axis 5 ft from propane tank

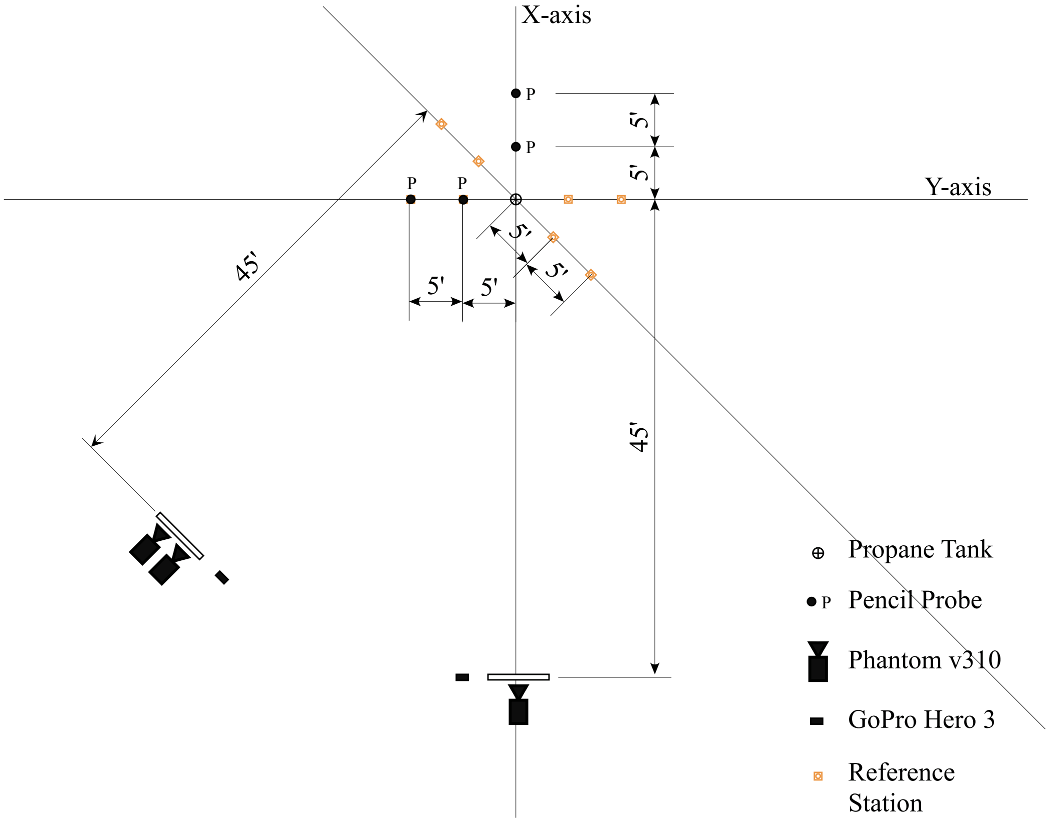

Figure 5: Shot 3 test setup

Table 2, is a summary of the overpressure and impulse data from shot 3 along with the equivalent charge masses of TNT calculated by CONWEP[4] and normalized on the weight, $0.95\,lb\,(0.43\,kg)$, of propane and oxygen in the tank. The average and standard deviation of the TNT equivalencies in Table 2 is 0.81 ± 0.15. Dewey found a slightly lower value of 0.55 (propane and oxygen) based on a 1966 study of a $20\,tn$ propane-oxygen charge, however a TNT equivalence variation of more than 20% is not uncommon for these types of blast effect measurements[2].

4 Software developed by the U.S. Army Corps of Engineers Protective Design Center to calculate conventional weapons effects from the equations and curves of TM 5-855-1, "Design and Analysis of Hardened Structures to Conventional Weapons Effects."

Axis/Distance	Overpressure (psi)	Impulse (psi-ms)	TNT Equivalency (lbs) Overpressure	TNT Equivalency (lbs) Impulse
X/5 ft	23.2	8.37	0.79	0.76
Y/5 ft	20.2	8.40	0.65	0.76
X/10 ft	6.5	4.03	0.96	0.63
Y/10 ft	6.9	5.05	1.06	0.89

Table 2: Overpressure and impulse data from shot 3 and CONWEP TNT equivalencies

The lethality of a single propane tank was examined without the shrapnel enhancement recommended in the Inspire article or the complexities of multiple tanks in a vehicle. This was done to simplify the analysis to a first order approximation using the idea of *lethal range*.

Lethal range is defined as the distance from a warhead where there will be a 50% probability of a kill. Using this methodology requires an estimate of the number and energy of the fragments produced. An estimate of the number of fragments can be calculated using a distribution developed by N. F. Mott[2]. A standard fragment energy of 4 kJ resulting in 90% lethality if it strikes a person is used as a standard fragment energy[3]. Using these values, the range at which there is a 50% probability of a death from fragmentation is 30 ft (9 m). Using EODTDA[5] with 0.76 lb TNT[6] the safe blast and fragmentation distance is 277 ft.

References

[1] AQ Chief. Car bombs inside america. *Inspire*, Spring 2014(12):64–71, 2014.

[2] Paul W. Cooper. *Explosives engineering*. VCH, New York, N.Y., 1996. ISBN 1560819278 (alk. paper).

[5] Software developed by NAVEODTECHDIV, Indian Head, MD, to calculate safe blast and heavy and light cased fragmentation distances.

[6] This was calculated using the average TNT equivalency of 0.81 multiplied by the mass of explosive (propane-oxygen) used in the test, 0.95 lb (0.43 kg)

[3] Warheads, introduction to naval weapons engineering, January 1998. URL `http://fas.org/man/dod-101/navy/docs/es310/syllabus.htm`.