Safety Handling Characteristics of LX-04-1

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Handling Safety of LX-04-1

LX-04-1 is DOE's safest "creep resistant" conventional high explosive (CHE) with excellent thermal and long term compatibility properties. Because LX-04-1 contains 15% Viton by weight, it exhibits outstanding resistance to mechanical stimuli such as could be encountered in an accident scenario at the Pantex Plant. A large energy fluence is required to initiate LX-04-1. The most likely methods to generate this energy into the individual cracked W70 HE is via dropping the unit onto the floor (or tooling) or the cracked HE rubbing against itself. In either case, not enough energy is available to cause the LX-04-1 to even mildly react as evidenced by the supporting data that follows.

Experimenters have developed a number of sensitivity tests, each seeking to initiate reaction in a rigidly prescribed manner so that results from different investigators may be compared. Although it is possible for an explosive to exhibit high sensitivity on some tests and low sensitivity on others, LX-04-1 consistently shows low sensitivity to detonation on all tests. Table 1 compares the general stability and energy properties of LX-04-1 with PBX-9404 and LX-10-2.

The sliding-impact (skid) test is our most reliable method of evaluating the hazards of handling large billets of explosive as are encountered in a manufacturing plant. Our version of this test involves dropping a 10.4-kg hemispherical billet of the explosive, supported on a pendulum device, from a preset height striking at an angle on a sand-coated steel target plate. The impact angle may be varied by changing the length of the pendulum arm and the height of the axis. The spherical surface of the billet concentrates the force of the impact in a small area, and the pendulum arrangement assures that the impact contains both sliding and vertical components, reproducibly simulating the conditions of an accidental fall from a workbench or a truck.

Figure 1 shows the test set-up, and Table 2 compares skid test data at a 14- and 45-deg incidence angle for LX-04-1 and four other PBX formulations. The reaction at impact was rated on a scale from 0 (no reaction) to 6 (detonation). The barest hint of a reaction rated 1, a puff of smoke rated 2, and a flash or flame rated 3. A 3-rated reaction would also shatter the explosive and

scatter the pieces. A medium low-order reaction with flame or light and consuming a major part of the HE is rated 4, and a violent deflagration is rated 5.

Table 2 illustrates two important observations. First, whereas both PBX 9404-3 and LX-10-2 detonated after falls of only 0.38m, (1.25 ft.) LX-04-1 did not detonate even after falling 3m (10 ft). Second, both PBX 9404-3 and LX-10-2 exhibit no middle ground; they either detonate or they don't. LX-04-1, on the other hand, can react without detonation, even at heights of 3m.

Table 3 shows special 100 pound skid test data for LX-04-1. Not until the HE is tested from heights of 5 feet are any reactions recorded. This data indicates that if either the upper or lower W70 fixturing is attached and the HE assembly is subsequently dropped onto a sand coated steel floor (i.e., the Pantex floor covering has somehow been removed) from a "nominal" table working height, the HE will not violently react.

Another sensitivity test assesses the hazard in accidentally dropping an encased explosive system from a great height, as from an airplane, and impacting a target at high velocity. In this test (Susan) we fire about 0.5 kg of explosive encased in a projectile against a target of steel armorplate, subjecting the explosive to severe crushing, shear, impact, and extrusion forces. We measure both impact velocity and energy release (shockwave transit time and overpressure) enabling us to draw a sensitivity curve of energy release vs impact velocity (see Fig. 2 and Fig. 3). The energy scale varies from 0 (no reaction) to 100 (violent detonation consuming all of the explosive).

We also take high-speed photographs of the impact, providing both a crosscheck on the impact velocity and a measure of projectile deformation. LX-04-1 ignited after about 25mm of projectile deformation, in keeping with its moderate threshold velocity of 44 m/s. Reaction levels are dependent on impact velocity, rising very slowly from threshold to about 107 m/s and then rising more rapidly as impact velocity increases. Thus, while LX-04-1 is moderately easy to ignite from mechanical impact, it has a low probability of building to a violent reaction or detonating from a minor ignition where there is little or no confinement. In contrast, PBX 9404-3 detonated after only 8.9 mm of deformation, consistent with its very low threshold velocity of 32 m/s.

The shapes of the energy vs impact-velocity curves in Figure 3 reinforce the conclusions of the skid test; any mechanical ignition of either PBX 9404-3 or LX-10-2 has a good chance of building to violent deflagration or detonation, whereas, LX-04-1 has both a higher initiation threshold and milder, self-limiting reactions near their thresholds.

In yet another sensitivity test, we fire a 30-06-caliber rifle bullet at 836 m/s into the center of a 3.2-mm-thick cold-rolled steel plate welded across the end of a 2-in. steel pipe nipple in which we have encapsulated with Adiprene adhesive a 50.8 mm dia. x 101.6 mm long cylinder of explosive.

Figure 4 compares rifle-bullet test results on various PBX's. Each point on the diagram represents a measurement of the shock overpressure and time of shock arrival from a single test of this sort. In addition to PBX 9404-3, LX-04-1, and LX-10-2, we used two different LX-14-like batches. The points above the dotted lines indicate detonations. The points below the dotted lines indicate burns.

The rifle-bullet test clearly differentiates between such high-sensitivity explosives as PBX-9404-3 and LX-10-2 on the one hand and LX-04-1 on the other. It also reveals something of an explosive's predictability, with a comparatively large scatter in the results for PBX 9404-3 and a very tight grouping for the LX-04-1 points.

The critical energy of an explosive has a rather strict boundary between shock initiation and noninitiation when plotted as a function of energy fluence and the shock wave. A critical energy equation has been derived from the conservation and Hugoniot relationships. Each explosive has a specific critical energy fluence value. Listed below are the critical energies for shock initiation of some explosives compared with LX-04-1:

<u>Explosive</u>	<u>Density</u> g/cc	<u>Critical Energy</u> cal/cm ²
PBX-9404	1.84	15
LX-10-2	1.86	21
LX-04-1	1.85	26

The worst case for skid test ignition of PBX-9404 is 0.35 cal/cm² (shock plus friction), whereas, for LX-04-1 is 2.0 cal/cm². Steven K. Chidester¹, calculated the velocity required to ignite PBX-9404 during HE removal from the case (HE movement against HE is essentially equivalent to HE movement against metal). Using his data, a relative velocity of 5-in./s is required to raise the outer HE surface temperature to 100°C. This temperature is well below the ignition temperature for LX-04-1 of ~190°C. Therefore, even in the highly improbable event of cracked HE moving against itself, velocities approaching 5 in./s are extremely unlikely within the confinement provided by the disassembly tooling. Thus, the two main safety concerns of impact and skidding have been addressed and found to be non-hazards in this application.

¹ Steven K. Chidester, Calculation of the W48 HE Temperature Increase Caused by Frictional Heating from Case Removal (U), report (SRD), p. 5, December 12/8/94, CODT-94-0710.

General Stability and Energy Properties of LX-04-1 Compared with PBX-9404 and LX-10

PROPERTIES

	<u>PBX-9404</u>	<u>LX-10-2</u>	<u>LX-04-1</u>
Theoretical density, g/cc	1.86	1.89	1.88
Typical density	1.84	1.86	1.86
Cylinder test comparison at 19 mm	1.000	1.022	0.908
C-J pressure, kilobars	372	385	350
Detonation velocity	8800	8817	8520
CRT, cc/1/4 g - 120°/22 hrs	0.36-0.40	0.02	0.02
DTA exotherm (onset)	180°C	270°C	270°C
Impact sensitivity, cm (12B)	40	40	55
Small scale gap in.	0.097	0.090	0.052

Table 1

Skid Test Comparisons Are Used To Help Determine a Pressed Explosive's Plant Handling Safety Characteristics

SKID TEST DATA

<u>Angle</u>	<u>Height</u>	<u>PBX-9404</u>	<u>LX-10-2</u>	<u>PBX-9501</u>	<u>LX-04-1</u>	<u>LX-14-0</u>
14°	0.88'	--	--	--	--	--
	1.25'	6-6-6-0-0	6-6-6-0-0	--	0	0-0-0-0-0-0
	1.75'	6-6-6-0-0-0		0-0-0-0-0-0	0-0	0-0-0
	2.5'	6-0-0		3	2-2-1-0	0-0-0
	3.5'	6-6		3-0-0	0-0	0-0-0-0
	5'			3-0	2-0	3-1-0-0-0-0
	7.1'			3	1	1
	10'				2	2
	14.1'				2-0	2-0
45°	2.5'	--	--	--	--	--
	3.5'	6-6-6-6-0-0	6-6-0-0-0-0	--	0-0-0-0-0-0-0	0-0-0
		0-0-0-0-0-0	0-0-0-0-0-0			
		0-0-0	0-0-0-0-0-0			
			0-0-0			
	5'	6-6-6-6-6	6	--	3-0-0-0-0-0	0-0-0
		0-0-0-0-0				
	7.1'	6-6		0-0-0	1-1-0-0-0	0-0-0
	10'	6-6		3-0-0-0-0-0	3-2	0-3-0
	14.1'	6		0-0	3-2	
	20'			0-0-0-0-0-0-0-0		

Table 2

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Very large charges of LX-04-1 can be safely handled from normal table top heights

100# Skid Test Results

<u>Angle</u>	<u>Height (ft)</u>	<u>LX-04-1</u>	<u>PBX-9403-3</u>
45°	0.88	0	0
	1.25	0	0
	1.75	0	0
	2.5	0	6
	3.5	0	
	5	3	

Table 3

LLNL/Pantex Skid Test Assembly

Susan Projectile Assembly

Figure 2

Susan test data shows accidental mechanical ignition of LX-04-1 has a low probability of building to a violent reaction or detonation when impacted lightly or unconfined

Figure 3

Rifle bullet impact comparisons

Figure 4

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