PHYSICAL PROPERTIES OF EXPLOSIVES

This work is for the development of testing methods and determination of physical properties of H.E. formulations.

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ABSTRACT

An eight-cycle bulk compliance test on LX-04-1 produced a gain in density of 0.017 gm/cc from an average starting density of 1.858 gm/cc, net gain of .810 gm/cc after one month storage.

A group of tensile specimens were tested on three test machines in three locations (Baldwin at LRL, Instrom in Pantex Engineering and Tinius Olsen in Pantex Development), using specimens from a single pressing. The tests showed that these machines are able to produce similar results and are not extremely operator sensitive.

It has been determined that LX-04-1 will not flow well enough at a loading of 50 psi to produce orientation grooves for pents.

A tabulation of density, tensile strength, strain at ultimate stress, granule size and HMX particle size has been compiled for evaluating the several powder lots of LX-04-1 which have been used.

Density and tensile strength appear to be better when PBX 9404 is pressed in the 300-ton (ram) press than it was for the same lot of material which was pressed in the 20-inch hydrostatic press.

PREVIOUS APPLICABLE WORK

Bulk compliance tests reported previously have depended on an operator to measure changes of specimen length during the temperature cycling. This

limitation required stopping the cycles for off-shifts and weekends or limiting the number of measurements which were practical. Therefore, a stop-motion camera has been employed to obtain continuous readings.

Some questions arose about the comparability of the test information obtained from different testing machines on viscoelastic materials, which led to the comparison described in this report.

Testing was started last quarter to determine if LX-04-1 will flow into unpressured voids when most of the surface is under mild pressure. Dead weight loading was tried, but proved to be bulky for the loading required and was discontinued until the hydraulic system of this report could be obtained.

DISCUSSION

Bulk Compliance of LX-04-1

An eight-cycle test of the bulk compliance of three samples from one lot (SR 49-63) of LX-04-1 at 16°F/hr temperature change was completed using the stop-motion camera for recording changes at 5-minute intervals. This is intended to be the first of several such tests using different rates of temperature change to determine quickest cycle for obtaining maximum density, and to define lot differences. The record of this run indicates that a longer dwell than one hour at the extreme temperatures is required for the LX-04-1 to reach maximum dimensional change; however, each of the 3 specimens gained .017 gm/cc in density in this test and gave an average bulk compliance of 9×10^{-6}.

The bulk compliance test run this quarter was the most successful of any which has been tried to date. An accurate set of measurements was made of the initial deformation of the LX-04-1 during loading to 800 psi which indicated an average reduction in length of .0239"/6" specimen. This is mathematically equal to a densification of .0062 gm/cc. Dial indicators were mounted on the units as quickly as possible after loading to permit continuous readings of changes in the specimen's length.

The temperature-controlling cam was allowed to run continuously throughout this test, so time is a less important consideration than in past tests; the data (see Figure 1) show dimensional and density changes as a function of chamber temperature for each cycle. The average density at the start was 1.858 gm/cc and was 1.875 gm/cc after removal from confinement. The length immediately before unloading was 5.942 inches from an initial length of 5.999 inches; after one month, the length had grown to 5.963 inches and the density reduced to 1.868 gm/cc. Table I gives a summary of this test.

Table I

Bulk Compliance Summary

Spec.	Lot No.	Bulk Comp. $(psi)^{-1}$	Length Change Loaded (inch)	Retained Lgth. Change 1 Mo. (inch)	Initial Density (gm/cc)	Density Just After Unloading	Density After 1 Mo. Unloaded
7	SR-49-63	11×10^{-6}	-.057	-.035	1.858	1.875	1.868
10	SR-49-63	8×10^{-6}	-.058	-.036	1.858	1.875	1.868
14	SR-49-63	8×10^{-6}	-.060	-.037	1.859	1.876	1.869

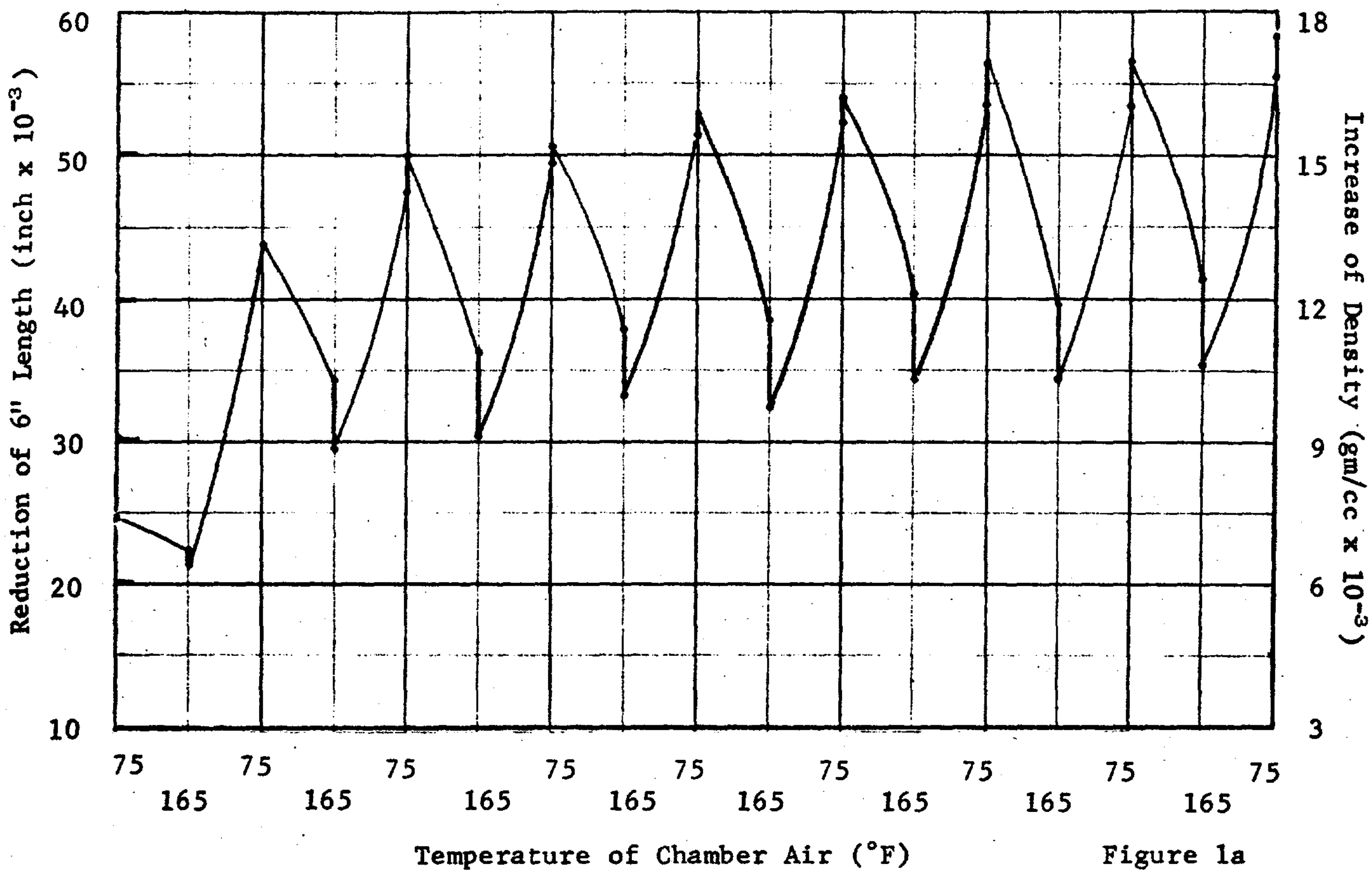

Figure 1a

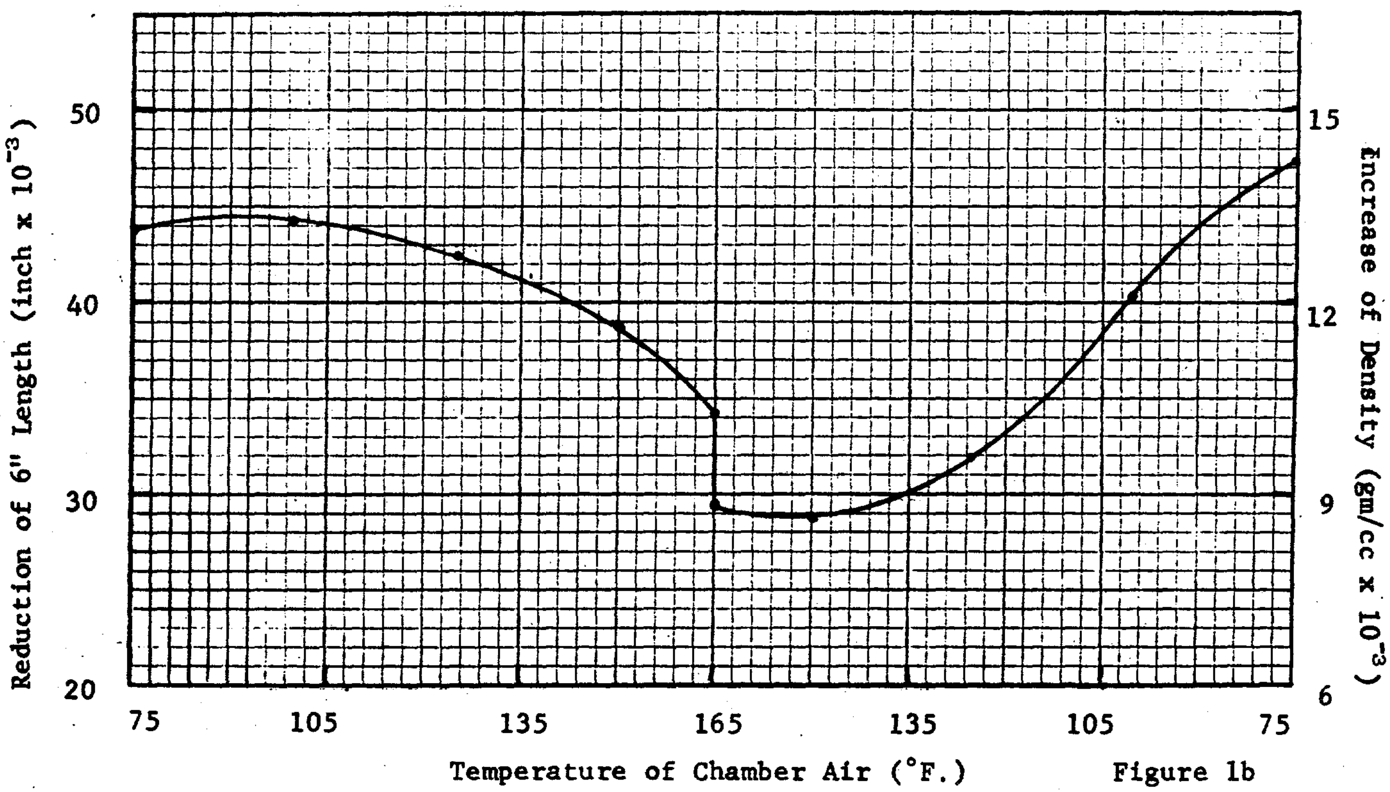

Figure 1b

One Typical Cycle

Test Machine Comparison

A series of tensile tests was performed using the Baldwin tester at LRL, the Instron tester in the Pantex Process Engineering group, and the Tinius Olsen tester in the Pantex Development Group, to determine whether the three different machines will give comparable data using common material at similar speeds and temperatures. Also, the variations arising from use of different extensometers and different operators were evaluated in this series.

The comparison was composed of 20 tensile specimens which were tested on each of the 3 testing machines at the same time. All of the specimens were fabricated from a single pressing of LX-04-1 from Lot SR-154-63 by the Pantex Development group. All were simultaneously dried five days in desiccant and tested at 73°F and .005"/min. crosshead speed on March 25 and March 26.

The measured strengths and strains at ultimate for this evaluation are shown in Table II and it does not appear to matter which machine is used as all values are quite similar. Differences due to operator, machine, and extensometer are all statistically insignificant. Average values of stress and strain of all test groups fell within a common statistical population.

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Table II

Test Machine Comparison

	Development			Process			LRL		
	Specimen Number	Ultimate Stress (psi)	Strain @ Ultimate ($\mu\varepsilon$)	Specimen Number	Ultimate Stress (psi)	Strain @ Ultimate ($\mu\varepsilon$)	Specimen Number	Ultimate Stress (psi)	Strain @ Ultimate ($\mu\varepsilon$)
		Tested 3-25-64			Tested 3-26-64			Tested 3-26-64	
Pantex	26	431	4240	15	413	5570	13	438	5260
Extensometer	23	426	5070	33	422	5070	19	436	4470
With	59	426	4470	18	425	4800	22*	431	4310
Operator 1	2	413	4320	55	434	4720	37	435	4270
	38	426	4410	45	425	5460	50	446	4190
$\overline{X}$		424	4500		424	5120		437	4500
σ		8	370		8	430		6	490
		Tested 3-25-64			Tested 3-26-64			Tested 3-26-64	
Pantex	44	438	4620	24	418	5010	4*	437	4580
Extensometer	8	428	5110	3	420	4790	28	433	4600
With	5	433	4300	27	406	6090	43	430	4870
Operator 2	56	429	4470	30	424	5480	46	440	4590
	14	413	3470	6	420	5260	58	433	4570
$\overline{X}$		428	4390		418	5330		435	4640
σ		10	670		8	560		4	140
		Tested 3-26-64			Tested 3-26-64			Tested 3-25-64	
LRL	41	418	4120	12	418	4220	7	428	4200
Extensometer	20	401	4120	51	429	4390	31	420	5040
With	32	422	4160	42	427	3630	34	430	4580
Operator 1	35	420	4780	57	434	4290	47*	434	3670
	29	420	4300	36	435	4110	49	430	4330
$\overline{X}$		416	4300		429	4130		428	4360
σ		10	320		8	330		6	570

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Table II

(Continued)

		Development			Process			LRL		
		Specimen Number	Ultimate Stress (psi)	Strain @ Ultimate ($\mu\epsilon$)	Specimen Number	Ultimate Stress (psi)	Strain @ Ultimate ($\mu\epsilon$)	Specimen Number	Ultimate Stress (psi)	Strain @ Ultimate ($\mu\epsilon$)
			Tested 3-26-64			Tested 3-26-64			Tested 3-25-64	
LRL		11	414	4560	39	427	4210	1	433	4190
Extensometer		52	435	4140	21	412	4970	10	419	4110
With		17	409	3840	60	430	4420	16	422	4490
Operator 2		54	411	3340	48	434	4170	25	423	5150
					9	424	4520	40	427	4520
	$\bar{X}$		417	3970		425	4460		425	4490
	σ		17	600		9	360		6	460

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*outer surface was rough

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[redacted]

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Flowability of LX-04-1

A static load was applied to LX-04-1 to determine whether or not it would flow into a keyway type slot when subjected to a long-term, mild pressure. Pressure was increased from 21 psi last quarter to 50 psi this quarter and maintained for three days with no measurable flow occurring.

The first attempt to obtain flow was tried using 520 lbs. of dead weights resting on an assembly consisting of a 5" x 5" x 3/8" block of Plexiglas with a 0.010-inch deep x 0.120-inch wide slot extending completely across the center of the bottom surface which rested on a 5" x 5" x $1\frac{1}{2}$ inch thick piece of LX-04-1 from Lot SR-51-63 and was supported on a surface plate. This loading was continued for two weeks at room temperature without any detectable flow having taken place, so the method of loading was abondoned due to the volume of weights required to obtain further increase in loading.

At this point, a frame was acquired which permitted the use of an air-operated hydraulic jack to create 1250 lbs. of load on the Plexiglas - H.E. assembly or 50 psi over the entire area. This loading was maintained for three consecutive days at room temperature with no detectable ridge being formed on the LX-04-1 and so it was decided that LX-04-1 will not flow under conditions which are now practically obtainable and testing was discontinued. If interest remains, trials could be made at moderately elevated temperature (say 150°F).

LX-04-1 Evaluation Data

This tabulation of available LX-04-1 data was begun at the request of LRL to gather as much information as possible in one place in order to determine which variables need to be controlled to obtain consistently good material. The data will not be complete so long as the material is in constant use, but will be added to as rapidly as information becomes available.

Table III is made up of tensile test results from both LRL and Pantex, chemical analysis, particle and granule size from Holston and Pantex.

300-Ton (Ram) Press

The 300-ton press has been reactivated and the billets produced of PBX 9404 (Lot SR 618-GG-62). As others have often found, the ram press yielded significantly higher density. The billets had a density of 1.850, σ .001 gm/cc, while material from the same lot pressed in the 20-inch hydrostatic press had a density of 1.840, σ .002 gm/cc. As one would expect, the higher density material seemed to have a slightly greater tensile strength when tested, although this difference is statistically insignificant. The data are shown in Table IV.

LX-04-1 pressings have also been made in the 300-ton press, but test results are not available at this time.

TABLE IV

TENSILE TEST OF 300-TON PRESSINGS

PBX 9404 LOT NUMBER	PRESS	TENSILE ULTIMATE (psi)	STRAIN AT ULTIMATE (μ ϵ)	SPECIMEN DENSITY (gm/cc)	AVERAGE CORE DENSITY (gm/cc)
SR-618J-62	300 Ton	344	1280	1.852	1.850 σ .001
SR-618J-62	300 Ton	365	2320	1.852	
	Mean	355	1800		
SR-618GG-62	300 Ton	416	1980	1.852	1.850 σ .001
SR-618GG-62	300 Ton	422	2800	1.852	
SR-618GG-62	300 Ton	440	1900	1.853	
SR-618GG-62	300 Ton	371	2760	1.847	
	$\overline{X}$ =	412	2360		
	Std. Dev.	34	580		
SR-618GG-62	20 Inch	380	2130	1.841	1.840 σ .002
SR-618GG-62	20 Inch	371	2360	1.841	
SR-618GG-62	20 Inch	332	2240	1.841	
	$\overline{X}$ =	361	2240		
	Std. Dev.	31	140		

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New Equipment

The 20,000-pound, tri-mode, closed loop test machine which was purchased from Research Inc. of Minneapolis, Minn. has been installed and adjusted and is ready to use as soon as the operator can become familiar enough with it. The environmental chamber for use with this tester is in place and will be connected soon to allow full temperature range testing to be accomplished in the near future.

The recording system for measuring linear coefficient of thermal expansion which was purchased from LaClare Instrument Co. has been completely rebuilt at Pantex. This work has removed the temperature-strain cross-feed problems completely and improved the system design.

Tooling has been received from LRL for testing the compressive creep of various H.E.'s at Pantex. This equipment will be modified as required to permit using lead weights for loading rather than the tuballoy which was available at LRL but is not at Pantex. Proper use of the equipment depends on how quickly a building can be rehabilitated for proper isolation, temperature, and humidity controls.

FUTURE WORK; COMMENTS; CONCLUSIONS

More bulk compliance testing will be done using additional specimens from the same pressing as those reported at this time. Different rates of temperature change will be used to determine if the speed of densification can be increased. The stop-motion camera will again be used to furnish a continual record of the entire run. This method is especially good because it will show clearly if any irregularities occur in the temperature cycle even during an unworked shift. Lot differences can then be determined in practical lengths of time.

The testing herein reported is fairly conclusive evidence that the results obtained from the Tinius Olsen, Instron, and the Baldwin testing machines may be regarded as interchangeable. It also shows that the machines are capable of producing reliable data for more than one operator and that with careful calibration, either the Pantex or the LRL extensometer will record equivalent strain values.

Since LX-04-1 did not flow at 50 psi loading for 3 days, it may be assumed that it will not flow without considerably more load being added, unless temperature is increased.

The LX-04-1 data chart in this report will be kept current with the addition of new information as it becomes available and copies of the latest data may be obtained on request.

Apparently, the 300-ton (ram) press will produce higher density PBX 9404 billets than the 20,000 psi hydrostatic press using material from the same powder lot. Billets of LX-04-1 have also been made in the 300-ton press and will be tested soon.

Measurements will be made of the linear coefficient of thermal expansion with specimens of LX-04-1 from various lots of material which have been used by the Development Group as soon as the recording system is checked out for accuracy and installed.

EVALUATION DATA FOR LX-04-1

LOT NO.	HMX BATCH NO	ROUGH DENSITY (gm/cc)	FINISHED DENSITY (gm/cc)	TENSILE ULTIMATE (psi)	STRAIN AT ULTIMATE (με)	COMP. HOL/PX % HMX	COMP. HOL/PX % Viton	HMX PARTICLE SIZE (cummulative % retained) Holston Pantex 210μ	125μ	74μ	44μ	30μ	20μ	10μ	8μ	6μ	4μ	2μ	1μ	MEDIAN SIZE
SR-388-62	BF-520	1.866				85	15			34	57	70	73	79						50
SR-541-62	BF-579 BF-583	1.859	1.857	351	4129	85	15			28	40	56	60	70						37
SR-583-62	BF-674	1.855	1.854	303*	2770*	85 86	15 14			28	44	55	68	84						36
SR-584-62	BF-675	1.861**	1.854	292*	4010*	85 85	13 14			21	47	60	74	86						41
SR-585-62	BF-677	1.863	1.860	137*	1706*	86 85	14 15	4 3	16 11	37 26	50 44	56 52	63 56	80 61						43
SR-586-62	BF-765	1.864	1.858	232 (6)	2590 (6)	85	15	1	9	25	42	56	58	82						36
SR-672-62	BF-906	1.863				85 85	15 15		11	38	58	67	76	90						51
SR-673-62	BF-906	1.864**	1.864	298 (6)	3200 (6)	85 85	15 15	1	11 6	38 25	58 53	67 65	76 70	90 74						51
SR-48-63	BF-977	1.867(6)**	1.866(5)	250 (11)	3010 (11)	85 85	15 15	1 1	8 6	25 19	38 37	55 47	64 52	73 57						34
SR-49-63	BF-985	1.845(2) 1.864(4)**	1.862(4)	305 (10)	3360 (10)	85 85	15 15	2 2	12 8	27 12	38 32	53 44	60 52	66 57						34
SR-50-63	BF-993	1.860(6) 1.867(6)**	1.866(6)	364 (20)	4270 (20)	85 85	15 15	3 2	13 8	29 21	51 40	57 49	66 55	75 62						36
SR-51-63	BF-1003	1.866(6)**	1.864(7)	347 (10)	4060 (10)	85 83	15 17	2	12	29	47	56	62	80						39
SR-84-63		1.852(2) 1.866(6)**	1.869(6)																	
SR-102-63	BF-1067, 1068,1069		1.861(16)	341 (13)	2760 (13)	86 85	14 15		9	31	46	54	59	82						40
SR-103-63	BF-1067 1068,1069	1.868(4)	1.863(57)	442 (20)	4030 (44)	85 85	15 15													
SR-152-63		1.860(1) 1.868(1)**	1.868(2)	432 (4)	4370 (4)	85	15													
SR-153-63		1.859(4)	1.853(2)	393 (4)	4120 (4)	85	15													
SR-154-63		1.849(3) 1.853(4)**	1.856(2)	434 (3)	3320 (3)	85	15	2	12	26	38	51	67	84						31
SR-155-63		1.850(5) 1.860(6)**	1.857(2)	448 (4)	3260 (3)	85	15	2	12	26	38	51	67	84						31
SR-156-63						85	15	2	12	35	51	59	69	87						45
SR-157-63						85	15	2	12	35	52	59	69	87						45
SR-164-63		1.852	1.846(17)																	
SR-195A-63																				
SR-198-63								1	12	30	45	56	66	80						37
SR-4A-64						85	15	1	12	30	52	59	69	84						45
SR-5A-64						85	15	1	12	33	49	59	65	86						39
SR-6A-64						85	15	2	10	29	43	55	67	81						35

* VALUES OBTAINED FROM LRL TESTING OF EVALUATION

** REPRESSED

SAMPLES NUMBERS IN PARENTHESIS ( ) INDICATE THE NUMBER OF SPECIMENS REPRESENTED