FULMINANT PROPERTIES OF HIGH EXPLOSIVES

EQUATION OF STATE STUDIES

This project consists of (1) essentially routine experimentation, including determination of detonation velocity, gap sensitivity and drop weight impact sensitivity; and (2) an experimental program whose goal is the development of high precision one and two-dimensional hydrodynamic data for use in establishing empirical detonation product equations of state.

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Quarterly Report for April, May, June, 1964

Engineering Order No. 814-00-008

ABSTRACT

Installation of the new Altec-Lansing M-30 microphone system in the impact machine was completed during the quarter. Eighteen series of impact hammer tests were completed. Of these, eight were made with the new 2.5 kg hammer. Routine tests conducted with the 5 kg hammer included EL-511 β, Tacot-T, TNT, PBX 9404, LX-04-1 and PBX 9010; tests made with the 2.5 kg hammer included PBX 9404, LX-04-1, PBX 9010 and PETN.

Half-inch gap sensitivity testing continued with a group test on four RX-04-AB materials and four LX-04-1 materials. Differences in shock sensitivity due to particle size and recrystallization were observed.

Equation of State work during the fourth quarter consisted of three cylinder shots of LX-04-1, two small spherical shots (mockup of the large sphere shot) fired as technique checks, and a full scale sphere shot.

DISCUSSION

Data for all drop weight impact machine testing done during the quarter are displayed in Table I. All data were generated using 35 milligram samples on 5/0 sandpaper; tests 16c through 20b were made with the 5 kg hammer and tests 21 through 24b were made with the new 2.5 kg hammer. Noise intensity measurements for all tests were made with an Altec-Lansing M-30 microphone system and a Hughes storage oscilloscope. We have noted a considerable improvement in our ability to separate different explosives after installation of the new microphone system and the new hammer. Our previous intention (to redesign the 2.5 kg hammer to make a 3 kg hammer) became a modification to the original design such that a 2.5 kg hammer with a better weight distribution (43% lead, 57% steel and aluminum) was obtained.

An interesting phenomenon occurred in test number 19. While conducting a three-H.E. series test on TNT, LX-04-1 and PBX 9404, we observed that the TNT "go's" were occurring at lower test heights and seemed to be "walking up and down". We noticed no unorthodox behavior in the tests on LX-04-1 and PBX 9404; the only known change in testing conditions was a fairly rapid rise in relative humidity due to a rainstorm. The test on TNT was halted at this point (25 drops completed), and testing on the LX-04-1 and PBX 9404 continued. We will probably use a desiccating cabinet at the site of the impact machine, previous observations and studies of the humidity effect not withstanding.

Table I

Impact Hammer Sensitivity Tests

Test No.	H.E. Type	No. of Drops	H.E. Lot Number	Mean (cm)	σ (log units)
		5 kg hammer			
16c	EL-511 (Type β)	44	--	22.9	0.06
16d	Tacot (Type T)	25	--	110.0	0.12
17a	TNT	48	--	142.9	0.16
17b	TNT[1]	50	--	164.2	0.08
18	PBX 9404	25	SR-548-61	26.1	0.03
19a	TNT	25	--	92.2	0.18
19b	LX-04-1	50	SR-152-63	25.8	0.15
19c	PBX 9404	50	SR-548-61	22.9	0.06
20a	PBX 9010	40	SR-254-59	19.0	0.07
20b	LX-04-1	50	SR-152-63	25.8	0.11
		2.5 kg hammer			
21	PBX 9404	25	SR-548-61	48.1	0.01
22	PBX 9404[2]	25	SR-548-61	50.7	0.06
23a	PBX 9404	25	SR-548-61	51.7	0.05
23b	LX-04-1	25	SR-152-63	63.2	0.03
23c	PBX 9010	25	SR-254-59	44.7	0.10
23d	PETN	20	--	25.7	0.08
24a	LX-04-1	49	SR-152-63	60.7	0.03
24b	LX-04-1	49	4162-002-01	50.7	0.04

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[1] Test made on some old castings of undetermined origin at request of another department.
[2] Minor adjustment made in microphone system sensitivity.

Routine 1/2-inch diameter gap sensitivity testing continued with 25-shot series on each of eight H.E.'s, conducted as a group test. The eight H.E.'s were RX-04-AB[3] (HS_cC, BS_aC, BS_cC, and Lot J02459) and LX-04-1 (HS_cF, BS_aF, BS_cF, and Lot SR-152-63). The group test was made in a manner similar to that reported last quarter, using 10 mil increments. Data for these shots are presented in Table II.

Table II

Gap Sensitivity Tests

Formulation (85/15 HMX/Viton)	Density (gm/cm^3)	G_{50} (mils)	σ (mils)
HS_cC	1.858	24	1
BS_aC	1.857	44	13
BS_cC	1.855	23	1
LRL Lot J02459†	1.855	58	28
HS_cF	1.855	79	7
BS_aF	1.861	75	23
BS_cF	1.860	44	8
Holston Lot SR-152-63‡	1.859	78	10

†Equivalent to HS_aC.
‡Equivalent to HS_aF.

[3] H is normal Holston process, B is British-like process, S_a is recrystallized from acetone, S_c is recrystallized from cyclohexanone, C is coarse (approximately Grade A), F is fine, like LX-04-1.

Two of the RX-04-AB materials (HS_cC and BS_cC) were considerably less shock sensitivity than any of the other materials tested in the eight-shot series, and they both appeared to have very nearly equal shock sensitivities.

The conclusions one might draw are:

(a) The particle size effects on shock sensitivity are clear, the fine being more sensitive than the coarse.

(b) Cyclohexanone reX yields lower shock sensitivity.

(c) The British process yields slightly lower shock sensitivity.

(d) Acetone recrystallization causes greater variability in shock sensitivity. The σ's are significantly higher by variance ratio tests (which is stretching things a bit, considering the nature of the σ as derived by the Bruceton method; but the appearance of the data seems clear too). We have found an explanation other than a difference in the material, since the tests were done in a mixed sequence which prevents ordering or other sequential or operator bias from entering.

See Figures 1 through 8 for a graphic presentation of the above shock sensitivity data. "X" indicates explosion, "O" indicates non-explosion.

No detonation velocity work or 0.2-inch gap sensitivity testing was performed during this quarter.

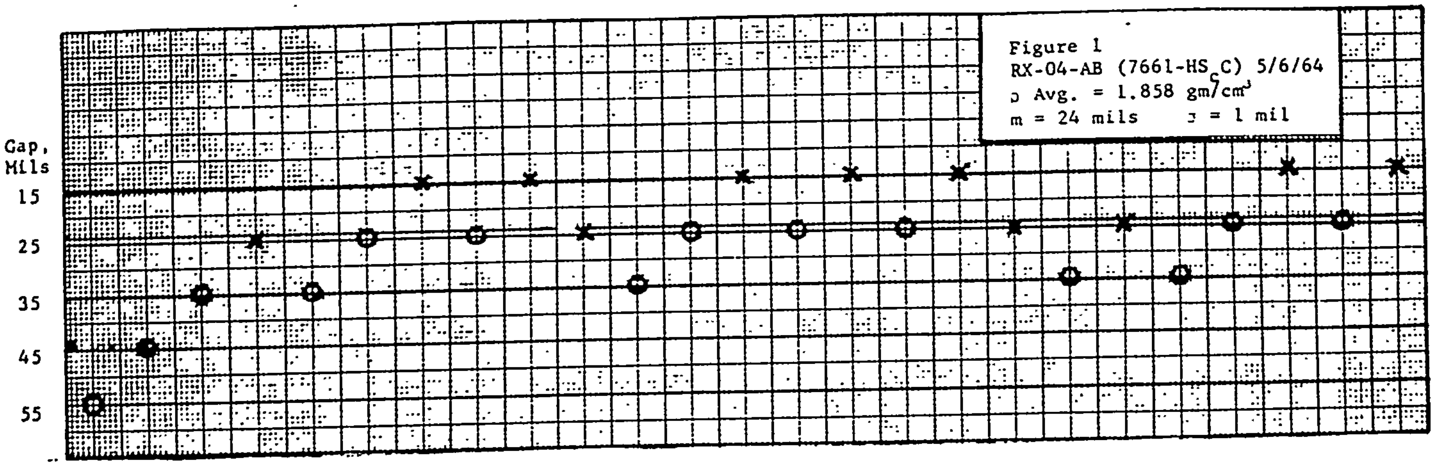

Figure 1
RX-04-AB (7661-HS_cC) 5/6/64
ρ Avg. = 1.858 gm/cm^3
m = 24 mils σ = 1 mil

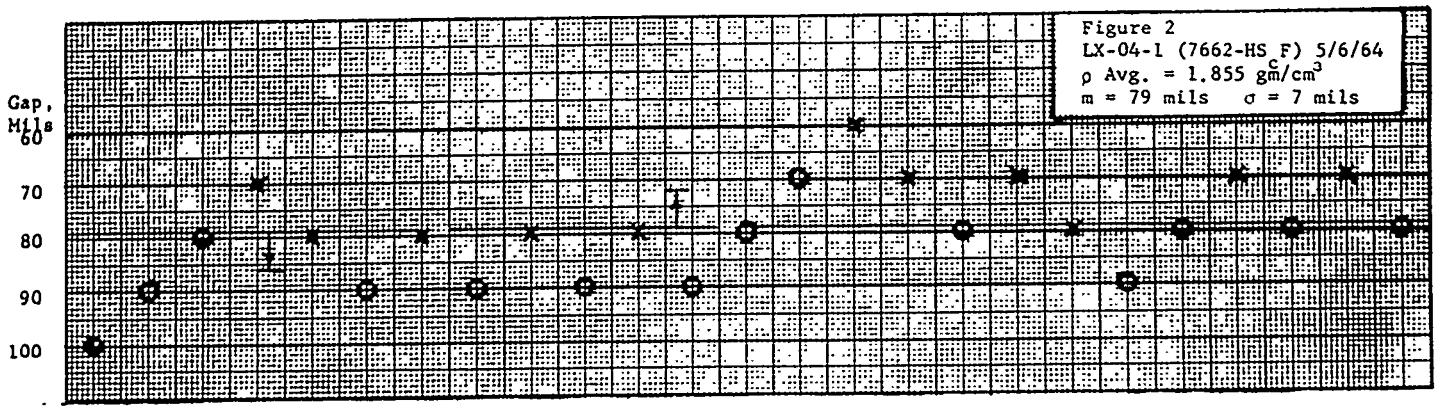

Figure 2
LX-04-1 (7662-HS_cF) 5/6/64
ρ Avg. = 1.855 gm/cm^3
m = 79 mils σ = 7 mils

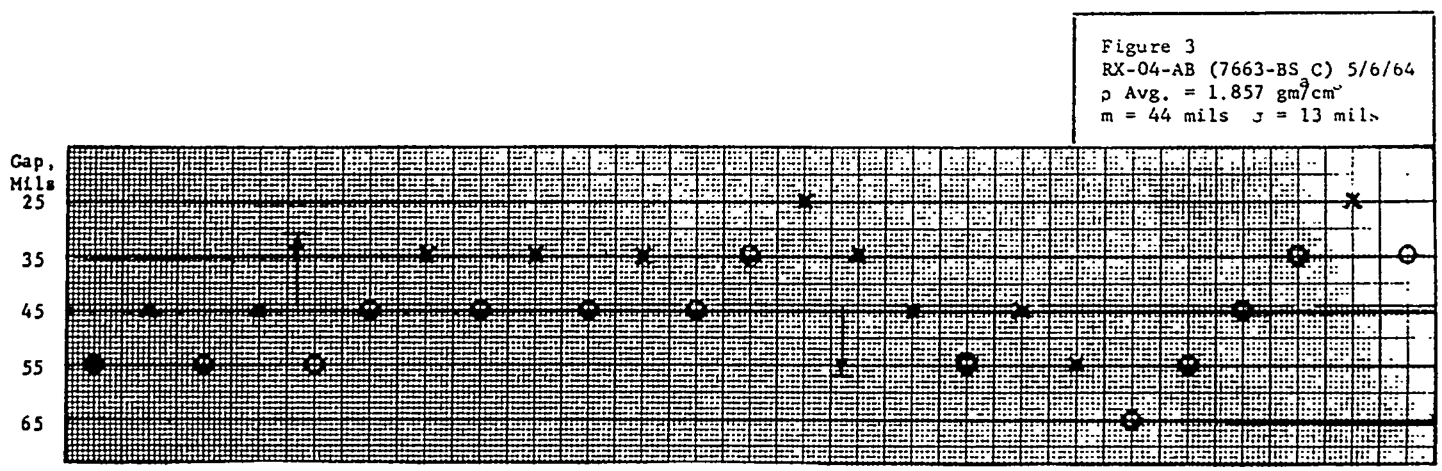

Figure 3
RX-04-AB (7663-BS_aC) 5/6/64
ρ Avg. = 1.857 gm/cm^3
m = 44 mils σ = 13 mils

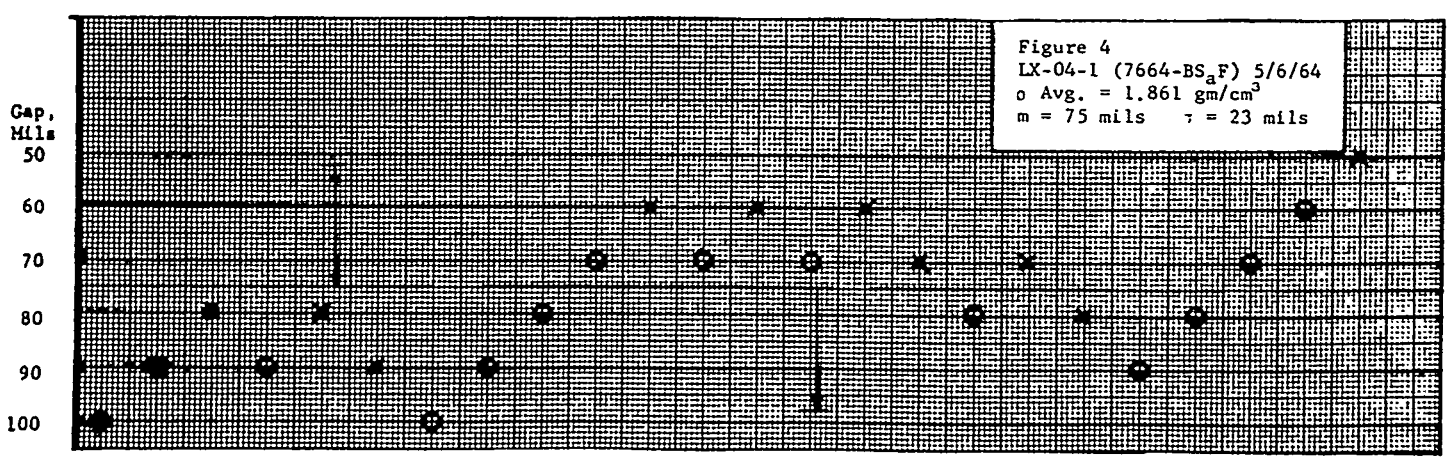

Figure 4
LX-04-1 (7664-BS_aF) 5/6/64
ρ Avg. = 1.861 gm/cm^3
m = 75 mils σ = 23 mils

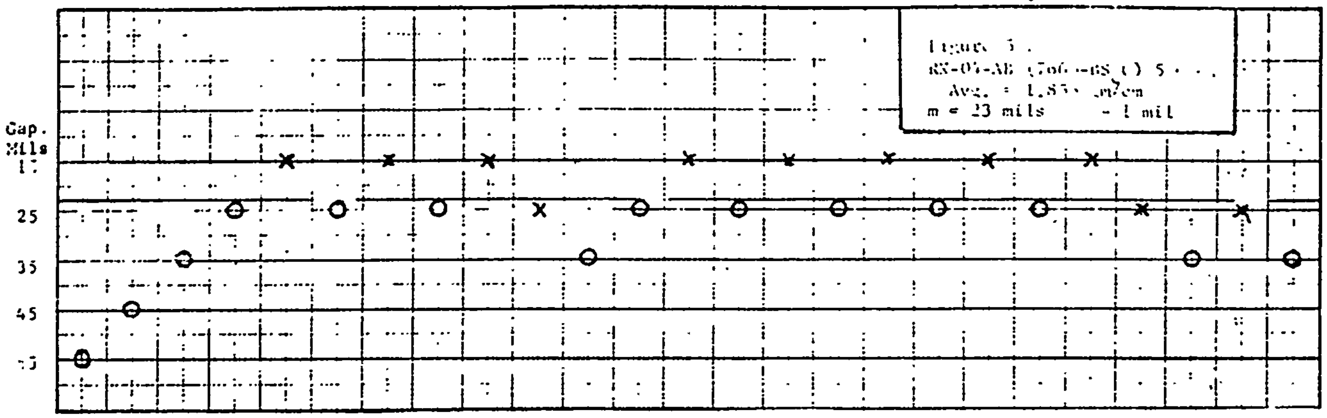

Figure 5.
RX-04-AB (7666-BS ( ) 5 . . .
Avg. = 1.85[illegible] gm/cm
m = 23 mils = 1 mil

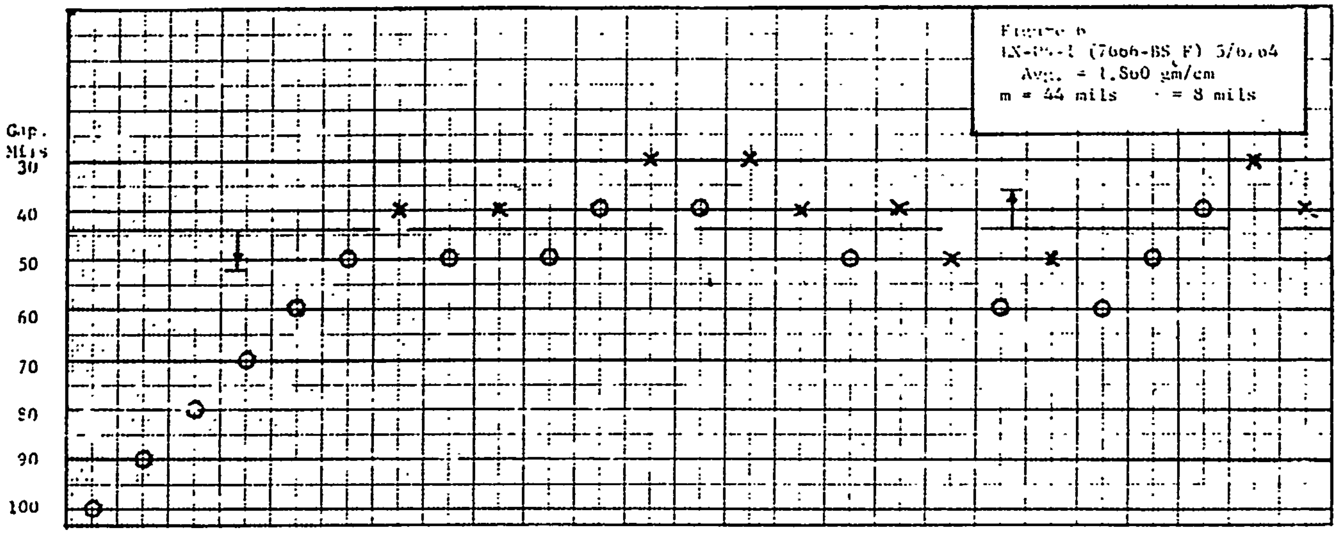

Figure 6
LX-04-1 (7666-BS F) 5/6/64
Avg. = 1.860 gm/cm
m = 44 mils = 8 mils

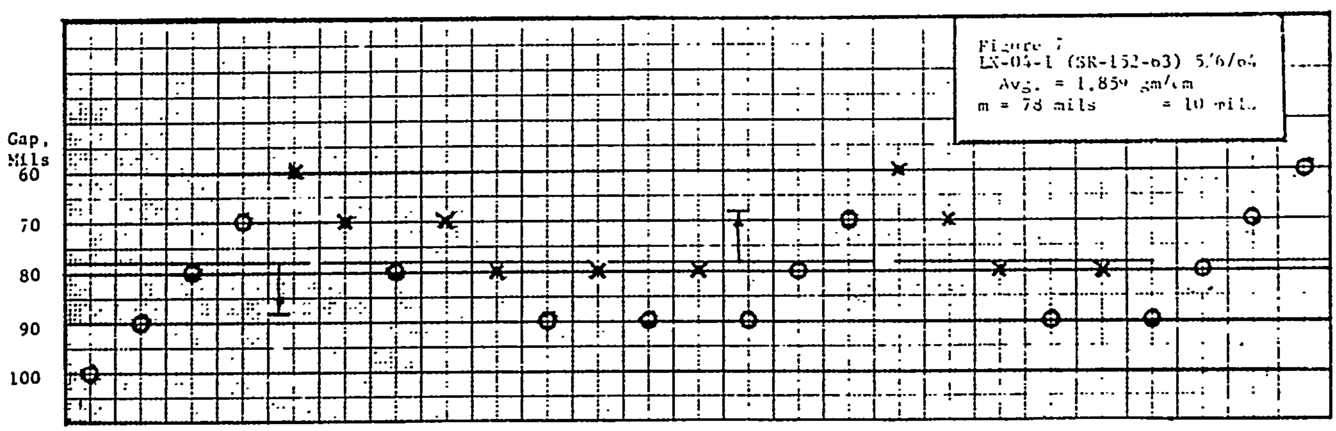

Figure 7
LX-04-1 (SR-152-63) 5/6/64
Avg. = 1.859 gm/cm
m = 78 mils = 10 mils

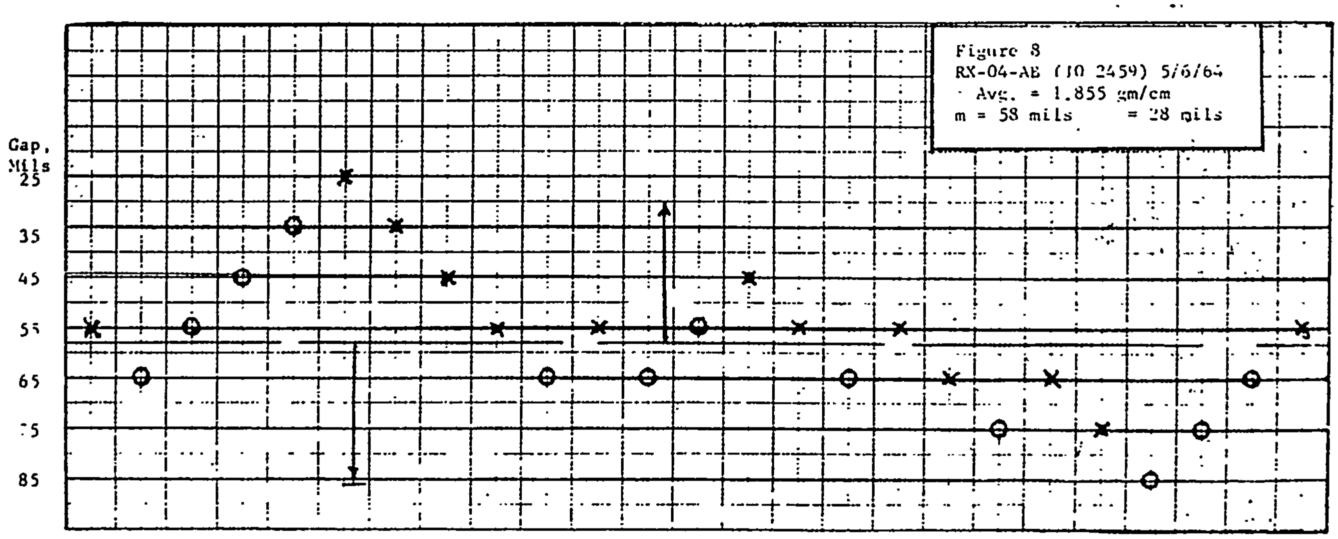

Figure 8
RX-04-AB (JO 2459) 5/6/64
Avg. = 1.855 gm/cm
m = 58 mils = 28 mils

EQUATION OF STATE

The first of three cylinder shots (Pantex Shot No. 10-4-23-1) was fired as a practice shot, with the hope that any unforeseen problems with technique, fixtures, optics, etc. would be brought to light. This shot used LX-04-1 at a density (of the segment viewed) of 1.866 g/cm^3 and a copper tube provided some months previously by LRL. The tube was not electro-polished, this refinement of the technique having been introduced some time after the tubes were dispatched to us. The shot configuration used is shown in Figure 9, and the diagnostic layout is sketched in Figure 10. The writing rate, slit width, aperture diameter, film type, and film development are shown for all three cylinder shots in Table III. The smear record that resulted from the first shot was good for the early portion of the cylinder expansion, but was obscured after about 7 μsec by H.E. products from the boostering system. The aperture was too large, the resultant film density being in excess of the 0.7 to 1.0 range that is most desirable for high precision film reading. The record, nevertheless, was judged satisfactory and useful by J. Kury and J. McDonnel of LRL.

Table III

Cylinder Shot Conditions

Pantex Shot No.	Writing Rate (mm/μsec)	Slit Width (inch)	Aperture Diameter (mm)	Film	Development
10-4-23-1	3.196	.005	64	Tri-X on Estar	6 minutes @ 68°F. Dektol
10-4-28-7	3.287	.005	31	Tri-X on Estar	6 minutes @ 68°F. Dektol
10-4-29-1	5.320	.005	45	Tri-X on Estar	6 minutes @ 68°F. Dektol

The second shot (Pantex Shot No. 10-4-28-7) was also at standard magnification (1 : 0.75 object to image, over-all) and writing rate. This firing used LX-04-1 (from the same pressing as the previous shot) at a density of 1.868. The aperture was reduced a bit more than one full stop. As may be seen in Figure 11, a larger, more massive shield was used between the boostering system and the specimen charge. The copper tube used was electro-polished at the points of view to minimize metal spraying. Framing camera coverage (see Figure 12) was added, primarily as a means of providing backup information should any anomalies appear in the smear record. The shot was successful and duplicated, according to McDonnel and Kury, the quality of the better LRL records. Film density was still a bit high and a further reduction in aperture to about 15 mm diameter would probably be useful. A change to a more gentle, less vigorous film development might, however, be more fruitful, while simultaneously reducing the film density.

The third cylinder shot (Pantex Shot No. 10-4-29-1) was fired for the purpose of examining the early wall motion at higher than normal magnification, and a faster writing rate. LX-04-1 from the same pressing (Lot SR-49-63) as the first two shots was used, with the segment in view being at 1.867 g/cm^3 density. Magnification was 1 : 1.7 object to image. The shot was fired inside a large vacuum container originally fabricated for the sphere shots. Details of this shot container may be seen in Figure 13, the shot layout is shown in Figure 14. Final vacuum was measured at 200μ at the gage. The gage was some 40 feet from the shot container and the pump was about the same distance away on another line so that the vacuum measurement was made at the far end of the system relative to the pump. Thus, the pressure recorded is a conservative measure of the actual pressure within the shot container. The smear record obtained was of good quality, though one edge was partially obscured by some extraneous light of undetermined origin.

As was expected from the results of our previously report analysis[4], the 62-inch focal length, 4-1/8-inch diameter lens used as the external objective (mounted indoors) with the B & W 168 smear camera yielded optical performance as good or better than the previously used blowaway lens system. Further, the high stability base (Estar, a polyester) of the Kodak Tri-X professional film used in the smear camera appears to have reduced the film shrinkage problem to negligible proportions.

Because of the disparity in quality and acutance between the cylinder and sphere records, we fired two small spherical mockups using the optical and lighting techniques evolved for the cylinder shots. The two aluminum hemispheres were machined from 6061-T6 and were 3.5-inch inner diameter and 0.25-inch wall thickness. The setup was the same as for cylinder shot 10-4-28-7 with the following exceptions: 0.002 inch slit, 45 mm aperture, development of smear record in Kodak Polydol for 12 minutes and adjustment of object and image distances to achieve 1 : 1 magnification. The shots were reasonably successful, though their edge sharpness still leaves a bit to be desired. Most of the fuzziness is probably due to spraying from the rather rough dome surface, the aluminum having been machined only to about a 125 finish. Framing camera records of the two shots show very pronounced metal spraying beginning quite early. It seems likely that this spraying actually begins a few μsec before it is discernible in the framing camera view, with a resulting perturbation of the view seen by the smear camera.

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[4] 3rd Quarterly Report, 1963.

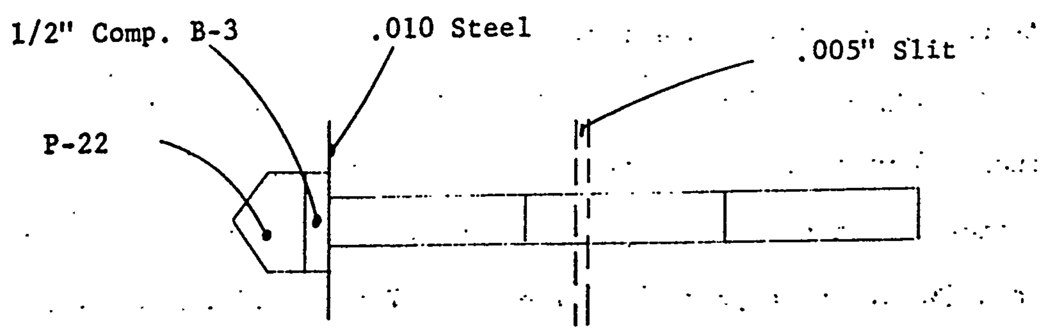

Figure 9

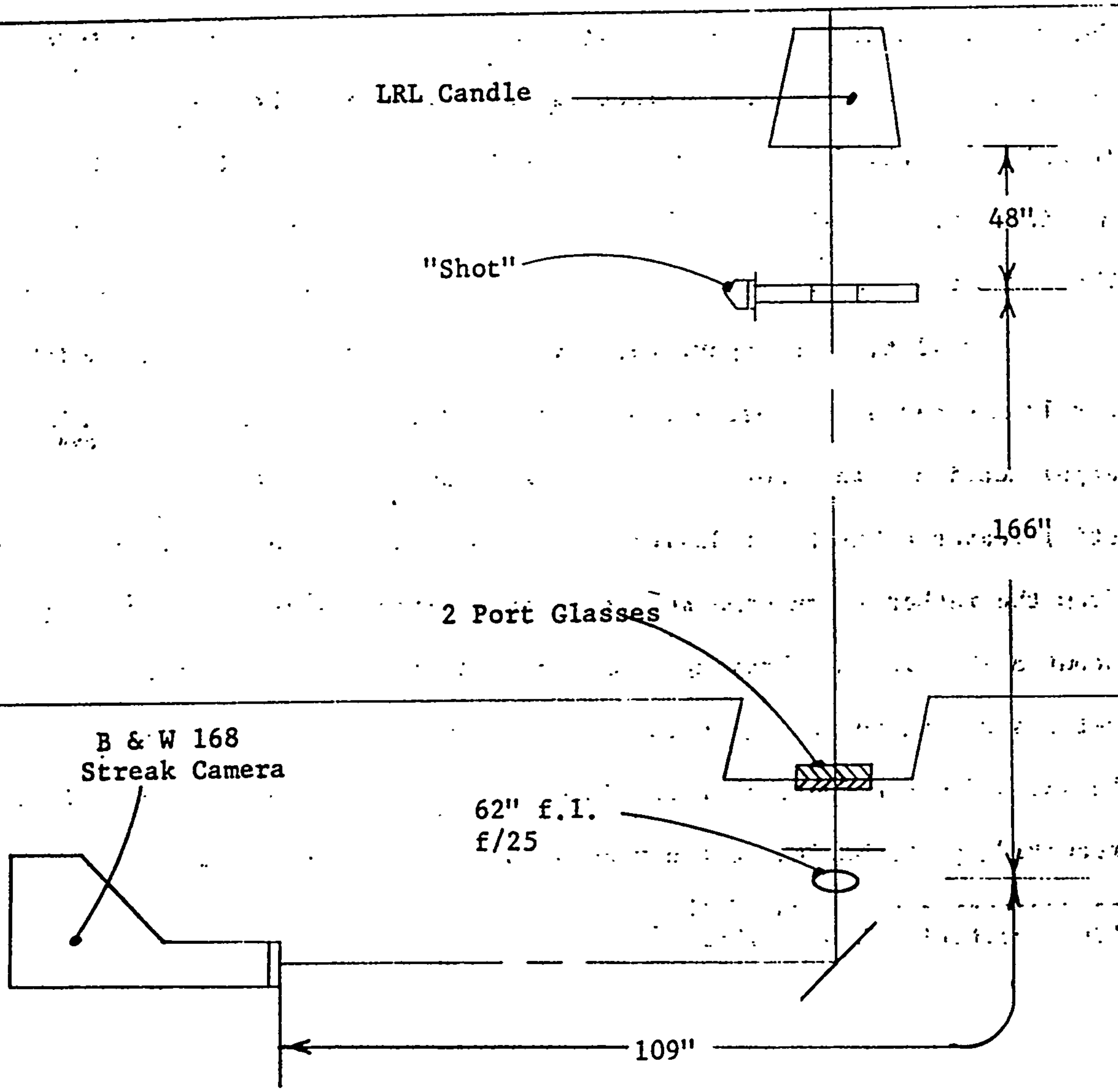

Figure 10

Figure 11

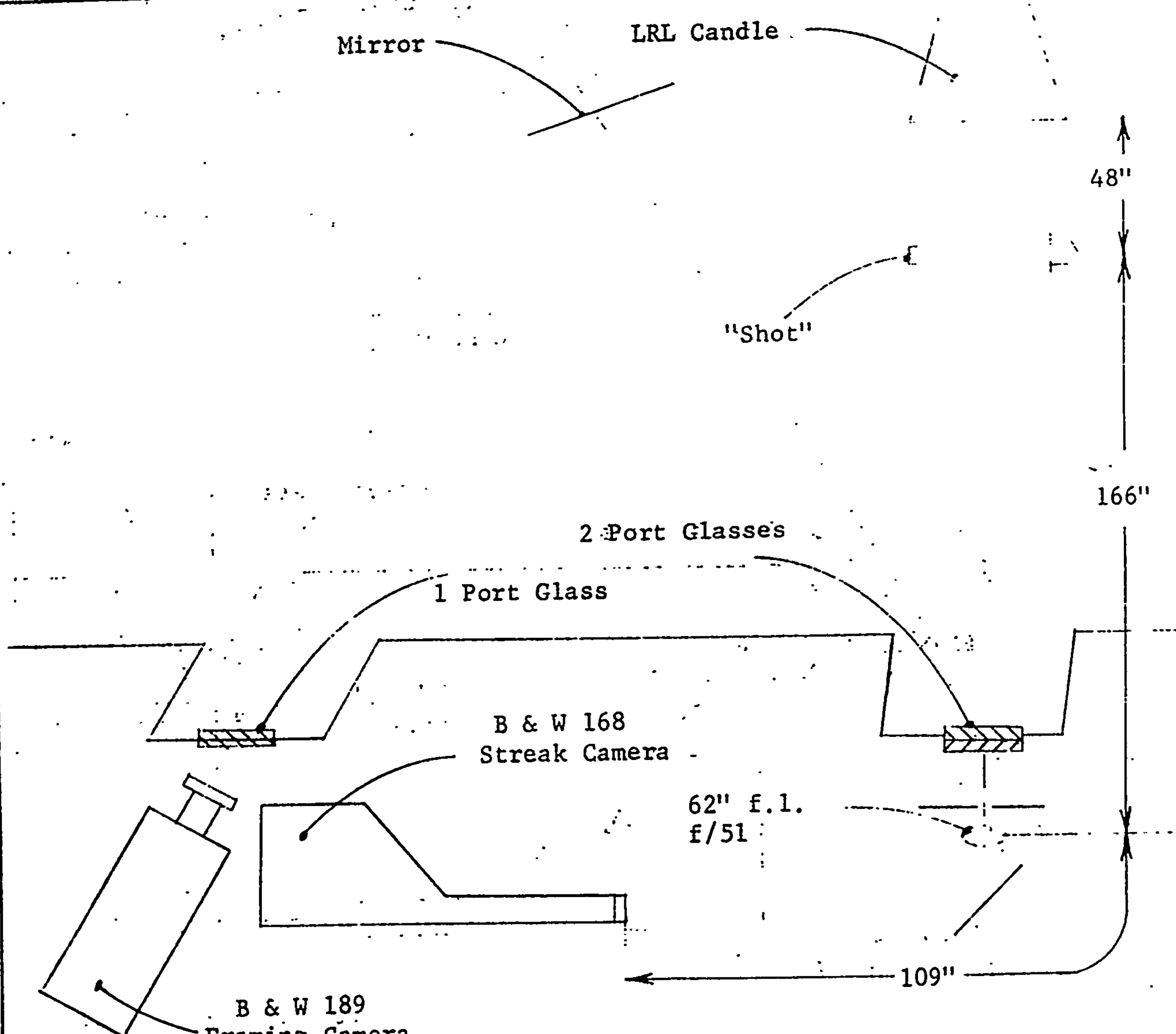

Figure 12

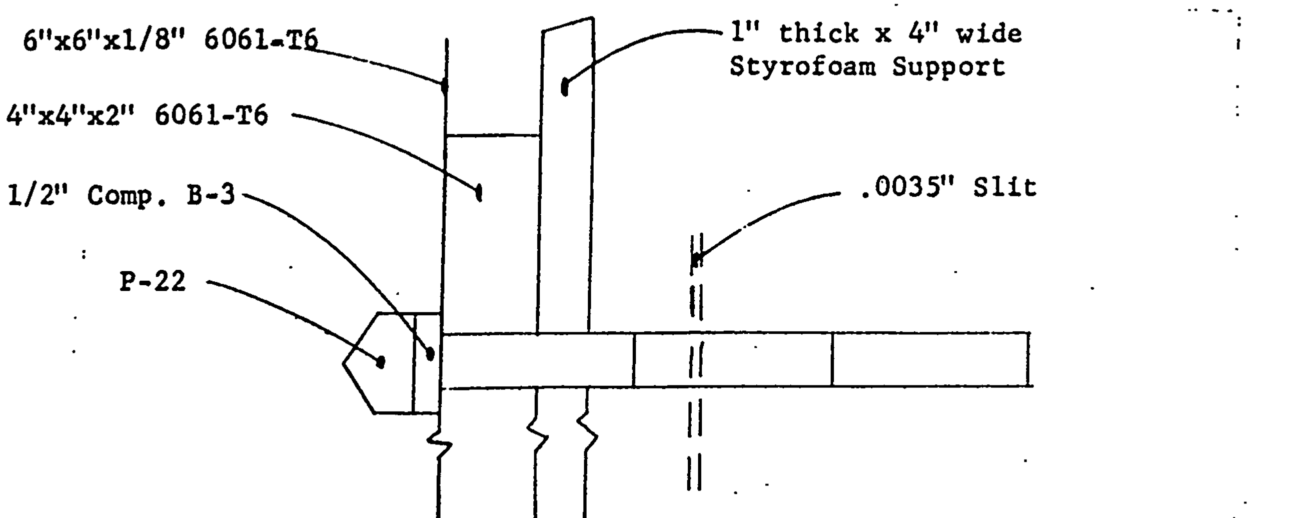

Figure 13

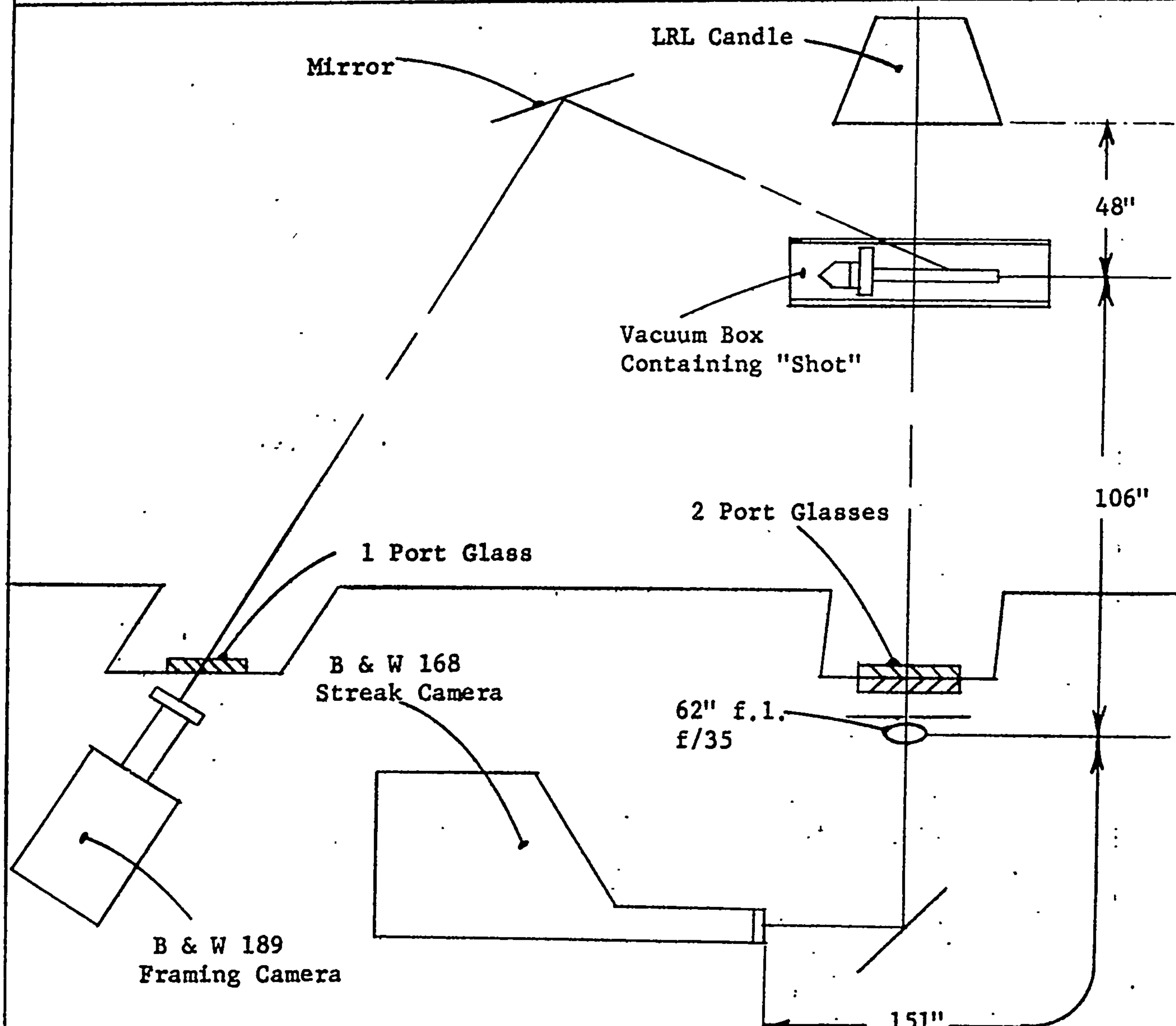

Figure 14

The No. 5 Equation of State shot (Pantex Shot No. 10-6-26-1) consisted of a large scale, nominal 2 cm void sphere shot in vacuum. Conditions for this shot are presented in Table IV. The 0.002-inch slit of the B & W Model 168 camera was aligned approximately 10° off the pole and centered on a 1-1/2-inch diameter electro-polished spot, parallel to and along the edge of a metal scale on the centerline of a spherometer. A framing camera record was obtained with the B & W Model 189.

Table IV

Sphere Shot Conditions

H.E.	PBX 9404 @ 1.837 gm/cm^3
H.E. Outer Radius	13.240 cm
Dome Metal	6061-T6 Al (electro-polished finish)
Density	2.695 gm/cm^3
Inner Radius	15.241 cm
Wall Thickness	0.479 cm
Void	2.001 cm
Firing Temperature	35°C.
Camera Writing Rate	5.31 ± 0.02 mm/μsec
Pressure in Vacuum Chamer	600μ at time of firing
Magnification, object : image	1 : 0.702
LRL candle	4 feet behind point of view glass front

Although the streak camera trace edges are fairly sharp, a considerable amount of density fluctuation across the trace was caused by the use of an inferior quality slit plate. Some fuzziness or loss of acutance appears in the early portions of the trace, but the trace becomes sharper later in time. There was apparently no multiple trace (see Figure 15). Very little detail is discernible in the framing camera record, due to the unavoidably poor viewing angle, lighting conditions and a strong reflection from the Plexiglas windows of the vacuum box.

The streak camera[5] indicates a relatively slow jump-off of approximately 1.2 mm/sec, with an average velocity of approximately 3.2 mm/μsec in the latter portion of the trace. Streak camera records were sent to LRL for precise analysis.

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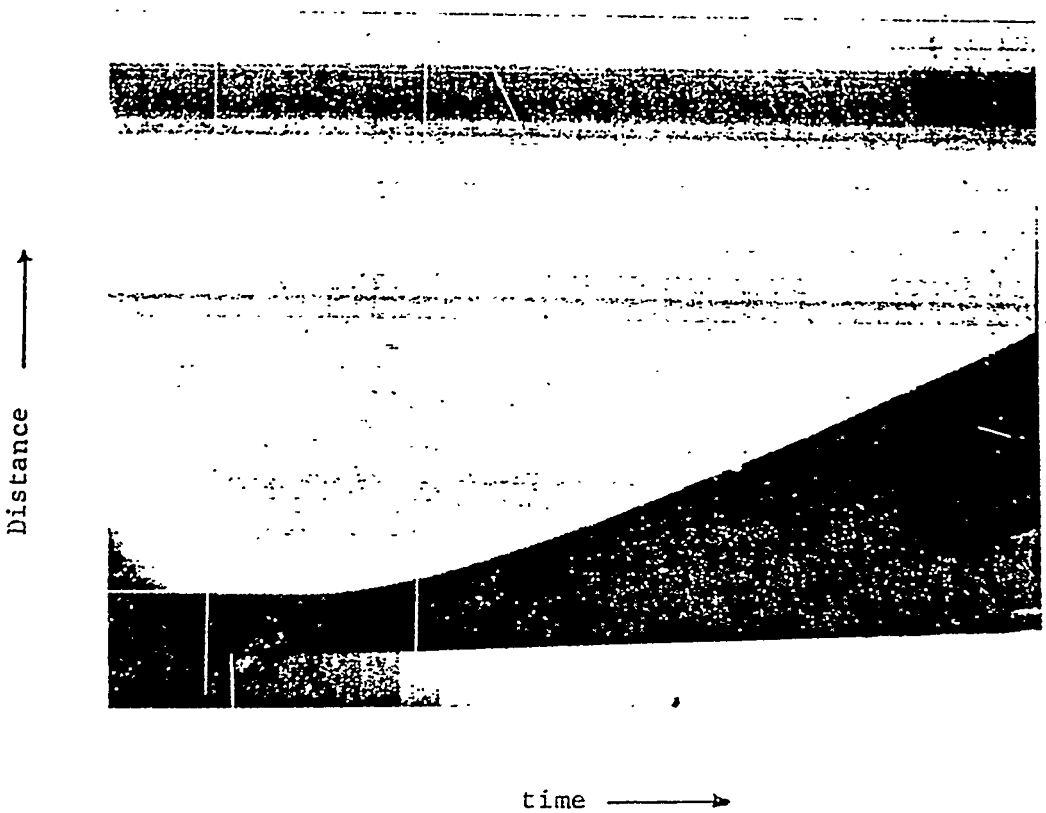
[5] The mirror speed count for this camera was lost when the time interval counter failed to trigger. The shot was fired by means of an automatic fire circuit, which was tested twice prior to firing the sphere shot. During the two tests, the counter indicated times which would yield a writing rate of 5.31 ± 0.02 mm/μsec. This writing rate is supported by measurement of the gate circuit time made immediately after the sphere shot.

Figure 15



Spherical Equation of State Shot

FUTURE WORK; COMMENTS; CONCLUSIONS

Routine impact sensitivity testing of familiar H.E.'s will continue using our new hammer.

Gap sensitivity testing in the 0.2-inch diameter test will continue to be restricted to testing with limited-quantity explosives. Half-inch diameter gap sensitivity work now scheduled consists of the implementation of the GMX-2 small scale (1/2-inch) liquid-filled gap test with the kind help of LASL, and a series on LX-04-1 at three densities. The purpose of the latter is to attempt a determination of a $\Delta G_{50}/\Delta\rho$ curve for LX-04-1.

Detonation velocity work scheduled for next quarter consists of a $\Delta D/\Delta\rho$ study of LX-02-1 and a $\Delta D/\Delta d$ (at small diameters) study of the same material.

Equation of State work scheduled for next quarter includes a cylinder test at 6 : 1 magnification and other tests as required. Precision cylinders have been ordered.