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DETONATION PRESSURE OF HNS I AND II

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ABSTRACT

Detonation velocity and pressure measurements on Sandia-furnished Chemtronics HNS I and HNS II Lots 66-48 and 66-47, respectively, were made using the aquarium technique with supplemental pin switch timing. There was reasonable agreement between the two lots. The major portion of the measurements was made using 12.7 mm diameter pellets over the density range of 1.0 to 1.7 Mg/m^3. A limited test series on HNS I at ρ = 1.685 and 1.60 Mg/m^3 was fired varying the pellet diameter from ∿ 6.3 to 12.7 mm, indicating no diameter effect on detonation velocity or pressure. An alternate method used for measuring detonation velocity and pressure was the antenna technique using a PMMA monitoring stack. The antenna technique was used only on 12.7 mm diameter HNS I pellets at ρ = 1.685 and 1.60 Mg/m^3. Results showed no significant difference from the aquarium test results.

DISCUSSION

The HNS I and II provided by Sandia, Albuquerque for this series were Chemtronics Lots 66-48 and 66-47, respectively. A complete series of tests was conducted on the 12.7 mm diameter pellets of HNS I covering the density range from 1.0 to 1.7 Mg/m^3. Only a partial series at densities of 1.0, 1.2, 1.3, and 1.65 Mg/m^3 was conducted using the HNS II to complement those data previously obtained for HNS II using Ensign-Bickford Lot 5537-02 at densities of 1.4, 1.5, 1.6, and 1.69 Mg/m^3(*1*).

AQUARIUM-EXPERIMENTAL

The aquarium test assemblies illustrated in Fig. 1 consisted of an SE-1 detonator, 12 pressed-to-shape pellets of the sample explosive, the Plexiglas aquarium and four sets of foil switches for detonation velocity measurements. The sample explosive was pressed into 12.7, 9.5, or 6.3 mm diameter by 6.4 mm long pellets. Each pellet was then serialized, gaged and weighed for density calculation. The location of each pellet in its assembly was also noted with the pellets being arranged so as to provide a consistent average density across each detonation velocity section as well as the output pellet. The entire assembly was held together in compression by bolts attached to supporting frames holding the detonator and output pellet. Adhesive (Eastman 910) was used to hold only the silver foil switches in place. The first two pellets following the detonator were used as run-up pellets to assure the existence of stable detonation conditions prior to that pellet section across which detonation velocities were measured. The next nine pellets were separated into three 14.1 mm segments by 0.0064 mm silver foil switches, monitored by raster scopes. By separating the detonation velocity pellet section it was possible to determine whether the detonation velocity was stable across this section. The final output pellet was terminated in water. The shock transmitted to the water was monitored by shadowgraphic streak photography, which resulted in a shock velocity profile in the water.

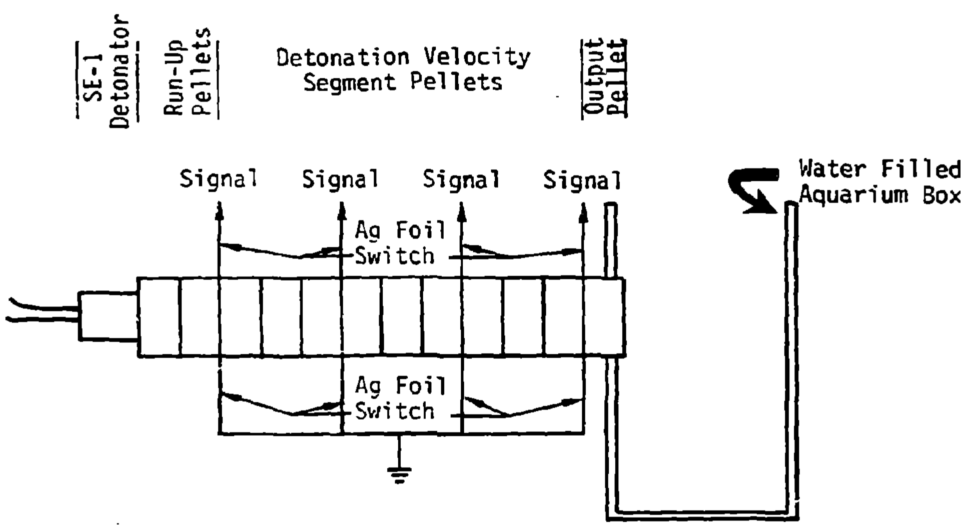


Fig. 1. Typical Aquarium Test Assembly

Analysis of the resultant streak record distance-time data was concentrated in the first 2 mm of actual motion. A linear fit to these data was then generated providing the initial shock velocity, U_S, in the water. The segment in the first 2 mm to be used in the linear fit was chosen from a plot of this portion of the trace, deleting selected points at the initial jump off where reading of the film was sometimes difficult and/or at the end of the 2 mm trace if attenuation of the shock in water was evident.

Using this U_S the corresponding initial particle velocity, U_P, in water was calculated from the following relationship

$$U_P = -0.607 + 0.372\, U_S + 0.0283\, U_S^2,$$

which is a quadratic fit derivable from reference(2). Then, using

$$P_{H_2O} = \rho U_S U_P$$

where ρ is the density of water corrected for temperature, the pressure transmitted to the water by the explosive (P_{H_2O}) can be calculated. At this point the shock velocity (U_S), particle velocity (U_P) and pressure (P_{H_2O}), in the water and detonation velocity (D) and density (ρ_{HE}) of the explosive were known. Using this information an iterative solution of the following pair of equations for the detonation pressure (P_{CJ}), and gamma, of the explosive was obtained.

$$P_{CJ} + P_{H_2O} \left[1 - \frac{(\gamma^2 - 1)\, U_P - (\gamma - 1)\, D}{2\gamma D}\right]^{\frac{-2\gamma}{\gamma-1}}$$

$$P_{CJ} = \frac{\rho_{HE} D^2}{\gamma+1}$$

These relations result from Deal's Gamma-Law(3) which assumes that the detonation products expand adiabatically according to ideal gas theory expressed by PV^{γ} = constant. Coleburn(4) has transformed this by use of the Riemann relation into the more functional form shown above.

AQUARIUM-RESULTS

During the pressing operations preceding test fire assembly some observations were made concerning pressability of the two HNS lots. Higher densities were obtainable with HNS II but HNS I pellets at lower densities had more physical integrity than did corresponding HNS II pellets. For example, free standing usable pellets down to 1.2 Mg/m^3 were made with HNS I while with HNS II densities down to only 1.3 Mg/m^3 were possible. Pellets below these densities were made by pressing the powder in increments ($\sim$ 6.3 mm each) into syntactic foam cavities 12.7 mm in diameter by varying lengths, depending on whether they were run-up, detonation velocity, or output pellet segments to correspond to the usual aquarium assembly. A difference in pressability between the Ensign-Bickford HNS II(*1*) and Chemtronics HNS II was also noted. The lowest density of Ensign-Bickford HNS II which would produce a physically workable pellet, though fragile, was 1.4 Mg/m^3 while a 1.3 Mg/m^3 Chemtronics HNS II pellet was made which was physically much better than the 1.4 Mg/m^3 Ensign-Bickford HNS II pellet. Unfortunately, the lower density pellets made density measurements and shot assembly more difficult.

A total of 24 each 12.7 mm diameter aquarium shots for detonation velocity and pressure were fired on the Chemtronics HNS I and HNS II, the results of which are summarized in Tables I and II and Figs. 2 and 3. The number of tests conducted in this series was not sufficient for a rigid statistical analysis, but based on previous experience with these test techniques one might expect the detonation velocity to be accurate within ± 1%, detonation pressure within ± 0.5 GPa and density at the high end within ± 0.005 Mg/m^3 but uncertain at the low end where the fragility of the pellets precluded direct physical measurements of the pellet.

For comparison purposes the data points for the Ensign-Bickford HNS II generated earlier(*1*) are also shown in Figs. 2 and 3. Detonation pressure results for Chemtronics HNS II and Ensign-Bickford HNS II appear to agree reasonably well with the possible exception at $\rho = 1.6$ Mg/m^3. Detonation velocity results agree well at the high densities but appear to be diverging at lower densities.

The curves shown in Figs. 2 and 3 are the least squares straight line fits for the data, but using polynomial regression the best fits to the data were found to be

Chemtronics HNS I:

$$D = -0.49097 + 6.6206\rho - 1.2620\rho^2$$
$$P = -13.2716 + 19.3445\rho$$

Chemtronics HNS II

$$D = 17.1587 - 37.9874\rho + 34.5083\rho^2 - 9.2183\rho^3$$
$$P = -0.19828 - 0.98834\rho + 7.77110\rho^2$$

In addition to the 12.7 mm diameter aquariums an abbreviated series was fired on Chemtronics HNS I using 6.3 and 9.5 mm diameter pellets to investigate the effect of diameter. The results of this test series are summarized in Table III and compared to 12.7 mm diameter results in Fig. 4. Within expected experimental error there does not appear to be a significant diameter effect for either detonation velocity or pressure within the diameter range tested.

ANTENNA TEST - EXPERIMENTAL

The antenna test assembly illustrated in Fig. 5 was quite similar to the aquarium assembly in that 12 pellets (12.7 mm diameter) were used;

2 for run-up, 9 for detonation velocity measurements and 1 for output. Instead of the silver foil switches for detonation velocity measurements 0.01 mm aluminized Mylar inserts were placed between every pellet after the run-up pellets with detonation velocity being monitored by the "detonation electric effect"(5,6) produced by these inserts at each interface. The output pellet was terminated with laminated PMMA discs ∿ 1.9 mm thick attached to a brass disc antenna. The entire assembly was then submerged in dimethylpolysiloxane fluid for electrical noise suppression.

Signals picked up by the brass antenna from the interfaces of the assembly were displayed on oscilloscopes yielding transit times from which shock velocities were calculated. The initial shock velocity in the PMMA monitor stack was calculated as the average velocity through the first PMMA disc. From this point on analysis was identical to that used in the aquarium test except that the equation of state for PMMA(7) shown below was used instead of that for water.

$$U_S = 2.510 + 1.545\ U_p$$

ANTENNA TEST - RESULTS

Only four antenna tests, all on HNS I, were fired. No signals were produced from the aluminized Mylar inserts for detonation velocity, but signals were picked up at the interface between the detonator and first run-up pellet and between the output pellet and first PMMA disc, from which an average shock velocity across the entire HNS pellet stack was calculated. This average detonation velocity was reported because without the signals following the run-up pellets, the detonation velocity was probably unstable in the first part of the HNS stick over which detonation velocity was measured.

The results of this antenna series are summarized in Table IV and compared to the corresponding aquarium test results in Fig. 6. Within estimated experimental error, there does not appear to be any significant difference between the antenna and aquarium test results.

CONCLUSIONS

The detonation velocity and pressure of Chemtronics HNS I and II were measured at various densities indicating no significant difference in pressure, but with some differences observed in detonation velocity at lower densities. Comparing the Chemtronics HNS II data with previously generated Ensign-Bickford HNS II data there appears to be some difference again in the low density area but such a conclusion requires extrapolation of the Ensign-Bickford HNS II data beyond its original data set and as such is suspect. There did not appear to be a diameter effect on either detonation velocity or pressure in the range of diameters tested. Comparison of the antenna test data with the aquarium test data did not show any appreciable differences in detonation velocity or pressure for HNS I.

Table 1. 12.7 mm Diameter HNS I Aquarium Test Data

(HNS Lot 66-48 Tests Fired at Ambient Temperature; 20 ± 6 C)

Test No.	Detonation Velocity Density (Mg/m^3)	Output Pellet Density (Mg/m^3)	Detonation Velocity D (km/sec)	$\bar{D}$ (km/sec)	Parameters in Water U_s (km/sec)	U_p (km/sec)	P (GPa)	Gamma	Detonation Pressure P_{CJ} (GPa)	$\bar{P}_{CJ}$ (GPa)
1	1.684	1.685	7.063		5.589	2.356	13.15	3.182	20.10	19.89
2	1.683	1.685	7.076	7.070	5.524	2.312	12.76	3.290	19.67	
3	1.651	1.650	6.999	6.995	5.412	2.235	12.08	3.370	18.50	18.41
4	1.651	1.650	6.990		5.388	2.219	11.94	3.401	18.32	
5	1.598	1.598	6.895	6.889	5.296	2.157	11.41	3.418	17.20	18.01
6	1.598	1.598	6.883		5.541	2.323	12.86	3.022	18.82	
7	1.500	1.500	6.584	6.597	5.295	2.156	11.40	3.045	16.07	15.59
8	1.500	1.499	6.609		5.132	2.047	10.49	3.334	15.11	
9	1.401	1.401	6.305	6.304	4.932	1.916	9.44	3.285	12.99	13.21
10	1.401	1.401	6.302		5.014	1.970	9.85	3.141	13.43	
11	1.298	1.298	5.949	5.964	4.720	1.779	8.38	3.197	10.94	11.23
12	1.298	1.298	5.979		4.327	1.848	8.92	3.028	11.52	
13	1.199	1.199	5.648	5.644			LOST			
14	1.199	1.199	5.639		4.774	1.814	8.66	2.663	10.40	
15	1.000	1.001	4.849	4.867	4.198	1.454	6.10	2.580	6.57	6.63
16	1.000	1.012	4.884		4.216	1.464	6.16	2.608	6.69	

Table II. 12.7 mm Diameter HNS II Aquarium Test Data

(HNS Lot 66-47, Tests Fired at Ambient Temperature; 18 ± 8 C)

Test No.	Detonation Velocity Density (Mg/m³)	Output Pellet Density (Mg/m³)	Detonation Velocity D (km/sec)	$\bar{D}$ (km/sec)	Parameters in Water U_s (km/sec)	U_p (km/sec)	P (GPa)	Gamma	Detonation Pressure P_{CJ} (GPa)	$\bar{P}_{CJ}$ (GPa)
17	1.650	1.650	7.014	7.019	5.527	2.313	12.75	3.204	19.31	19.34
18	1.650	1.650	7.023		5.530	2.316	12.81	3.201	19.37	
19	1.301	1.301	5.860	5.845	4.860	1.870	9.08	2.862	11.56	11.44
20	1.300	1.300	5.829		4.817	1.841	8.86	2.908	11.31	
21	1.201	1.204	5.328	5.334	4.776	1.815	8.64	2.384	10.10	10.12
22	1.198	1.201	5.340		4.783	1.820	8.69	2.376	10.14	
23	1.003	1.002	4.479	4.469	4.315	1.525	6.58	1.995	6.71	6.62
24	1.002	1.012	4.459		4.259	1.490	6.34	2.080	6.53	

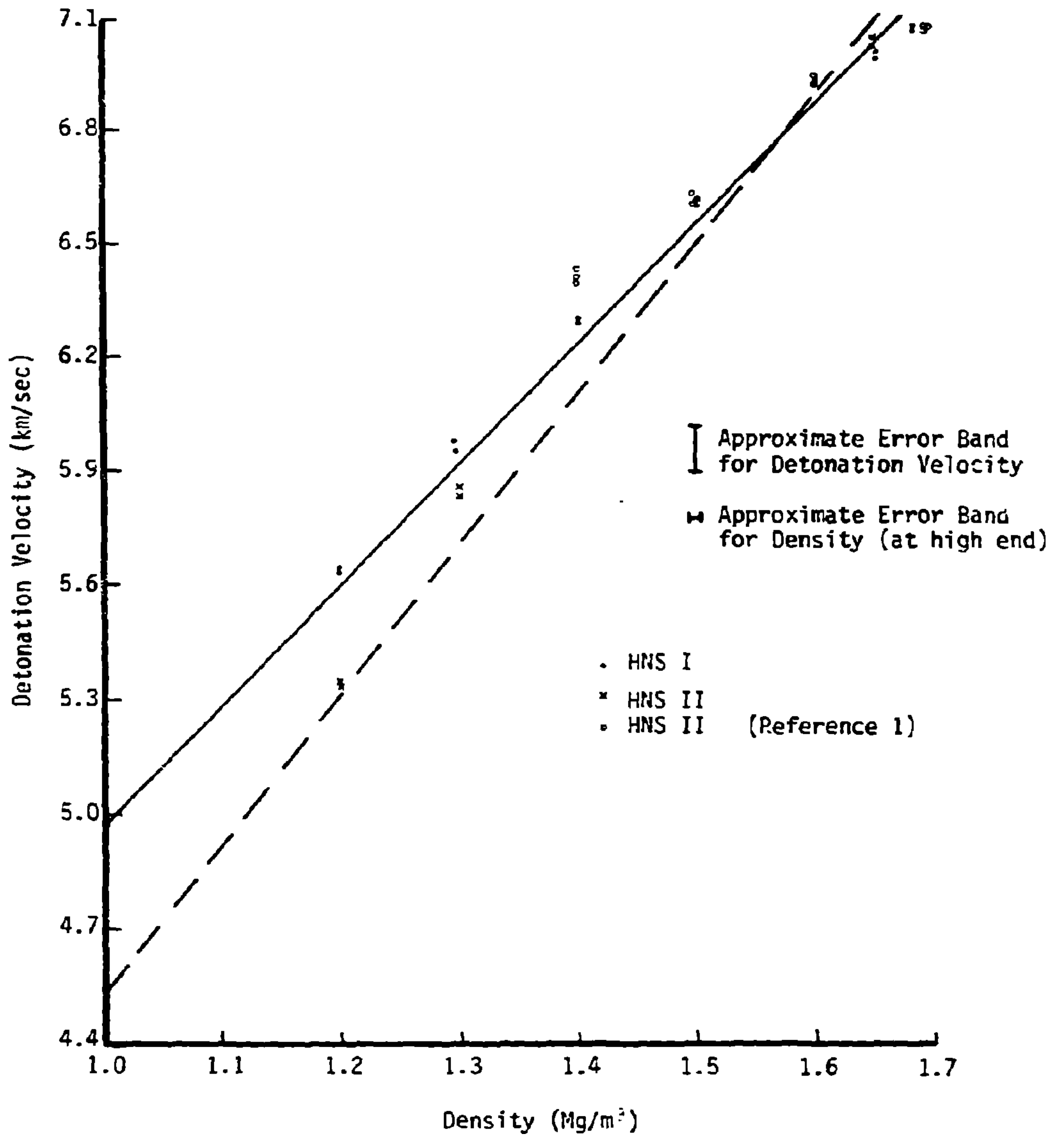


Fig. 2. Detonation Velocity versus Density of HNS I and II

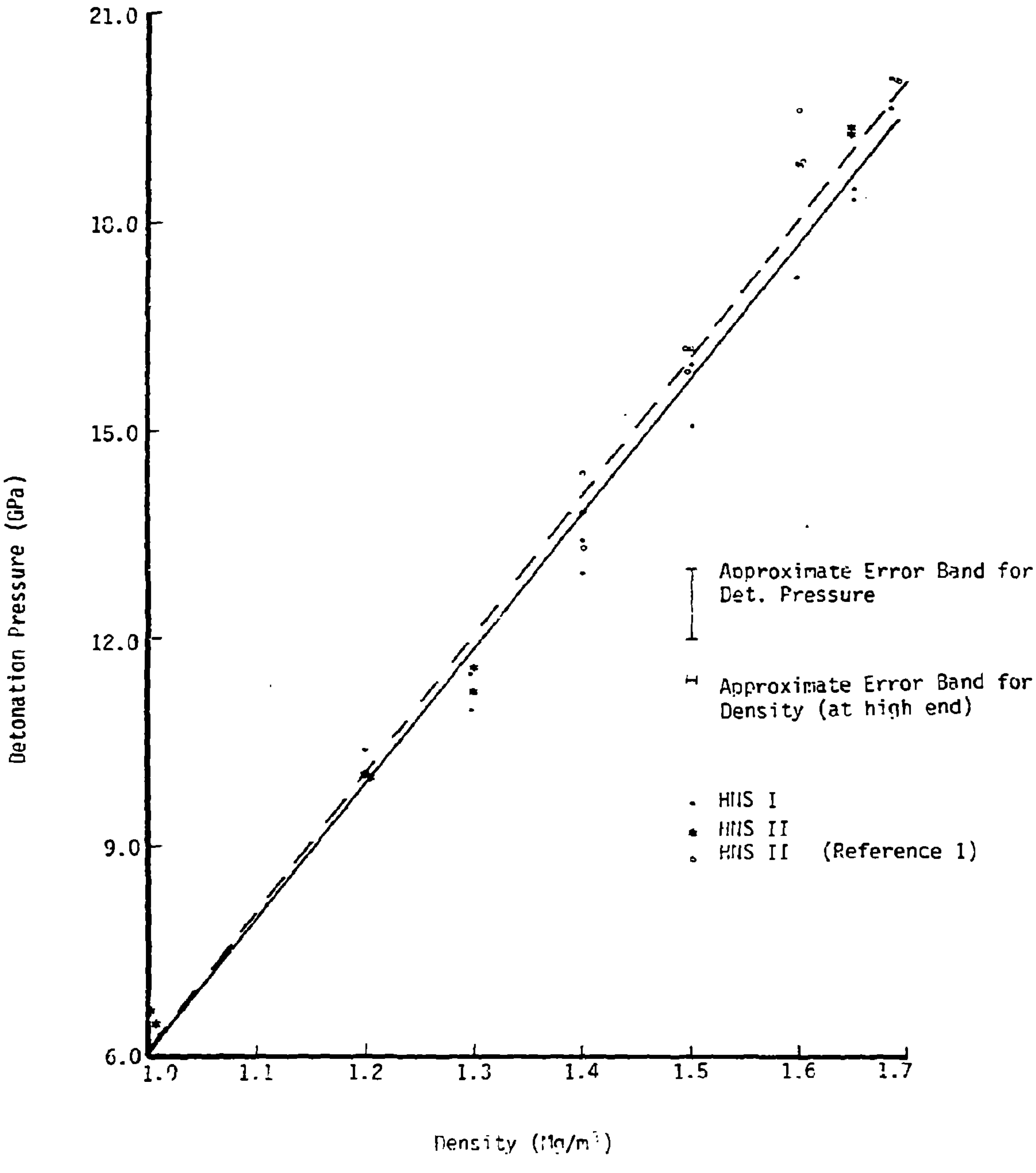


Fig. 3. Detonation Pressure versus Density of HNS I and II

Table III. Diameter Effects on HNS I Aquarium Test Data

(HNS Lot 66-48, Tests Fired at Ambient Temperature; 24 ± 4 C)

Test No.	Diameter (mm)	Detonation Velocity Density (Mg/m^3)	Output Pellet Density (Mg/m^3)	Detonation Velocity D (km/sec)	$\bar{D}$ (km/sec)	Parameters in Water: U_s (km/sec)	U_p (km/sec)	P (GPa)	Gamma	Detonation Pressure P_{CJ} (GPa)	$\bar{P}_{CJ}$ (GPa)
25	9.5	1.685	1.685	7.025	7.023	5.548	2.328	12.86	3.217	19.72	20.00
26	9.5	1.685	1.685	7.021		5.625	2.381	13.35	3.097	20.27	
27	9.5	1.605	1.605	6.880	6.889	5.403	2.229	12.01	3.239	17.92	18.09
28	9.5	1.604	1.604	6.897		5.450	2.261	12.30	3.178	18.26	
29	6.3	1.683	1.684	6.992	7.007	5.579	2.350	13.07	3.139	19.89	19.89
30	6.3	1.683	1.684	7.022		5.572	2.345	13.03	3.173	19.89	
31	6.3	1.595	1.595	6.857	6.908	5.417	2.238	12.10	3.187	17.91	17.99
32	6.3	1.594	1.594	6.958		5.417	2.239	12.08	3.273	18.06	

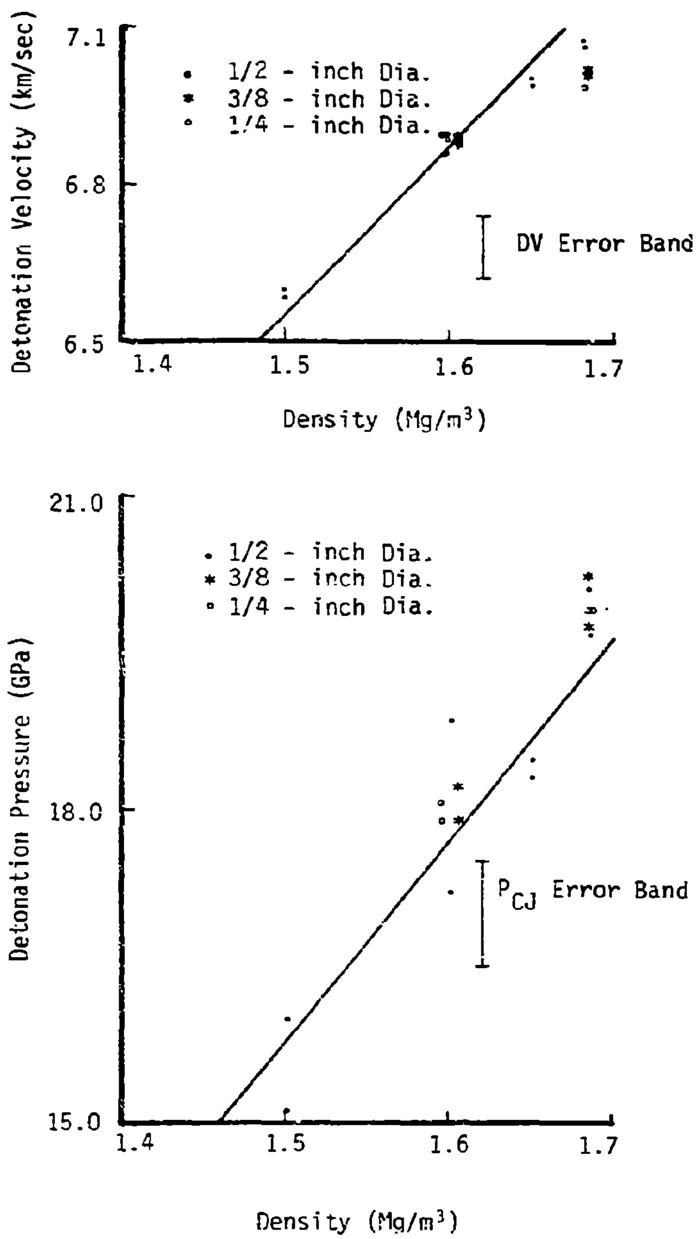
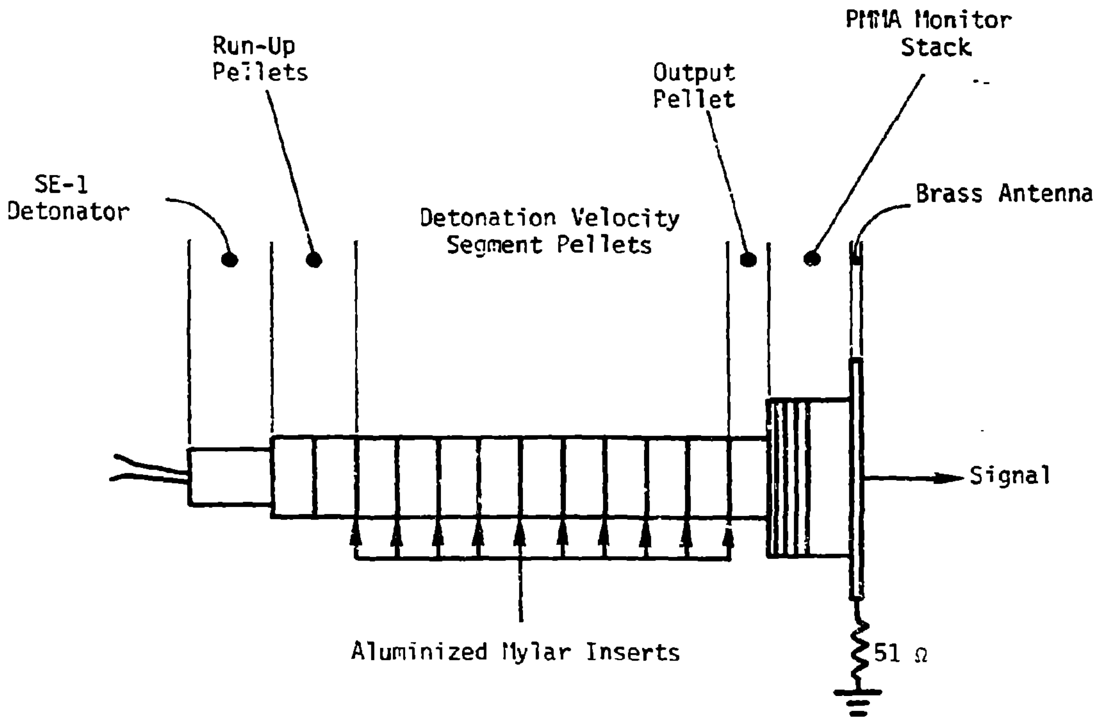


Fig. 4. Diameter Effect on Detonation Velocity and Pressure of HNS I



(Total assembly emersed in dimethylpolysiloxane fluid)

Fig. 5. Typical Antenna Test Assembly

Table IV. 12.7 mm Diameter HNS I Aquarium Test Data

(HNS Lot 66-48, Tests Fired at Ambient Temperature; 20 ± 5 C)

Test No.	Detonation Velocity Density[a] (Mg/m³)	Output Pellet Density[b] (Mg/m³)	Detonation Velocity D (km/sec)	$\bar{D}$ (km/sec)	Parameters in PMMA U_s (km/sec)	U_p (km/sec)	P (GPa)	Gamma	Detonation Pressure P_{CJ} (GPa)	$\bar{P}_{CJ}$ (GPa)
33	1.682	1.685	6.985	6.983	5.873	2.177	15.09	3.087	20.12	20.29
34	1.682	1.685	6.981		5.920	2.207	15.42	3.015	20.45	
35	1.598	1.598	6.790	6.809	5.577	1.985	13.06	3.304	17.12	17.43
36	1.598	1.598	6.827		5.657	2.037	13.60	3.200	17.73	

[a] Average density of all main pellets

[b] Density of pellet providing monitored shock input into PMMA

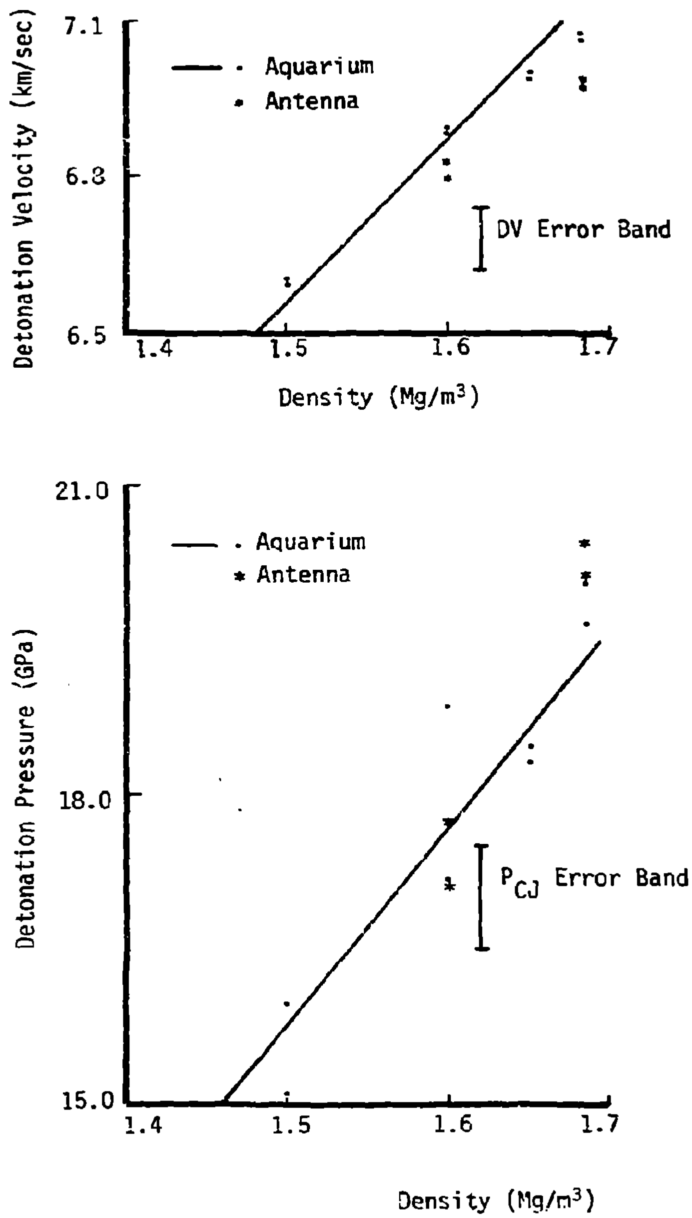


Fig. 6. Comparison of Aquarium and Antenna Results for HNS I

All of the Chemtronics HNS I and II tests were limited to only two shots per data point which does not allow an adequate statistical analysis and one should fire more shots to improve the reliability of this data.

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