On the existence of higher than normal detonation pressures

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With the increasing popularity of combustion driving in strong shock tube experiments, the possibility of detonation must be considered seriously. In addition to the extreme and relatively well-known conditions associated with a detonation, there exists a phase during the transition from a flame to a detonation during which pressures and velocities of propagation can exist which are higher than those associated with the fully formed detonation. This has been discussed theoretically by Oppenheim (1952) and has been shown experimentally by several workers. A luminous front having a higher than detonation velocity has been observed by Bone, Fraser & Wheeler (1936) and others. J. B. Smith (1949), using calibrated burst diaphragms at the end of a pipe, has observed reflected pressures in fuel gas–air, acetylene–air, and hydrogen–air mixtures which were approximately four times greater than those associated with a reflected normal detonation. Turin & Huebler (1951), using quartz pressure transducers in the side of a tube, observed pressures during this transition process about three and a half times higher than those at a later time when detonation was fully developed. They worked with Toledo natural gas. Mooradian & Gordon (1951) also have clear indications of this phenomenon with hydrogen–air mixtures.

Tube length	Peak pressure	Time to half maximum pressure	Impulse
24 ft.	no detonation	—	—
32 ft.	2600 lb./in.^{2}	200 microsec	0·8 lb. sec/in.^{2}
47 ft.	710 lb./in.^{2}	1000 microsec	1·0 lb. sec/in.^{2}

Table 1.

Several experiments have been run in this laboratory using a quartz pressure transducer (SLM model PZ14) mounted in the end flange of a $3\frac{1}{4}$ in. square tube. A stoichiometric hydrogen–air mixture at atmospheric pressure was ignited near one end of the tube with a spark plug, and the pressure on the other end of the tube was measured as a function of time. This pressure record was then integrated between the time of impact and the time the pressure dropped to 150 lb./in.^{2} abs. to obtain the impulse applied to the end of the tube during this interval. The pressure level corresponding to constant volume combustion is about 120 lb./in.^{2} abs., and that due to a reflected normal detonation wave is on the order of 500 or 600 lb./in.^{2}. Our measurements are given in table 1.

The 32 ft. length was marginal with respect to occurrence of this over-detonation when the ignition was at the extreme end. However, moving the spark plug 32 in. from the end resulted in this over-detonation on each run at this length. Over-detonation was accompanied by a much more substantial noise than was detonation, like the difference between blows by a sledge hammer and a carpenter's hammer.

This over-detonation phenomenon may have escaped the attention of some experimenters using combustion driving in shock tube experiments. It must be noted that not only are the limits for the occurrence of detonation rather uncertain, but also that the first departure from the expected constant volume combustion may result in a pressure loading much more severe than that which would result from a fully developed detonation. The long distances noted above do not offer comfort since the use of oxygen instead of air greatly reduces the formation distance for detonation. This hazard may be reduced by using a number of points of ignition and by choosing a gas loading sequence such that the mixture does not go through a condition which is more readily detonable than the final mixture desired (i.e. loading of hydrogen last).

References

BONE, W. A., FRASER, R. P. & WHEELER, W. H. 1936 *Phil. Trans.* A, **235**, 29.

MOORADIAN, A. J. & GORDON, W. E. 1951 *J. Chem. Phys.* **19**, 1166.

OPPENHEIM, A. K. 1952 Gas dynamic analysis of the development of gaseous detonation and its hydraulic analogy. *Fourth Symposium on Combustion*, p. 471. Williams & Wilkins.

SMITH, J. B. 1949 Explosion pressures in industrial piping systems. Paper presented before the International Acetylene Association; copies available from Eng. Div., Factory Mutual Labs, Boston, Mass.

TURIN, J. J. & HUEBLER, J. 1951 *Report Comm. Industr. Commer. Gas Res., Project I.G.R.–59*. Amer. Gas Assn.