Preface

The high potential heat production and high reactivity of hydrogen are unique properties that attract great attention of investigators. In the last 10 years, a hailstorm of various publications on this topic has been issued. Investigations of hydrogen explosion processes take a special place in the ranks of such articles and presentations. The dynamics of the increase in publications can be evaluated by comparing information generalized and systematized in [1] and [2]. The totality of data on specific subjects related to the details of hydrogen explosion phenomena can be found in [3–14].

The data base stored on this issue has been constantly increasing with new investigations and publications; the results, which are of great value for use in hydrogen storage operations and its safe industrial application, have being systematized. It is very important to get rid of groundless fears of using hydrogen as an energy carrier that are caused by lack of trustworthy data on the thermo-gas dynamic parameters of hydrogen combustion and explosion processes. Conditions, under which hydrogen is used, constrain the application of standard hydrocarbon utilization schemes; it is necessary to take into consideration the specifics in getting a solution to a particular problem.

However, application of new schemes does not create insuperable hindrances; usage of innovative technologies is grounded on a complete database of hydrogen as a new type of fuel. Founders of combustion theory called upon investigators to generalize and accumulate data considered from both scientific and practical points of view.

It is clear from the above dedication (Fig. 1) that even in 1985 Ya.B. Zeldovich was optimistic about renewal of combustion and detonation sciences. His optimism was based on the confidence that basic representations of explosion phenomena, given in classical works, would be developed and broadened by describing new combustible systems.

The validity of Ya.B. Zeldovich's prediction has been proven when problems of using hydrogen as a promising fuel for high-efficiency and ecologically clean technologies have arisen.

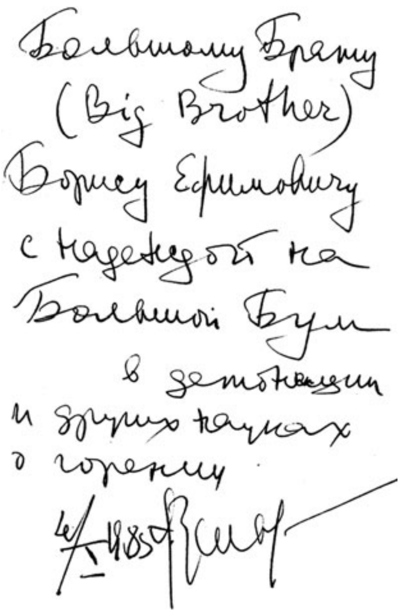

Fig. 1 Dedication of Academician Ya.B. Zeldovich to B.E. Gelfand (To my Big Brother Boris with hope for a Big Boom in detonation and other combustion sciences)

Figure 2 and Tables 1, 2, and 3 represent the comparison diagram of ten parameters characterizing combustion and detonation of hydrogen and a typical current fuel (benzine). Hydrogen as a fuel is unique in relation to its detonability, its combustion limits, its flame velocity and extremely low ignition energy.

Due to the various subjective and objective reasons the book on hydrogen combustion and explosion published recently [2] does not include some useful data on combustion limits of binary fuels containing hydrogen. The class of binary fuels (for example, hydrogen+hydrocarbon) significantly widens options of potential safety use of hydrogen as a fuel.

The scheme of the data analysis presented in [2] broadens the concept of the current situation specified by problems of using known chemical reaction schemes while analyzing explosion phenomena which occur in practically important temperature and pressure ranges of combustible mixtures. The role of chemical reactions and gas dynamic processes is greatly divided for their model-surrogates where their feedback is assumed to be suppressed on the grounds of wrongfully and non-typically decreased energy paths.

Special attention has been paid to explosion phenomena accompanied by high pressure loads on structures. Such phenomena include reflections of detonation waves with extensive reaction zones near the detonation limits [3, 15–18] and collisions of non-stationary complex shock waves+combustion fronts with obstacles during DDT process.

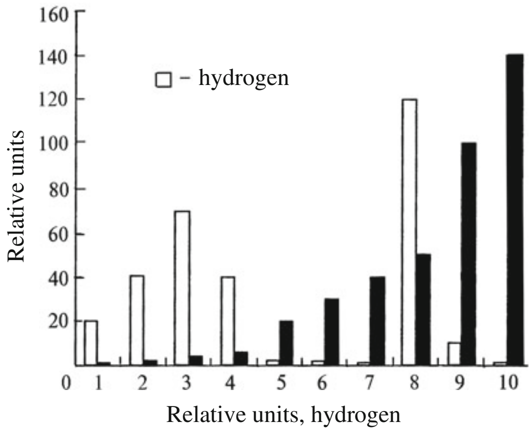

Fig. 2 Comparison diagram of hydrogen/benzine properties: *1* – buoyancy; *2* – detonability; *3* – combustion limits; *4* – flame velocity; *5* – fire hazard; *6* – molecular weight; *7* – flame radiation; *8* – energy per mass unit; *9* – energy per volume unit; *10* – ignition energy [5]

Table 1 Combustion process parameters

Parameter	Hydrogen	Methane	Benzine
Concentration limits of combustion	4–75 vol.% α=0.1–2.5	5–15 vol.% α=0.53–1.7	1.0–7.6 vol.% α=0.7–1.8
Stoichiometric composition in air, vol.%	29.53	9.48	1.76
Min ignition energy, mJ	≈0.02	≈0.29	≈0.24
Ignition temperature, K	≈750	≈810	≈500–770
Flame temperature, K	≈2,300	≈2,150	≈2,470
Normal flame velocity, cm/s	≈265–325	≈37–545	≈37–543
Max quenching gap, cm	≈0.064	≈0.203	≈0.2
Fraction of energy to radiation, %	≈17–25	≈23–32	≈30–42

Table 2 Fuel thermodynamic parameters

Parameter	Hydrogen	Methane	Benzine
Molecular weight	2.016	16,043	107
Gas density at normal conditions, g/m^3	83.76	651.19	4,400
Calorific efficiency, kJ/g	**119 (low)** **142 (high)**	**50 (low)** **55 (high)**	**44 (low)** **48 (high)**
Specific heats ratio	1.383	1.308	1.05
Diffusion coefficient, cm^2/s	0.61	0.16	0.005
Specific heat, J/g ·	14.89	2.22	1.62

Data on diffusion flame parameters of hydrogen jet discharges into the surroundings have been summarized as an additional dangerous factor used for the analysis of safe hydrogen transportation. Conditions of spontaneous ignition of both hydrogen and its mixtures with combustible and incombustible additives have been

Table 3 Parameters of aviation fuel/propellant

Parameter	Hydrogen	Methane	Kerosene
Composition	H_2	CH_4	$C_{12,5}H_{24,4}$
Boiling point T, °C	−252.7	−161	167–266
Density at T, g/cm^3	≈0.071	≈0.423	≈0.8
Calorific efficiency, kJ/kg	≈119,970	≈48,140	≈49,100
Flame temperature, K	≈2,300	≈2,150	≈2,400
Evaporation heat, J/g	≈440	≈510	≈360
Concentration limits of combustion, vol.%	4–75	5–15	0.84–6
Concentration limits of detonation, vol.%	13–65	6.3–13.5	1.1–3.3
Min Ignition energy, mJ	≈0.02	≈0.29	≈0.25
Min HE charge for detonation initiation, kg THT	≈0.001	>10	≈1
Self-inflammation temperature in the air, K	≈750	≈810	≈600–700
Radiation energy, %	17–25%	23–32%	33–43
Toxicity	Not toxic	Not toxic	At > 500 ppm

specified. The authors hope that the present monograph can play a role as a guide in an ocean of data useful for specialists working with hydrogen as a fuel or a working medium in various technological processes.

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