

# Effect of Inert Gas and Porous Media on Premixed Hydrogen/Methane/Air Explosions in Tubes

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## Abstract

This paper experimentally investigates the effect of nitrogen and porous media on the explosion behavior of hydrogen/methane/air mixtures. The study examines the impact of nitrogen volume fraction and the location of porous media (distance to the ignition source) on hydrogen/methane/air mixtures with a fixed hydrogen-to-methane volume ratio of 1:1. The results indicate that the presence of nitrogen and porous media significantly alter explosion dynamics, influencing both flame propagation and peak explosion pressures. The greater the volume fraction of nitrogen and the closer the porous medium is to the ignition source, the more the explosion of the hydrogen/methane/air premixed gas is suppressed. These findings have the potential to prevent the explosion of hydrogen/methane-blended fuels and have significant implications for their practical applications.

## Keywords

Hydrogen/Methane, Nitrogen, Premixed Flame, Explosion Suppression, Porous Media

## 1. Introduction

In the wave of global energy structure transformation to low-carbon, the integrated utilization of hydrogen energy and natural gas has become a key technological path in the energy field [1]-[4]. As an emerging clean energy carrier, hydrogen/methane hybrid fuel (commonly known as hydrogen-doped natural gas) is composed of hydrogen and methane in varying proportions, and its combustion characteristics and performance depend significantly on the mixing ratio [5] [6]. This blend not only inherits the convenience of natural gas infrastructure but also

effectively improves the technical shortcomings of traditional natural gas, such as slow combustion rate, low flame propagation rate, and incomplete combustion during lean combustion [7] [8], thereby significantly improving energy efficiency and reducing carbon emission intensity. Driven by the “dual carbon” goal, China is actively promoting major energy projects, such as the “West-to-East Hydrogen Transmission,” which leverages the technical advantages of mixed fuels, and it is seeking to build a cross-regional hydrogen energy transmission network and promote the large-scale consumption and utilization of renewable energy.

At the molecular level, the high activity of hydrogen and the stability of methane have a complementary effect. The C-H bond energy in a methane ( $\text{CH}_4$ ) molecule is enormous (about 435 kJ/mol), which leads to the limitation of its oxidation reaction rate [9] [10]. Hydrogen ( $\text{H}_2$ ), by contrast, has a high diffusion coefficient and reactivity as a gas, owing to its low molecular weight. When mixed hydrogen acts as a “combustion promoter”, it significantly accelerates the chain reaction of methane molecules by providing highly reactive H radicals [11] [12]. The explosion limit concentration of hydrogen has an extensive range (4%-75% in air), which far exceeds the explosion limit of methane (5%-15%) [13]. This means that even a small amount of hydrogen leakage can rapidly form an explosive mixture in a confined space, with a very low minimum ignition energy (0.02 mJ), approximately 1/10 that of methane [14] [15]. More noteworthy, the addition of hydrogen will significantly alter the combustion kinetics of the gas mixture. When the hydrogen proportion exceeds 50%, the maximum rate of pressure rise during explosion increases exponentially, the flame-propagation velocity increases sharply, and the risk of backfire increases significantly [16]. In tube scenarios, the risk of hydrogen leakage is particularly prominent. Due to the small diameter and low density of hydrogen molecules, their diffusion and leakage at tube flanges, sealing threads, valves, etc., can exceed that of pure natural gas by more than twice. Experimental data show that the leakage of hydrogen-mixed natural gas containing 20% hydrogen is twice that of pure natural gas when transmitted through standard tubes, a characteristic that makes confined spaces, such as underground pipe corridors, high-risk areas for explosion accidents [17]. When leaking gases accumulate in confined spaces and encounter ignition sources such as electrical sparks, mechanical friction, or electrostatic discharge, catastrophic explosions can occur, resulting in significant casualties and property damage [18] [19].

Alterations in flame-propagation characteristics are another key risk factor. [20] found that the addition of hydrogen gas can significantly shorten the time required for the flame to reach the tube outlet, and that the peak explosion pressure increases with increasing hydrogen gas addition [21] [22]. When the hydrogen content reaches 50%, the maximum explosion overpressure can reach 2.25 times that of pure methane. To complicate matters further, in the tube system, mixed-gas explosions often exhibit a secondary-explosion phenomenon. After the initial explosion, the unburned gas is ejected into the surrounding area and reignited, forming a secondary fireball with greater destructive power. [23] studied

the effects of obstacle blocking rate and shape on methane/hydrogen explosion characteristics in tubes and found that the propagation velocity and maximum explosion overpressure of the premixed flame increased with the increase of the obstacle blocking rate and hydrogen gas integral number. This multi-hazard chain reaction jeopardizes the traditional single-gas explosion protection strategy [24], [25], which found that the “tulip” flame appeared in all five experimental conditions. For low hydrogen content, the flame front became asymmetrical, and the upper lip propagated faster after the “tulip” flame reversed. The explosive characteristics of hydrogen-containing premixed gases in narrow pipes, and found that the hydrogen doping ratio ( $\chi$ ) and ignition position significantly affect the flame structure [26], flame wave front velocity, and explosion overpressure. Simulated the explosion overpressure generated by a hydrogen/methane/air mixture with a hydrogen doping ratio of less than 25% using the CFD software FLACS [27]. The results indicate that the overpressure produced by the mixture was not significantly higher than that produced by methane alone. The effect of the number of side vents on the explosion characteristics of hydrogen-doped methane (10% H<sub>2</sub>) through a square tube experimental system was studied. It was found that when the first vent is located at 200 mm from the ignition source, increasing the number of vents does not change the speed of flame propagation to the first vent [28]. However, after the flame passes through the vent, its structure is destroyed, and it loses the basis for sustained acceleration; consequently, the downstream overpressure decreases significantly with increasing vent size. This phenomenon reveals the optimal direction of the multi-vent arrangement; setting the vent at the beginning of flame development can effectively inhibit the subsequent energy accumulation. The explosion-venting effect is influenced by the coupling of multiple factors [29], including dynamic parameters such as the layout, size, number, obstacle distribution, and opening time of the vents.

Industrial applications require the safe use of hydrogen/methane hybrid fuel, a key enabler of the energy transition. The growing global need for energy has driven a significant increase in the use of natural gas, which is mostly methane and is transported through large underground pipeline networks [30]. This reliance on natural gas, however, presents inherent safety concerns, particularly the risk of explosions in the event of pipeline breaches or leaks [31]. To mitigate these risks, a common strategy is to blend natural gas with hydrogen to enhance combustion efficiency. However, this modification also requires a thorough understanding of the resulting changes in flammability characteristics [32]. Specifically, the introduction of hydrogen can significantly expand the combustion limits of methane, thereby increasing the mixture’s propensity for ignition and the potential for deflagration or detonation in confined spaces [33]. The heightened flammability and accelerated flame propagation associated with hydrogen enrichment necessitate advanced safety measures and a detailed investigation of explosion-suppression techniques [34].

One fundamental approach to mitigating explosions in hydrogen/methane/air mixtures is the application of inert gases. Gases such as nitrogen (N<sub>2</sub>), carbon di-

oxide, and helium are commonly used to dilute the combustible mix, thereby reducing the concentration of flammable gases below their flammability limits [34]. These inert agents exert a substantial inhibitory effect on critical explosion parameters such as flame speed and overpressure development in confined environments [35] [36]. CO<sub>2</sub>, in particular, demonstrates superior suppression capabilities due to its thermal and kinetic effects, which effectively decrease thermal diffusivity, lower flame temperatures, and reduce the concentration of active radicals, which are crucial for combustion [37]. While inert gas dilution can prevent ignition and combustion, excessive dilution can reduce fuel reactivity and energy density, posing challenges for energy system efficiency [37]. Furthermore, the inert gas introduction method is critical, as non-premixed injection can, under certain conditions, induce turbulence that paradoxically accelerates flame propagation [38].

Porous media also serve as practical physical barriers that can significantly influence explosion dynamics by interfering with combustion processes. Their intricate pore structures promote the collision and recombination of free radicals within the pore walls, thereby disrupting the chain reactions that drive explosions and diminishing shock waves [39]. The efficacy of porous media in flame suppression is directly influenced by their physical characteristics, with increased thickness leading to greater suppression in hydrogen-methane gas mixtures [40]. For instance, research indicates that the critical quenching hydrogen blending ratio for effective flame suppression varies with the thickness of the porous medium, with a 9% ratio for a thickness of 50 mm and 20% for 60 mm [41]. While generally beneficial for mitigation, some studies suggest that specific porous media configurations can, under certain conditions, promote flame acceleration and even the transition from deflagration to detonation, necessitating careful design considerations [42].

From a combustion kinetics perspective, the explosion behavior of hydrogen/methane/air mixtures is governed by chain-branching reactions involving highly reactive radicals such as H, O, and OH, which strongly control flame propagation velocity and pressure rise in confined spaces. Hydrogen enrichment enhances radical production, thereby accelerating flame propagation and increasing explosion overpressure. Effective explosion suppression strategies must therefore act by reducing chemical reaction rates, lowering flame temperature, or promoting radical termination. Inert gas dilution and porous media are widely applied mitigation measures; nitrogen dilution suppresses combustion by decreasing reactant concentrations and adiabatic flame temperature, while porous media enhance heat loss and facilitate radical quenching at solid surfaces. However, existing studies largely investigate inert gas dilution and porous media suppression as independent mitigation strategies, with limited effort to interpret their combined suppression effect within a unified combustion kinetics framework. In particular, the coupled inhibition mechanisms of nitrogen dilution and porous media on hydrogen/methane/air explosions, involving simultaneous reductions in reaction rates, flame temperature, and active radical concentration, remain insufficiently

understood. This gap limits the ability to generalize suppression strategies for hydrogen-enriched fuel systems in confined geometries. In addition, the coupled suppression mechanisms of nitrogen dilution and porous media in hydrogen/methane/air explosions have rarely been interpreted within a unified combustion-kinetics framework. This motivates the present study to combine pressure-based experimental analysis with fundamental combustion theory to elucidate the intrinsic mechanisms of suppression.

Therefore, this study systematically investigates the suppression of hydrogen/methane/air explosions in ducts using nitrogen dilution and porous media, with particular emphasis on elucidating their coupled suppression mechanism through pressure-based experimental analysis and combustion theory. Experiments were conducted on hydrogen/methane/air mixtures with varying hydrogen volume fractions, measuring key parameters including flame behavior, propagation velocity, and overpressure. The research systematically examines the inhibitory effects of both nitrogen and porous media on hydrogen/methane/air explosions. The findings provide valuable scientific insights to enhance safety protocols for the utilization of hydrogen and methane.

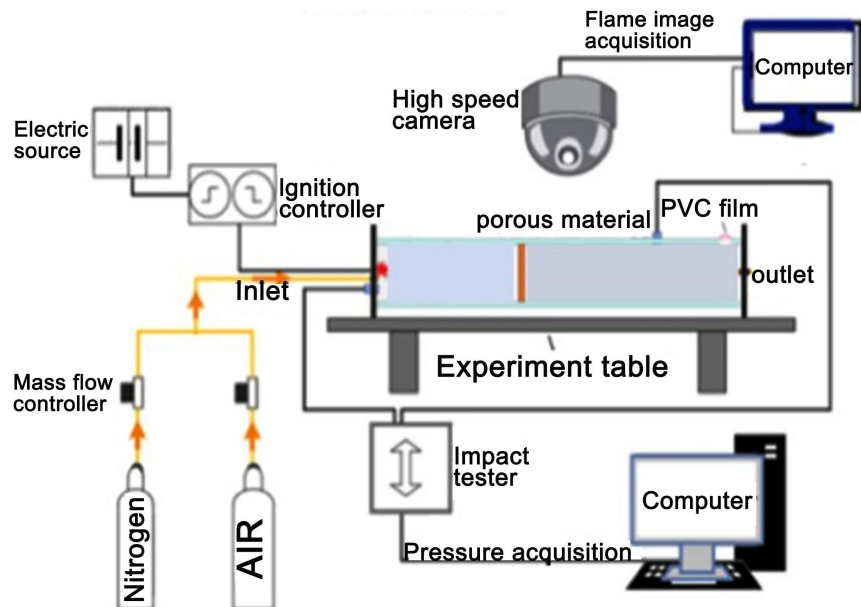
## 2. Experimental Setup

The experimental setup employs a sealed horizontal tube to simulate flame propagation in confined spaces, enabling detailed observation of flame behavior and precise pressure measurements during gas explosions. A schematic diagram of the experimental apparatus is shown in **Figure 1**. The test section consists of a 1000 mm × 100 mm × 100 mm square tube, with an aspect ratio sufficient to allow full flame development. Both ends of the tube are sealed with 10 mm thick stainless-steel plates, with rubber gaskets inserted between the plates and tube to ensure optimal gas tightness.

To control experimental duration and minimize uncertainties, a quad-mixing ventilation system was implemented, as illustrated in **Figure 1**. After ventilation, the tube was sealed, and the gas mixture was allowed to stabilize for 1 minute to reduce the effects of subsequent flow disturbances. A custom-made electric spark igniter was mounted on the left endplate. Although the ignition system can deliver spark energies of 30 - 70 mJ, all experiments reported in this study were conducted with a fixed ignition energy of 50 mJ to ensure consistency and comparability across different test conditions. The ignition electrodes reliably provided sufficient energy to initiate explosions within the tube. A high-speed camera captured the evolution of the explosion flames, while a high-frequency pressure sensor (range: 0.1 - 1.0 MPa) installed above the igniter collected pressure data at 1 MHz. The acquired pressure signals were digitized using a computer for monitoring overpressure characteristics.

All experiments were conducted under stoichiometric conditions using a 1:1 volume ratio of hydrogen to methane. The nitrogen gas volume fraction in fuel/air mixture ( $\varphi$ ) was increased from 0% to 25%, with increments of 5%, specifically

5% N<sub>2</sub>, 10% N<sub>2</sub>, 15% N<sub>2</sub>, 20% N<sub>2</sub> and 25% N<sub>2</sub>. Tests were repeated under identical initial conditions (101 kPa, 290 K) to ensure reproducibility. Porous medium plates were employed to investigate their effects on flame obstruction and pressure suppression. These plates disrupted flame-propagation paths, allowing the study of flame-obstacle interactions. The plates consisted of aluminum foam with uniform porosity, positioned at 200 mm and 400 mm from the ignition source ( $D = 200$  mm and 400 mm). Each test condition was repeated at least three times to ensure accuracy. Explosion suppression was considered adequate when flames failed to penetrate the porous medium plates.



**Figure 1.** A schematic diagram of the equipment system of the experiment.

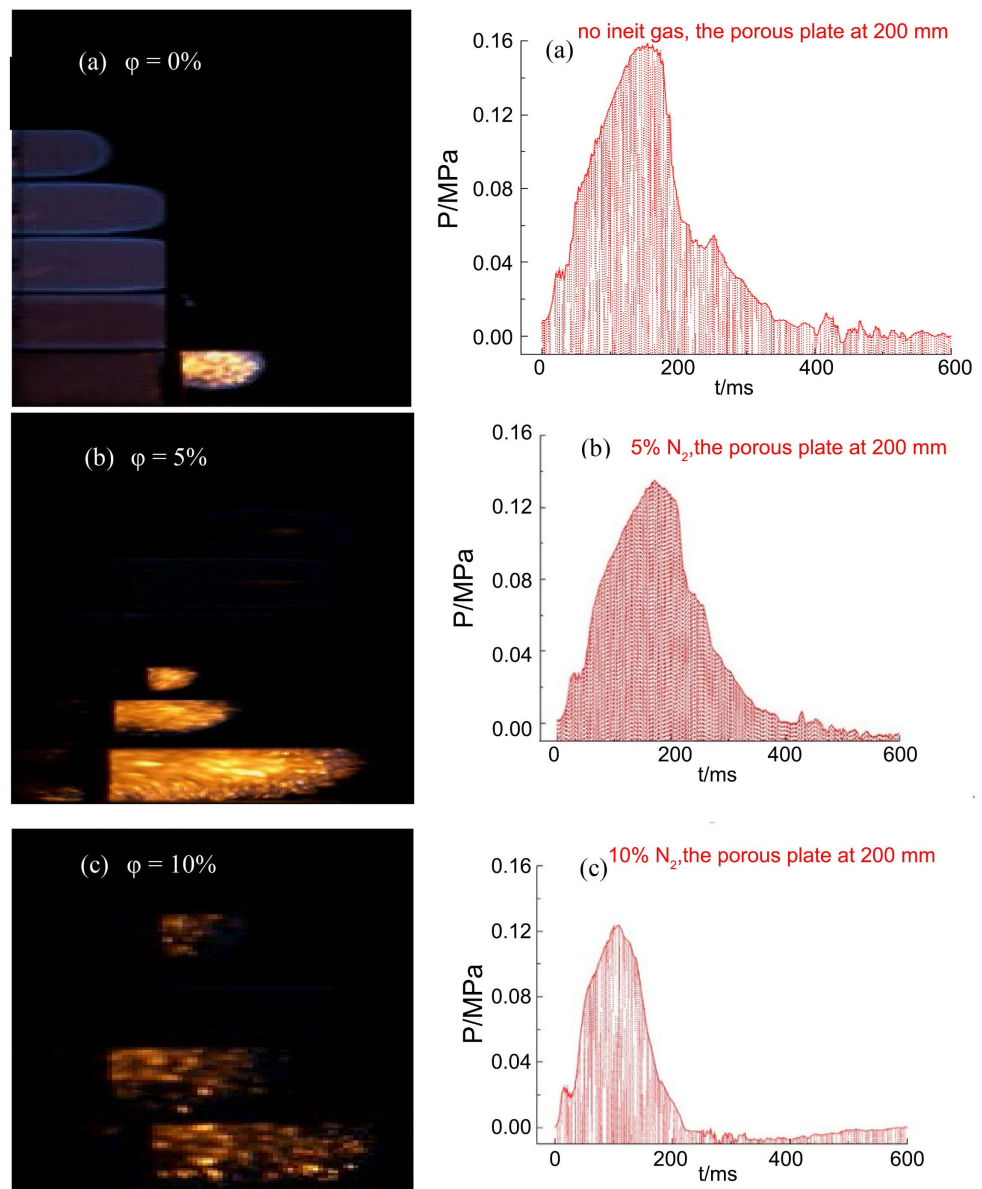
### 3. Results and Discussion

#### 3.1. Flame Propagation Behavior When $D = 200$ mm

**Figure 2** shows flame propagation in a porous medium at  $D = 200$  mm, where the flame can be extinguished when  $\phi$  exceeds 10%. **Figure 2(a)**, **Figure 2(b)**, and **Figure 2(c)** correspond to cases of  $\phi = 0$ , 5% and 10% respectively. As shown in **Figure 2(a)**, the pressure curve exhibits a rapid rise followed by a pronounced peak, indicating intense combustion and fast flame propagation within the confined tube when the nitrogen content was 0%. The steep pressure rise reflects a high rate of energy release and strong coupling between flame acceleration and pressure buildup in the early stage of the explosion. From a combustion theory perspective, the rapid pressure rise observed at low nitrogen concentration is primarily driven by flame acceleration due to the volumetric expansion of high-temperature combustion products in the confined tube. The high laminar flame speed of the hydrogen/methane mixture enhances flame pressure coupling, thereby accelerating pressure buildup. As nitrogen concentration increases, dilution effects reduce the laminar flame speed and weaken the interaction between flame turbu-

lence and the flow, thereby limiting flame acceleration and suppressing pressure rise.

After reaching the maximum value, pressure decreases sharply as the combustible mixture is consumed and thermal energy dissipates to the tube walls. At the same time, when 5% nitrogen is added, the rate of pressure rise and the peak explosion pressure are both noticeably reduced. Compared with the nitrogen-free condition, the pressure curve no longer shows a sustained plateau near the peak value but instead exhibits a rapid rise followed by an immediate decay, indicating weakened combustion intensity and reduced flame-driving pressure. This behavior demonstrates nitrogen's effective inerting properties, which suppress combustion.



**Figure 2.** The development of flame and pressure when  $D=200$  mm. (a) No inert gas, (b) 5% N<sub>2</sub>, (c) 10% N<sub>2</sub>.

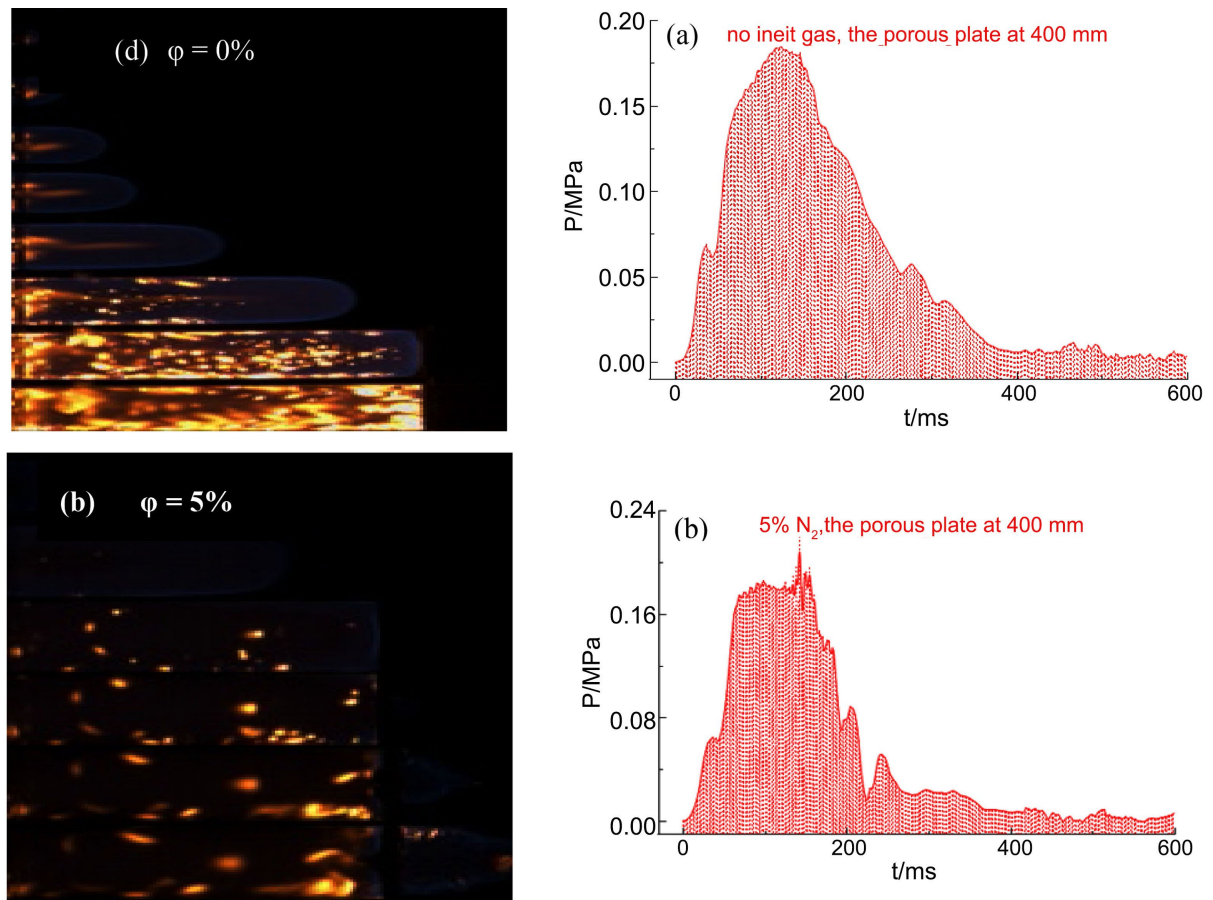
In **Figure 2(c)**, when nitrogen is increased to 10%, the flame still passes through the porous plate, but it's even duller and more fragmented, suggesting weaker combustion. On the other hand, the pressure curve initially decreases and then slowly rises as the flame burns later, due to delayed combustion. Interestingly, a brief negative pressure relative to the initial pressure baseline is observed after the main pressure peak when the nitrogen concentration reaches 10%. This pressure drop is not caused by air consumption or gas replenishment limitations, since the tube is fully sealed and operates under constant-volume conditions. Instead, the negative pressure can be attributed to the rapid cooling of high-temperature combustion products after flame extinction, which reduces gas temperature and internal pressure. In addition, the condensation of water vapor produced during combustion further reduces the gas-phase molar volume, contributing to the transient pressure decrease. Finally, the dynamic response and slight overshoot characteristics of the high-frequency pressure sensor may also amplify this effect in the recorded signal. Similar post-explosion pressure decay phenomena have been widely reported in confined combustion experiments and do not indicate continued combustion or mass loss within the system. Although flame images show visual differences under different nitrogen concentrations, these observations are treated as qualitative trends only. The suppression effect is quantitatively confirmed by the consistent reduction in peak explosion pressure and pressure rise rate with increasing nitrogen content. The combined action of nitrogen dilution and the porous media plate, located close to the ignition source, effectively limits pressure accumulation, demonstrating a strong explosion-suppression effect.

### 3.2. Flame Propagation Behavior When $D = 400$ mm

When the porous dielectric plate is placed 400 mm from the ignition source, the flame in the pipeline develops more fully, resulting in a more complex pressure trend, as shown in **Figure 3**. In **Figure 3(a)** shows the premixed flame initiates with a spherical flame, changes to a finger-shaped flame, and eventually expands into a planar flame in front of the porous media plate. Due to the free development of the flame and the fact that it was not hindered at the first 400 mm. The flame was fully expanded, and a yellow, highly wrinkled and turbulent flame front appeared on the inner side. From the initial turn of the pressure curve, it can also be seen that the explosion pressure at this time is higher, and the initial peak exceeds 0.06 MPa. After the first pressure increase, the tube pressure rises rapidly, peaks, and then falls quickly. This pressure evolution reflects enhanced flame acceleration, resulting from a longer free-propagation distance before interaction with the porous media. In confined ducts, an extended flame development length promotes stronger flame flow interaction and turbulence generation, thereby intensifying pressure flame coupling. As a result, pressure accumulation is more pronounced when the porous medium is located farther from the ignition source.

This pressure change operation is directly related to the redevelopment of the flame in the tube after it passes through the porous media plate. In fact, the ex-

tended propagation distance before flame porous media interaction significantly enhances flame acceleration and pressure accumulation by allowing stronger flame flow coupling.



**Figure 3.** The development of flame and pressure when  $D = 400$  mm. (a) No inert gas, (b) 5%  $N_2$ .

**Figure 3(b)** shows an image of a flame filled with 5%  $N_2$ , in which the flame evolution is related to the presence of the inert gas. However, even with the addition of an inert gas, combustion remains incomplete, and the flame color becomes dull and dark. Overall, the brighter the flame color, the more heat is generated in the combustion zone, and the higher its temperature, which means the more combustible chemical reaction can occur. So, it is evident that the influence of the inert gas weakens the combustion reaction of the premixed gas. In **Figure 3(b)**, the maximum explosion pressure peak in the pressure curve is also significantly decreased, and at the pressure peak, pressure accumulation and loss compete to maintain relative equilibrium.

When the concentration of  $N_2$  in the hydrogen/methane/air mixture surpasses 5%, the general pattern of flame evolution becomes nearly similar across all tests. However, as the nitrogen content increases, the flame appears progressively dimmer and more diffuse, indicating reduced combustion intensity and lower temperature. The increased presence of inert nitrogen reduces the flame's visible lu-

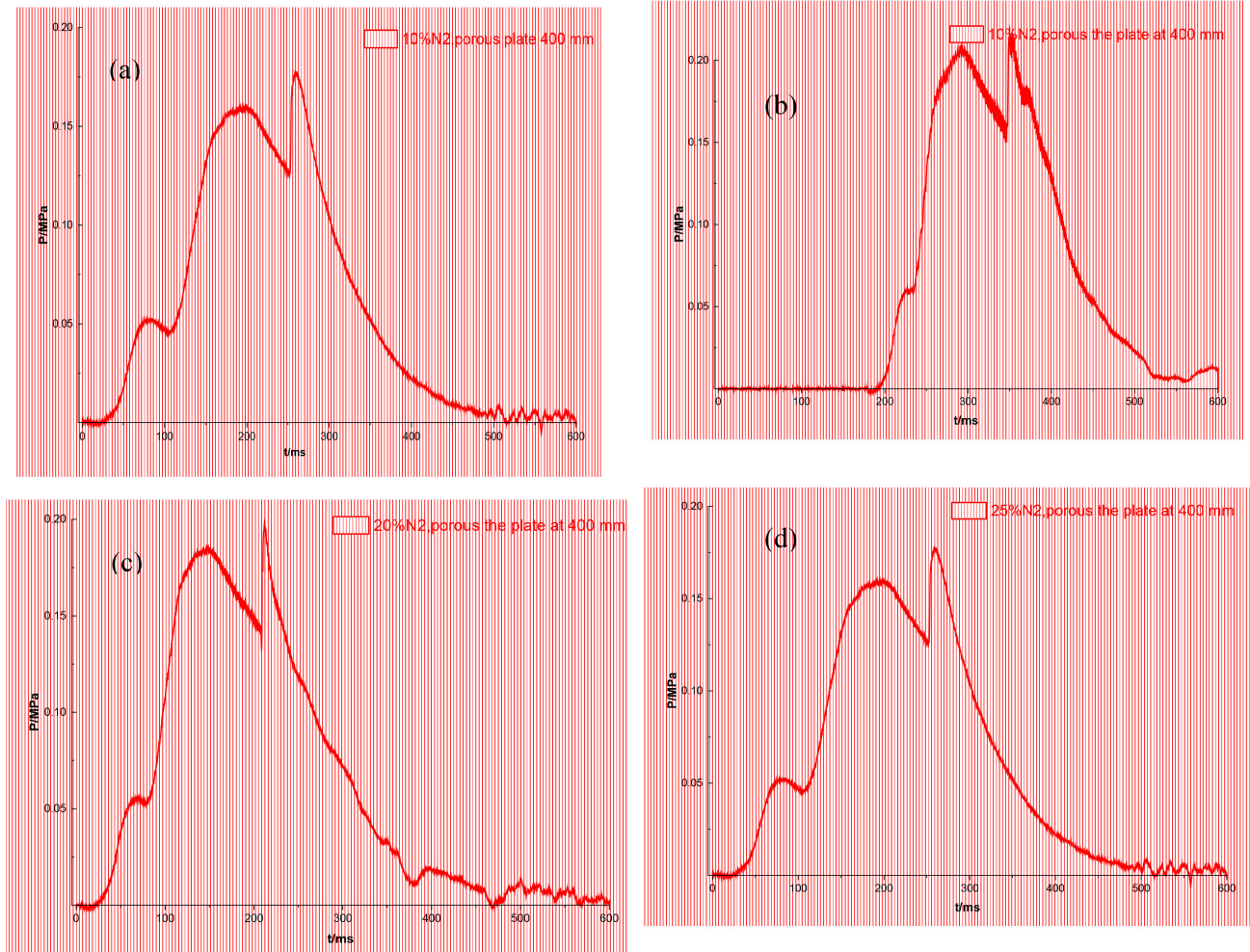
minosity by diluting reactive species and absorbing heat, resulting in a blurred or faint flame appearance. Because these flames become less distinguishable at higher nitrogen levels, several flame images are not shown in this paper. In addition, the flame-front images obtained during the experiments were not sufficiently consistent or clear for quantitative interpretation due to variations in camera exposure, limited optical access, and occasional obstruction by luminous radicals or soot. Therefore, flame images are used only as qualitative visual illustrations of flame evolution, and no physical or chemical inferences are drawn solely from their appearance. All conclusions regarding explosion suppression are based primarily on pressure-time data.

Variations in camera exposure, limited optical access, and occasional obstruction by soot or luminous radicals prevented the acquisition of a complete and reliable sequence of flame evolution across all test conditions. As a result, the visual records could not be used to support a systematic comparative analysis across mixtures. Pressure data, however, were captured with high accuracy across all trials, enabling a robust, reproducible evaluation of explosion behavior. Therefore, the discussion focuses on the pressure-time characteristics, which provide a reliable representation of combustion dynamics even in the absence of high-quality flame images.

**Figure 4** shows the pressure variation of nitrogen from 10% to 20%, and also focuses on analyzing the pressure conduct. The results show that the overall pressure trends are similar in shape. However, the peak explosion pressure, particularly the peak observed when the flame front reaches the porous media plate, gradually decreases with increasing nitrogen concentration. This indicates that nitrogen addition effectively suppresses combustion intensity and reduces the maximum explosion pressure. Furthermore, as the nitrogen fraction increases, the pressure peak shifts to approximately 200 ms. This delay reflects the slowing of flame propagation and the reduced rate of pressure buildup due to the inert gas. Furthermore, the rate at which pressure decays after reaching its maximum also becomes slower with more nitrogen. This behavior suggests that nitrogen not only reduces the net pressure generated during combustion but also affects the rate at which pressure is released. The thermal and mass-dilution effects of nitrogen lower the overall reaction rate, reduce heat transfer, and hinder radical recombination. Consequently, both the buildup and dissipation of explosion pressure are moderated, demonstrating nitrogen's tough role in stabilizing and suppressing flame driven pressure dynamics.

With increasing nitrogen concentration, the flame transition becomes less dependent on the porous media, suggesting that higher inert gas content facilitates these structural transformations even over tiny distances. This effect is attributed to the decrease in flame propagation speed due to nitrogen dilution, which weakens the forward driving force and enhances the influence of reverse flow effects within the tube. As shown in **Figure 4(d)**, the slower flame propagation results in a more gradual and clearly identifiable pressure evolution. The peak pressure oc-

curs approximately 200 - 300 ms, and the pressure release continues beyond 600 ms. The data further indicate a strong correlation between flame velocity and pressure conduct; slower flame speeds lead to slower pressure buildup and release, highlighting their close interdependence.



**Figure 4.** The development of pressure when  $D = 400$  mm. (a) 10% N<sub>2</sub>, (b) 15% N<sub>2</sub>, (c) 20% N<sub>2</sub>, (d) 25% N<sub>2</sub>.

### 3.3. Suppression Mechanism of Nitrogen and Porous Media

Overall, in the absence of inert gas addition, the hydrogen/methane/air mixture exhibits the highest reactivity and the most intense flame. Without a diluent to absorb heat or moderate chemical reactions, combustion proceeds at rates below the natural kinetics of hydrogen and methane, leading to rapid flame propagation and sharp pressure rises. In the 0% N<sub>2</sub> case, the laminar flame speed is highest. Hydrogen's high diffusivity and low ignition energy significantly speed up the flame, while methane adds stability, producing a rapidly expanding spherical flame. The flame temperature also peaks in the absence of nitrogen, leading to stronger chain-branching reactions and abundant reactive radicals (H, O, OH), which intensify the flame's brightness and instability. The surface becomes in-

creasingly wrinkled as it propagates. In a confined state, this mixture produces the steepest pressure rise and the highest peak explosion pressure. The rapid pressure buildup reflects the highly energetic nature of undiluted combustion, posing significant explosion risks in enclosed spaces such as tubes.

Nitrogen acts as an inert diluent gas that does not participate in the combustion reaction, but still significantly influences flame behavior through physical mechanisms. When nitrogen is added to a combustible hydrogen/methane/air mixture, it dilutes the concentration of reactive species (fuel and oxygen), thereby reducing the number of collisions that lead to ignition and propagation. Additionally, because nitrogen has a high specific heat capacity but does not contribute chemical energy, it absorbs part of the heat released during combustion, thereby reducing the adiabatic flame temperature. This thermal effect reduces the reaction rates of key radical species, such as H, O, and OH, which are crucial for chain-branching reactions that sustain the flame. As a result, the flame propagates more slowly, exhibits lower turbulence, and produces a smoother and more stable front. In explosion studies, the presence of nitrogen therefore leads to a lower maximum explosion pressure and a reduced rate of pressure rise, reflecting its strong inerting and suppression effects on combustion.

The flame fragmented after passing through the porous plate, losing its continuous structure and exhibiting signs of incomplete combustion. This disruption in flame propagation directly affects the pressure dynamics within the system. Porous materials have a cooling effect and destroy radical species at the wall surface in premixed flames. However, after passing through the porous medium, flame fragmentation may accelerate the transition from laminar to turbulent flow.

In addition to the physical suppression mechanisms described above, the observed inhibition of hydrogen/methane/air explosions can be interpreted from a combustion kinetics perspective. According to classical Arrhenius reaction rate theory, combustion rates depend exponentially on flame temperature, and even a modest reduction in temperature can significantly decrease the overall reaction rate. Adding nitrogen reduces the concentration of reactive species. It lowers the adiabatic flame temperature due to its high specific heat capacity, thereby suppressing chain-branching reactions involving H, O, and OH radicals. This kinetic inhibition is consistent with the experimentally observed reduction in pressure rise rate and peak explosion pressure with increasing nitrogen concentration.

From a flame transport standpoint, nitrogen dilution reduces the laminar flame speed by lowering the thermal diffusivity and chemical reactivity of the premixed gas, thereby limiting volumetric expansion rates in confined spaces and suppressing pressure accumulation. Porous media further enhance explosion suppression by increasing heat transfer to the solid matrix and promoting radical recombination at pore surfaces, thereby disrupting flame continuity and weakening downstream combustion. When nitrogen dilution and porous media are applied simultaneously, a coupled kinetic–physical suppression mechanism forms, shifting the combustion system away from conditions favorable for flame acceleration and resulting in a significantly enhanced explosion-mitigation effect.

Overall, the greater the volume fraction of nitrogen and the closer the porous medium is to the ignition source, the more the explosion of the hydrogen/methane/air premixed gas is suppressed.

#### 4. Conclusions

In this study, experiments were conducted to investigate the explosion behavior of a premixed hydrogen/methane/air mixture at varying porous-media and inert-gas concentrations across different locations. The flame behavior and overpressure dynamics were analyzed. The main conclusions are as follows:

- 1) The porous dielectric plate slows flame propagation, disrupts flame evolution, and restricts free pressure buildup. As a result, it reduces the maximum explosion pressure. Therefore, placing porous media plates is an effective method for reducing the intensity of gas explosions.
- 2) The farther the porous media plate is positioned along the tube, the more fully the flame can develop, leading to a higher maximum explosion pressure. Thus, placing the porous media plate closer to the expected ignition location helps reduce explosion hazards.
- 3) A rising amount of inert gas enhances its cooling effect on the premixed flame, reducing flame temperature and lowering explosion pressure. When inert gas and porous media plates are used together, they produce a substantially greater suppression effect on premixed gas explosions.

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#### Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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