減圧沸騰噴霧の物理過程と蒸気濃度計測

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- 減圧沸騰の物理過程
- 減圧沸騰噴霧による微粒化･蒸発過程の改善
- 減圧沸騰噴霧の微粒化･蒸発過程のモデリング
- ガス溶解燃料噴霧の微粒化過程
- 二成分･他成分燃料噴霧への減圧沸騰現象の適用
- 解析モデル
- KIVAコードへの減圧沸騰噴霧モデルの適用
- 赤外域2波長濃度測定法

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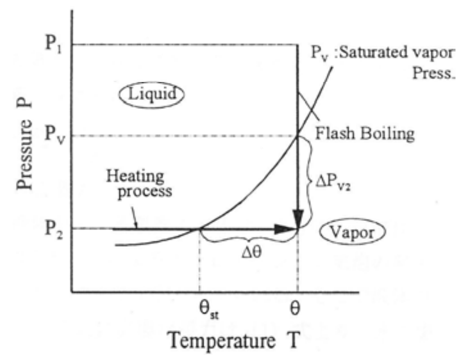
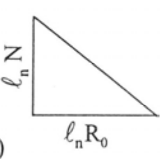
減圧沸騰による相変化



気泡の核生成過程

Heterogeneous Nucleation

- in Crevices ("Harvey" model)
- on Solid surface
- Solid particle
- Mixed air
- Dissolved air



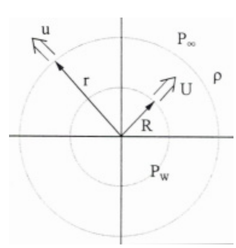
$$N = C \exp(-\frac{\Delta A}{k\,\Delta T})$$

Homogeneous Nucleation

$$N = C' \exp(-\frac{\Delta A}{k\,\Delta T})$$

Rayleigh-Plessetの式

- 液体の粘性と圧縮性を無視した場合の気泡の運動方程式



$$R \cdot \ddot{R} + \frac{3}{2}\dot{R}^2 = \frac{P_w - P_\infty}{\rho}$$

ただし　$\dot{R} \equiv \frac{dR}{dt}, \ddot{R} = \frac{d^2R}{dt^2}$

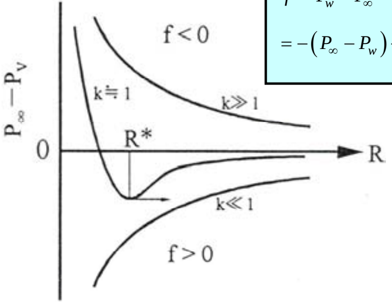
P_w　気泡壁の圧力

P_∞　無限遠の流体圧力

ρ　流体密度

気泡の安定性

$$f = P_w - P_\infty = -\left(P_\infty - P_w\right) - \frac{2\sigma}{R} + \frac{k}{R^3}$$



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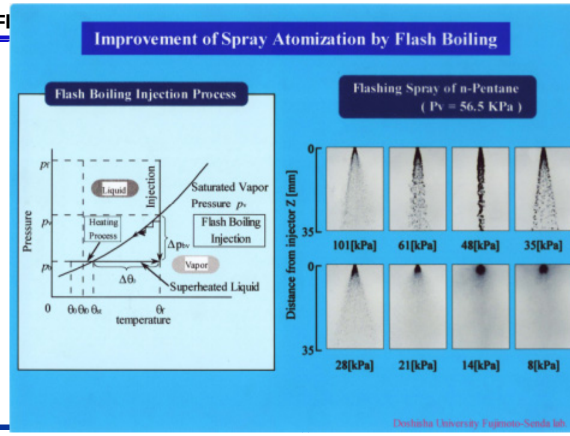
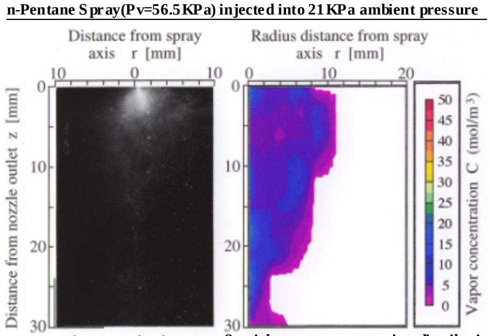


Spray Measurement of Flash Boiling Spray

n-Pentane Spray(P_v=56.5KPa) injected into 21KPa ambient pressure



Mie scattering image from droplets

Spatial vapor concentration distribution by two-wave length IR absorption method

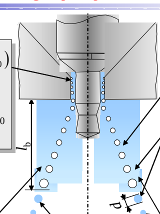
Modeling of Flash Boiling Spray

Nucleation process

$$N = 1.11\times10^{12}\exp(-5.28/\Delta T_0) \times \left\{10^{-4.34\exp(-5t)}\right\}$$

Initial bubble diameter $2R_0$

$2R_0$=20mm



Bubble growth process

$$R\ddot{R} + \frac{2}{3}\dot{R}^2 = \frac{1}{r}\left(P_W - P_r\right)$$

and

$$P_W = P_V + \left(P_{r0} + \frac{2\sigma}{R_0}\right)\left(\frac{R_0}{R}\right)^{3n} - \frac{2\sigma}{R} - \frac{4\mu_l \dot{R}}{R} - \frac{4\kappa\dot{R}}{R^2}$$

Vapor formation process

(1) By cavitation bubbles growth

$$dM_{cb} = \frac{4}{3}\rho_v \pi N\left(R_{n+1}^3 - R_n^3\right)$$

(2) Owing to heat transfer

$$dM_{ht} = \frac{\alpha_{ht}\left(T_a - T_f'\right)A\cdot dt}{h_{fg}}$$

(3) By superheated degree

$$dM_{sh} = \frac{\alpha_{sh}\left(T_l'' - T_{st}\right)A\cdot dt}{h_{fg}}$$

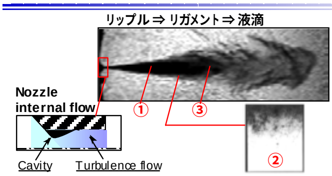
Droplet formation process

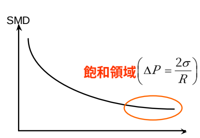
$$\varepsilon = \frac{V_{bubble}}{V_{bubble} + V_{liquid}} \ge \varepsilon_{max}$$

Droplet number = 2×Bubble number

噴霧の微粒化と蒸発の時空間特性

圧力噴射弁（高圧噴射）の場合 ⇒ P_{inj}, ρ_a, T_a





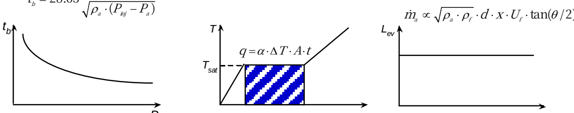
① 微粒化遅れ t_b（時間・空間）　② 液滴の蒸発時間（時間・空間）　③ 噴霧の蒸発長さ（時間・空間）

$$t_b = 28.65\frac{\rho_l \cdot d_0}{\sqrt{\rho_a\cdot\left(P_{inj} - P_a\right)}}$$

$$Nu = c\cdot \mathrm{Re}^a \cdot \mathrm{Pr}^a \longrightarrow Nu = 2$$

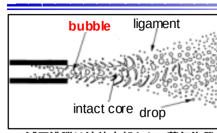
$$\dot{m}_f \propto \rho_f \cdot d_z \cdot U_f$$

$$\dot{m}_a \propto \sqrt{\rho_a\cdot\rho_f}\cdot d\cdot x\cdot U_f\cdot\tan(\theta/2)$$



噴霧の微粒化と蒸発の時空間特性

減圧沸騰噴霧の場合⇒二相領域Profile, $\Delta P_{bv}(\Delta\theta)$, ノズル形状



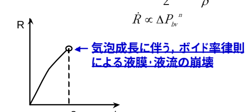
発泡気泡核数 → 核生成速度　$N \propto C\cdot\exp\left(-\frac{\Delta A}{k\Delta\theta}\right)$　$\Delta A = \frac{4}{3}\pi R^2\cdot\sigma$

蒸発速度 → 気泡の成長速度

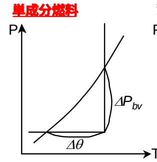
Rayleigh-Plesset式　$R\ddot{R} + \frac{3}{2}\dot{R}^2 = \frac{1}{\rho}\left(P_w - P_r\right)$　$\dot{R} \propto \Delta P_{bv}^{\ n}$

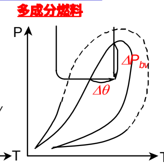
※ 減圧沸騰は液体内部からの蒸気泡発生による内部沸騰蒸発（潜熱は必要）

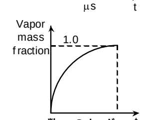
空気せん断力（Aerodynamic Force）不要
流体自身のエンタルピバランスで蒸発

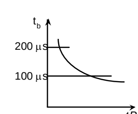


単成分燃料　多成分燃料









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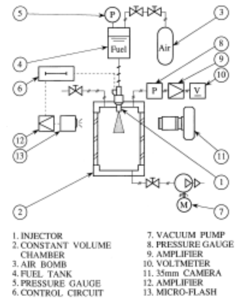
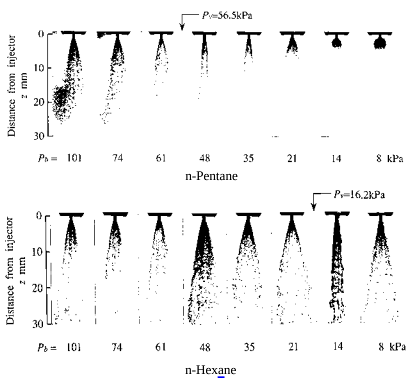
実験装置および方法

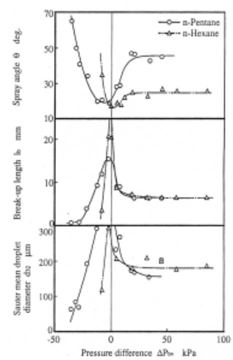


	n-Pentane	n-Hexane
Density ρ_l [kg/m^3]	626	656
Surface Tension $\sigma\times10^{-3}$ [N/m]	16.00	18.46
Viscosity $\mu\times10^{-6}$ [Pa･s]	240	307
Saturated Vapor Pressure P_v [kPa]	56.5	16.2

噴霧形状の背圧による変化

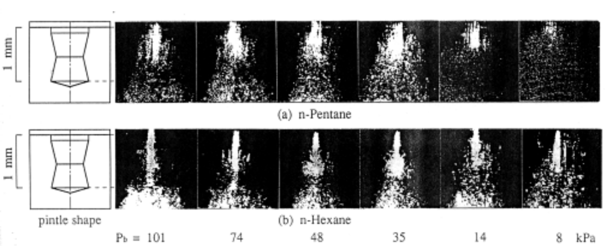


噴霧特性の差圧による変化

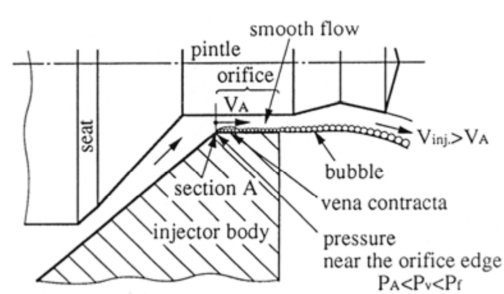


	n-Pentane	n-Hexane
Injection quantity Q_{inj} [mm^3/4ms]	13.2	13.6
Flow velocity at section A V_A [m/s]	18.3	18.8
Jet velocity at nozzle Outlet V_{inj} [m/s]	21.0	21.0
Reynolds number at section A Re	6500	5400

噴孔部拡大写真



噴射弁内部の燃料流動の模式図



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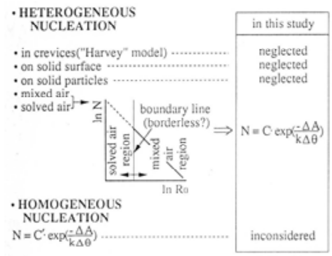
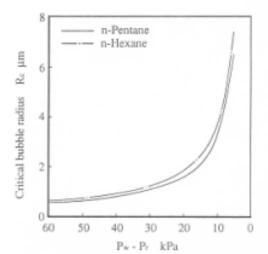
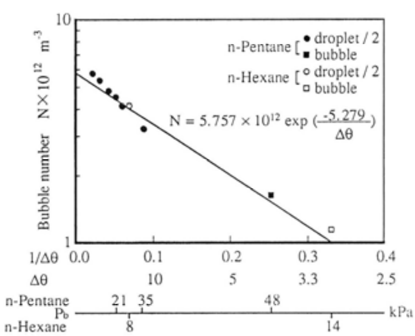
核生成モデルと臨界気泡径





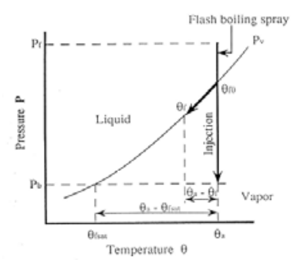
Spray and Combustion Science Laboratory, DOSHISHA Univ.

減圧沸騰噴霧における気泡核生成

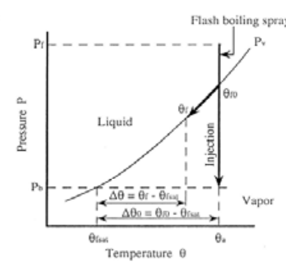


Spray and Combustion Science Laboratory, DOSHISHA Univ.

減圧沸騰噴霧における蒸発過程



(a) 熱伝達による蒸発過程



(b) 加熱度に起因する蒸発過程

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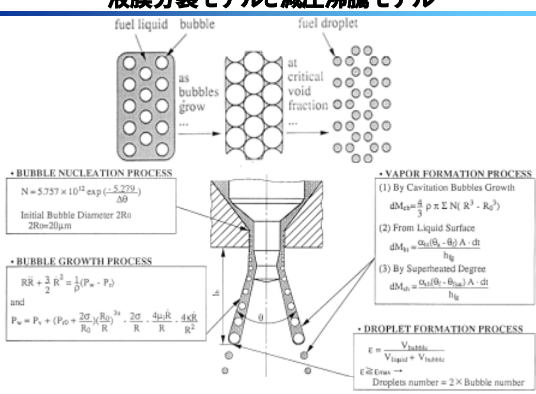
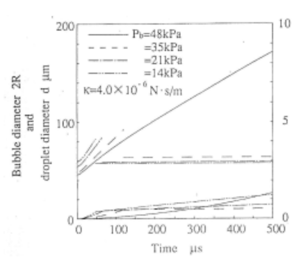
液膜分裂モデルと減圧沸騰モデル

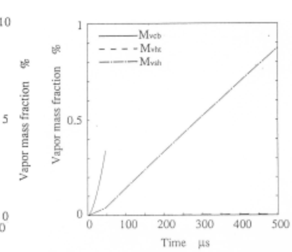


Spray and Combustion Science Laboratory, DOSHISHA Univ.

減圧沸騰モデルの計算結果



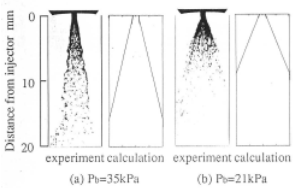
気泡径･液滴径･質量蒸発割合の時間変化 (n-ペンタン)



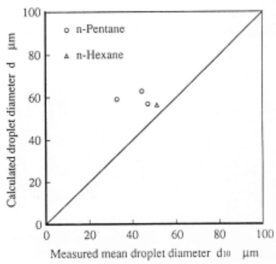
各質量蒸発割合の時間変化 (n-ペンタン, P_b=14kPa)

Spray and Combustion Science Laboratory, DOSHISHA Univ.

減圧沸騰モデルの計算結果

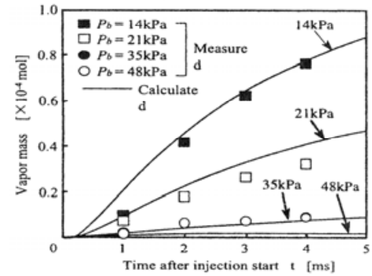


噴霧外形の比較(n-ペンタン)



液滴径の比較

減圧沸騰モデルの計算結果



蒸気質量の時系列変化

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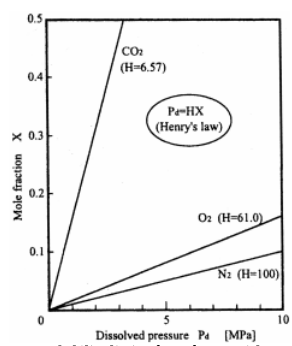
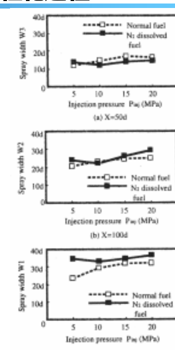


Solubility limit of gas for n-Tridecane



Change in spray width

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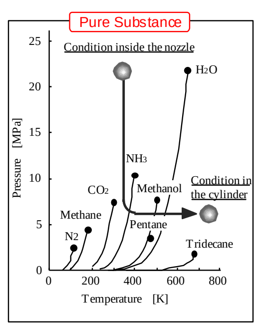
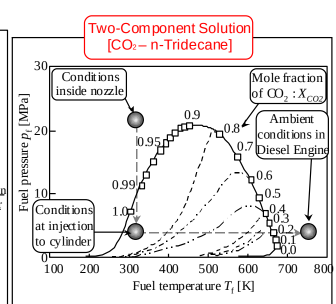
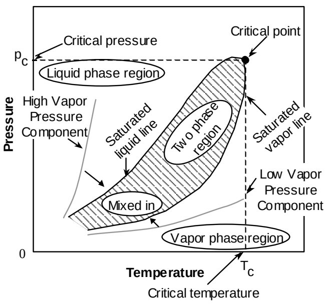
Phase Change Process in P-T Diagram



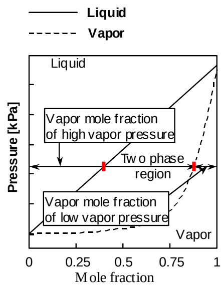


Two Phase Region Formation in Multi-component Fuel in Phase Change Process

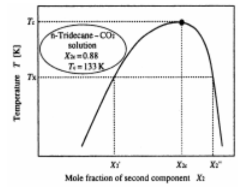
Pressure-temperature diagram



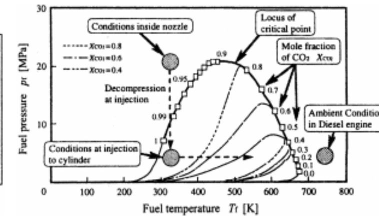
Pressure-Mole fraction diagram



液体相互溶解と臨界軌跡



Mutual solubility in binary solution



Effect of mole fraction on two Phase region for n-Tridecane-CO2

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Chemical Thermodynamics and Two-Phase Region

Estimation of Two-Phase Region

Expanded Corresponding State Principle

$P_r = P / P_C$, $T_r = T / T_C$

Peng-Robinson Equation of States

$$P = \frac{RT}{V-b} - \frac{a(T)}{\{V(V+b)+b(V-b)\}}$$

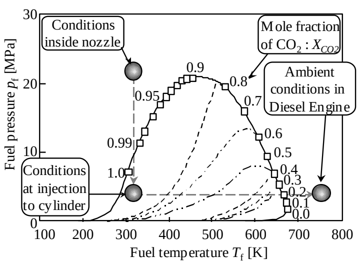
Fugacity of Liquid & Gas

$$\phi_i^G = f_i^G / (y_i \cdot P) \ , \ \phi_i^L = f_i^L / (X_i \cdot P)$$

$$f_i^G = f_i^L$$

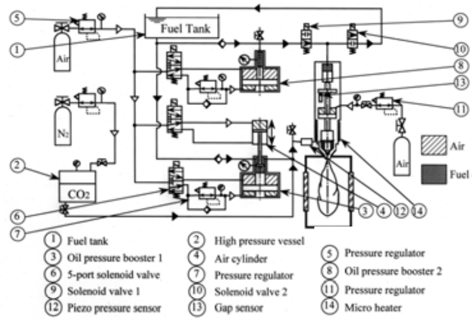
The prediction of Two-Phase Region

P-T Diagram for Mixing Fuel with Liquefied CO_2 & n-tridecane



Spray and Combustion Science Laboratory, DOSHISHA Univ.

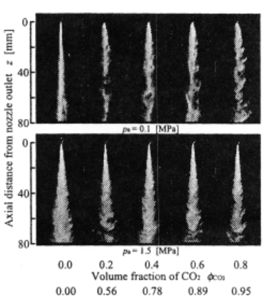
液化CO_2溶解燃料噴霧の噴霧特性



Injection system of gas dissolved fuel

Spray and Combustion Science Laboratory, DOSHISHA Univ.

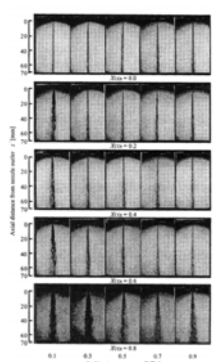
準定常噴霧の分散特性



Change in spray pattern with CO2 volume fraction for quasi-steady spray

Spray and Combustion Science Laboratory, DOSHISHA Univ.

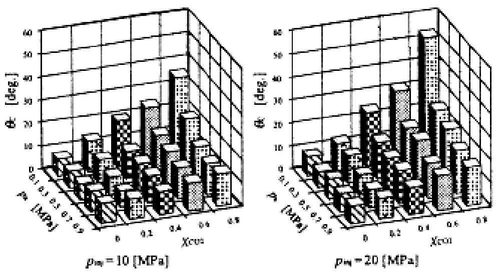
準定常噴霧の分散特性



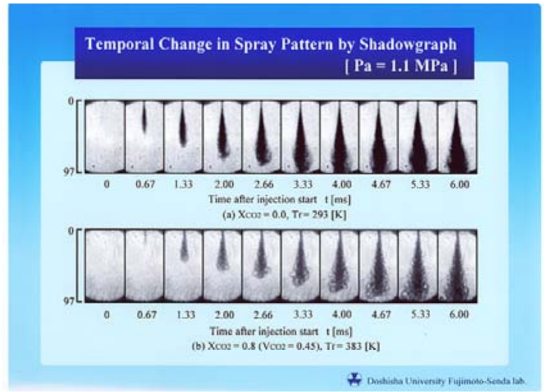
Change in spray pattern with ambient pressure and mole fraction of CO2 by transmitted light for quansi-steady spray(pinj=10[MPa],ra=1.5[kg/m3])

Spray and Combustion Science Laboratory, DOSHISHA Univ.

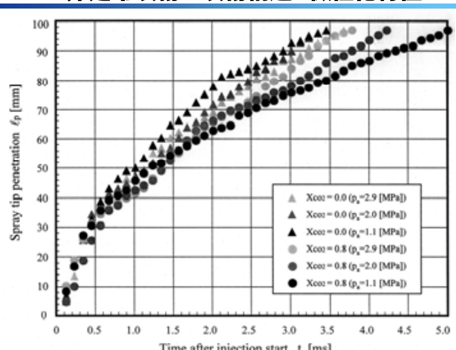
準定常噴霧の分散特性



Change in spray cone angle for quasi-steady spray

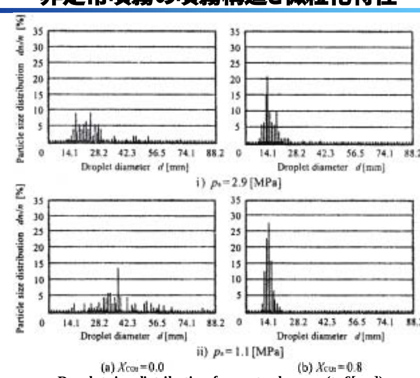


非定常噴霧の噴霧構造と微粒化特性



Temporal change in spray tip pattern by shadowgraph method for unsteady spray

非定常噴霧の噴霧構造と微粒化特性



Droplet size distribution for unsteady spray(t=6[ms])

燃料設計手法による高効率・低エミッション燃焼法の提案研究

- 減圧沸騰噴霧の特性を解析 ⟶ 噴霧を科学する
- 混合燃料による二相領域の形成と噴霧蒸発過程の制御
  - ↑(多成分燃料の蒸発解析)
  - ① 液化CO_2-軽油混合燃料噴霧による すす-NO_X同時低減
  - ② ガス・ガソリン-軽油混合燃料噴霧による燃焼過程の制御の可能性
- 今後の研究課題として (参考)
  - ① Sono-Chemistryによる燃料の改質
  - ② 固体燃料・重質系燃料の高品位液体燃料への改質

Proposal on Fuel Design Approach Research

(1) Physical Control = Capability of Time and Spatial Control on Fuel Vapor Distribution by Formation of Two Phase region in Mixing Fuel
→ Formation of Flash Boiling Spray → Improvement of Spray Evaporation

(2) Chemical Control = Capability of Control on Combustion Process
→ Emission Control – Soot & NOx
Simultaneous reduction of both Soot and NOx (CO2-gas oil mixing fuel)
→ Ignition Control (Gasoline-gas oil mixing fuel)
→ HC Control (Gasoline-gas oil mixing fuel)

(3) Improving Thermal Efficiency by Lower Injection Pressure
→ High Spray Atomization and Evaporation Quality with Flashing Process

(4) Control the Fuel Transportation Properties in Mixing Fuels

(5) Effective liquefaction of gaseous and solid fuels
→ Conversion of Heavy Fuels or Solid Fuels into high quality Lighter Liquid Fuels through Chemical-Thermodynamics

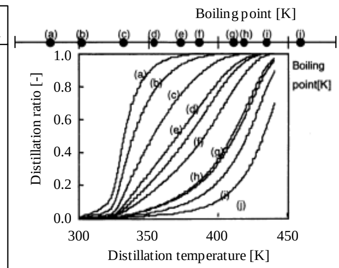
減圧沸騰噴霧の物性過程と蒸気濃度計測

- 減圧沸騰の物性過程
- 減圧沸騰噴霧による微粒化･蒸発過程の改善
- 減圧沸騰噴霧の微粒化･蒸発過程のモデリング
- ガス溶解燃料噴霧の微粒化過程
- 二成分･他成分燃料噴霧への減圧沸騰現象の適用
- ■**解析モデル**
- KIVAコードへの減圧沸騰噴霧モデルの適用
- 赤外域2波長濃度測定法

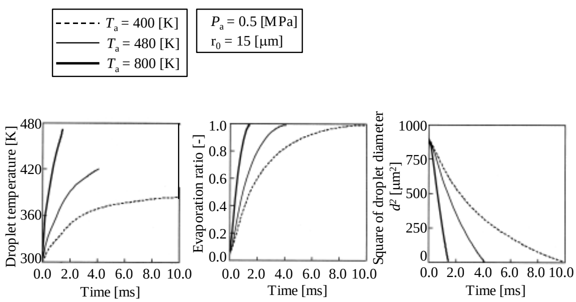
Distillation Analysis for Multi-component Fuel

10-components Fuel | Distillation Curve

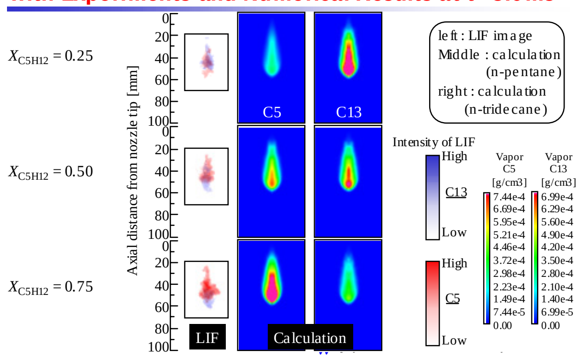
Component	Boiling Point [K]	Molar fraction
(a)n-butane	272.6	0.04
(b)isopentane	301.0	0.35
(c)2-methylpentane	333.4	0.12
(d)cyclohexane	353.9	0.06
(e)2,2,4-trimethylpentane	372.4	0.12
(f)toluene	383.8	0.06
(g)meta-xylene	412.3	0.06
(h)ortho-xylene	417.6	0.06
(i)propylbenzene	432.4	0.06
(j)butylbenzene	456.5	0.06



Time Dependence of Evaporation Analysis for 10-Components Fuel Single Drop



Comparison of Spray Structure –Vapor Spatial Distribution– with Experiments and Numerical Results at t=3.0ms



解析モデル

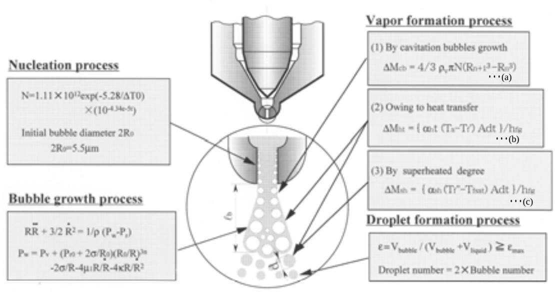
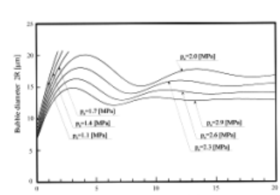
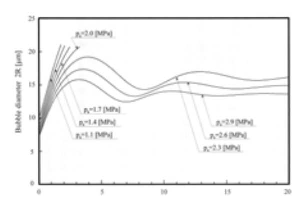


Fig.37 Analytical model of flash boiling spray in this study

減圧沸騰における減圧度に依存する気泡成長過程

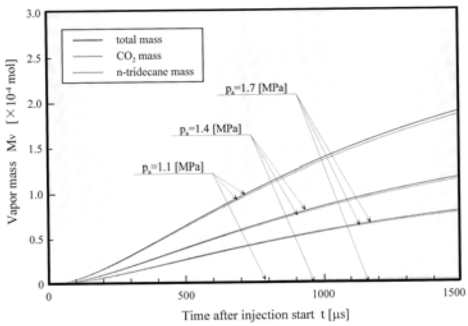


Change in bubble growth with ambient pressure (Xco2=0.6, Tf=383[K])



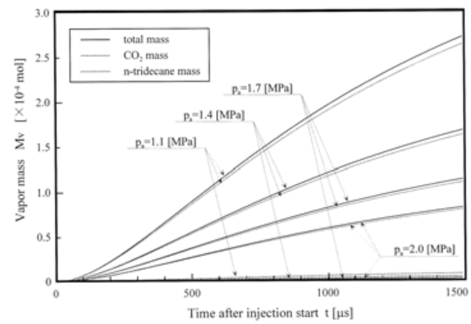
Change in bubble growth with ambient Pressure (Xco2=0.8, Tf=383[K])

減圧沸騰における燃料蒸気濃度



Temporal change in vapor mass (Xco2=0.6，Tf=383[K])

減圧沸騰における燃料蒸気濃度



Temporal change in vapor mass (Xco2=0.8，Tf=383[K])

減圧沸騰噴霧の物性過程と蒸気濃度計測

- 減圧沸騰の物性過程
- 減圧沸騰噴霧による微粒化･蒸発過程の改善
- 減圧沸騰噴霧の微粒化･蒸発過程のモデリング
- ガス溶解燃料噴霧の微粒化過程
- 二成分･他成分燃料噴霧への減圧沸騰現象の適用
- 解析モデル
- **KIVAコードへの減圧沸騰噴霧モデルの適用**
- 赤外域2波長濃度測定法

Flash-Boiling Spray Model

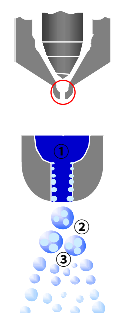
Initial fuel properties
↓ NIST database ($f(T, P)$)

Flash-boiling in nozzle orifice ①
Bubble nucleation (heterogeneous nucleation)
↓ Bubble growth (Rayleigh-Plesset equation)

Fuel injection ②
Injection of multicomponent fuel droplets
↓ with bubbles

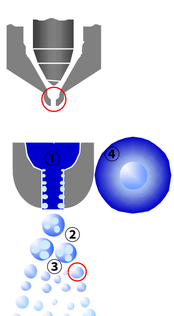
Breakup
↓ Modified TAB model (ϕ=6)

Vaporization
Vaporization on droplet surface
Flash-boiling in droplet

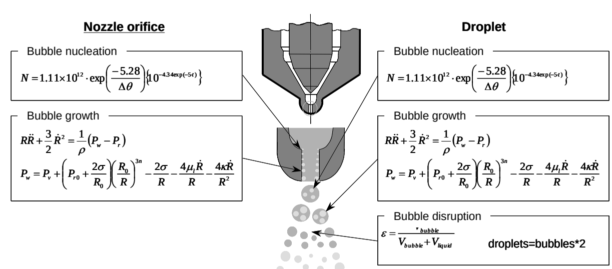


Flash-Boiling Spray Model (continued)

- **Vaporization on droplet surface** ④
  - Vapor-liquid equilibrium (fugacity)
  - Two-zone model (T_{ds}, T_{di})
  - Modified Spalding model ($Le \neq 1$)
- **Renewal of fuel properties**
  - NIST database ($f(T, P)$)
- **Flash-boiling in droplet** ②
  - Bubble nucleation (heterogeneous nucleation)
  - Bubble growth (Rayleigh-Plesset equation)
  - Bubble disruption (ε > 0.55)
  - ⇒ <u>Secondary breakup</u> ③
- **Renewal of fuel properties**
  - NIST database ($f(T, P)$)

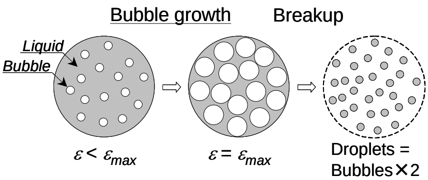


減圧沸騰噴霧モデル



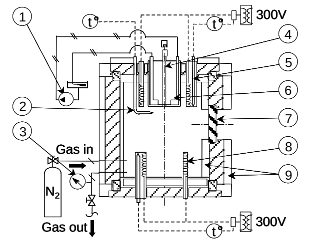
Schematic diagram of flash-boiling model

気泡崩壊



Breakup caused by bubble disruption

実験および計算方法と設定条件



1: Oil pump 2: Thermo-couple 3: Pressure gauge
4: Injection nozzle 5: Thermo-couple 6: Heating jacket
7: Optical window 8: Heater 9: Insulator

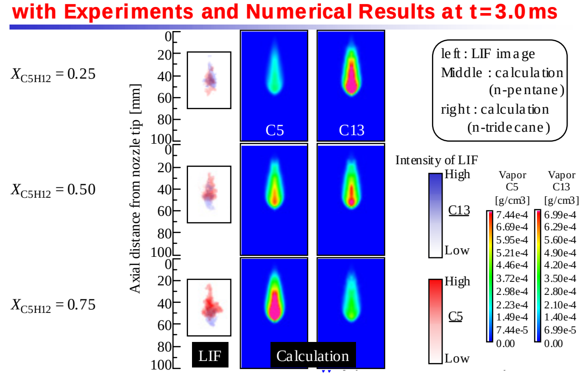
Schematic diagram of constant volume vessel

実験および計算方法と設定条件

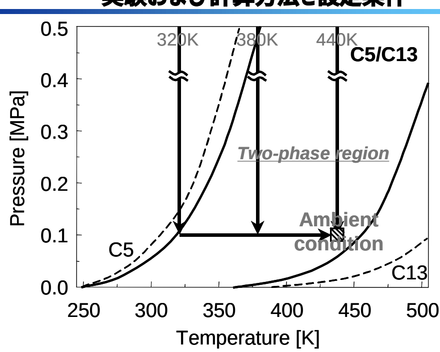
Experimental conditions

Fuel	C_5H_{12} / $C_{13}H_{28}$ 0.75 : 0.25 (mol %)
Ambient gas	N_2
Ambient pressure	0.1 MPa
Ambient temperature	440 K
Hole diameter	0.2 mm
Injection pressure	15.0 MPa
Initial fuel temperature	320, 380, 440 K

Comparison of Spray Structure –Vapor Spatial Distribution– with Experiments and Numerical Results at t=3.0ms

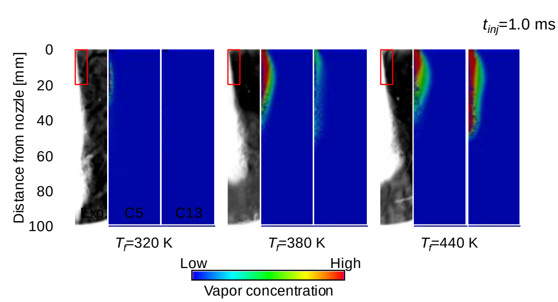


実験および計算方法と設定条件

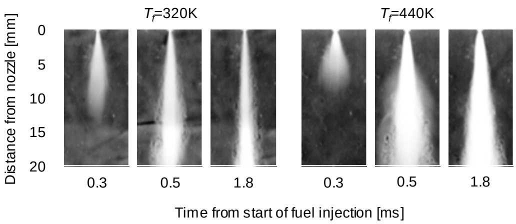


Initial fuel temperature variations

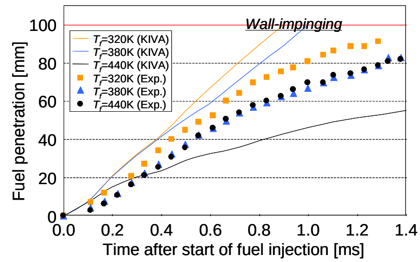
Droplet and Vapor Distributions



Enlarged Shadowgraph Images

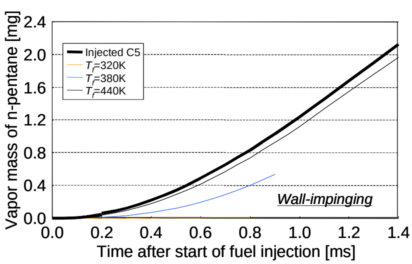


噴霧先端到達距離



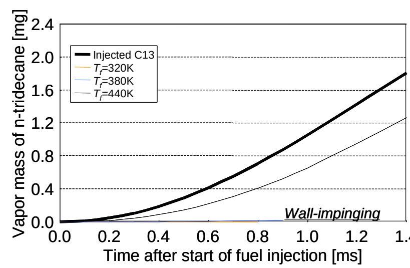
Fuel penetration

蒸気量



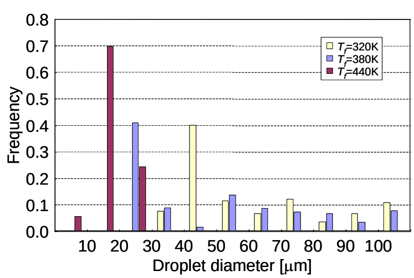
Vapor mass of n-pentane

蒸気量



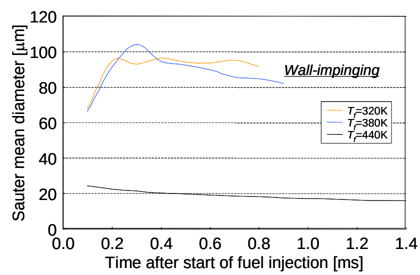
Vapor mass of n-tridecane

液滴粒径分布と平均粒径



Droplet diameter distribution (*tinj*=0.5 ms)

液滴粒径分布と平均粒径



Sauter mean diameter

減圧沸騰噴霧の物性過程と蒸気濃度計測

減圧沸騰の物性過程

減圧沸騰噴霧による微粒化･蒸発過程の改善

減圧沸騰噴霧の微粒化･蒸発過程のモデリング

ガス溶解燃料噴霧の微粒化過程

二成分･他成分燃料噴霧への減圧沸騰現象の適用

解析モデル

KIVAコードへの減圧沸騰噴霧モデルの適用

■赤外域2波長濃度測定法

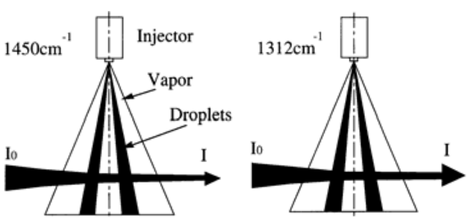
光計測法の分類

＊吸収法ーーLambert-Beer則＜濃度計測＞
モル吸光係数＝F (温度･圧力･濃度)

＊発光法ーー･自発光 (OH, CH,etc)
強度＝F (濃度･温度)
･強制発光 (LIFなど)
強度＝F (量子収率)

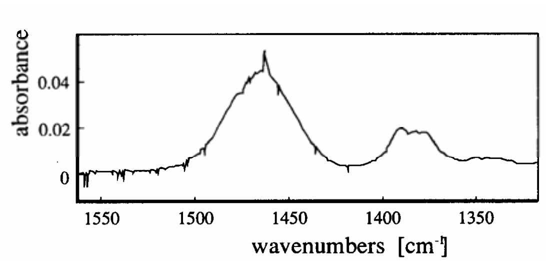
赤外域2波長濃度測定法

$$\log\left(\frac{I_0}{I}\right)_{1450} = \log\left(\frac{I_0}{I}\right)_{1450\,Vab} + \log\left(\frac{I_0}{I}\right)_{Lab} + \log\left(\frac{I_0}{I}\right)_{Lsc}$$



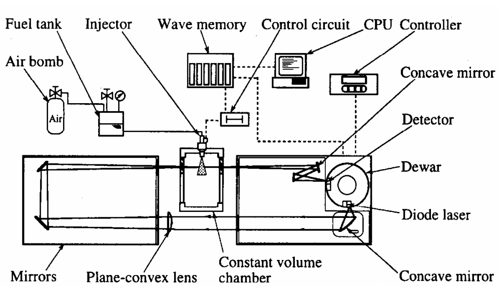
Schematic diagram of IRES theory

赤外域2波長濃度測定法



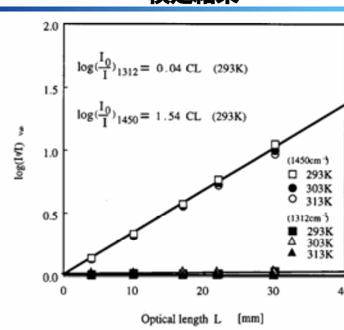
Absorption spectrum of n-pentane vapor (593 ppm)

実験装置，方法および実験条件



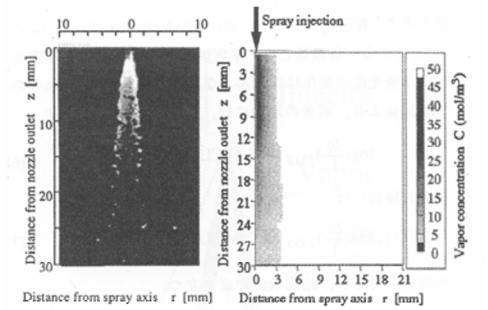
Schematic diagram of experimental apparatus
for measurement of vapor concentration distribution

検定結果



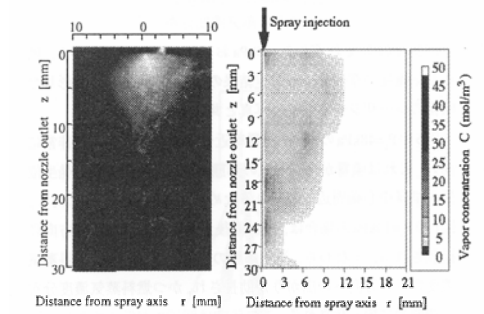
Relation between absorbance and optical length

燃料蒸気濃度分布



Concentration distribution of n-pentane vapor
(Pa=48kPa, t=2.0ms, DP=250kPa, Tf=Ta=293K)

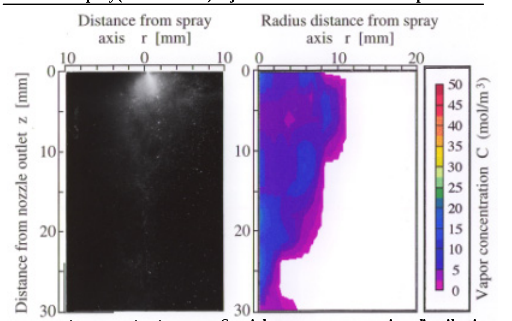
燃料蒸気濃度分布



Concentration distribution of n-pentane vapor
(Pa=14kPa, t=2.0ms, DP=250kPa, Tf=Ta=293K)

Spray Measurement of Flash Boiling Spray

n-Pentane Spray(Pv=56.5KPa) injected into 21KPa ambient pressure

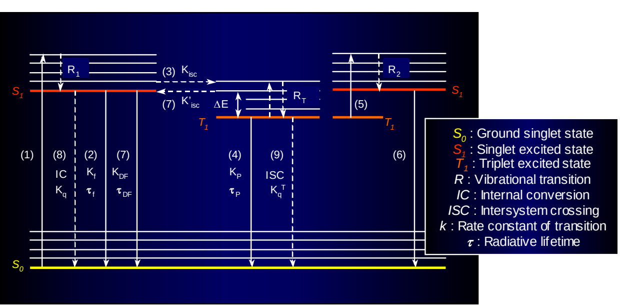


Mie scattering image from droplets

Spatial vapor concentration distribution by two-wave length IR absorption method

Exciplex蛍光法による壁面衝突噴霧の解析

The Absorption and the Transition Process of the Light



The Quenching Action of the Fluorescence

The Quenching by the Molecule

1) the Static Quenching

$$M + N \Leftrightarrow MN, MN + hv \rightarrow \text{energy loss}$$

2) the Dynamic Quenching

$$M + hv \rightarrow {}^1M^* \quad , \quad {}^1M^* + N \rightarrow M + N$$

h : Planck's Constant = 6.626×10-34 [$j \cdot s$]
v : the frequency of the fluorescence [s^{-1}]

Table. Characteristics of the static and dynamic quenching

	Static quenching	Dynamic quenching
Fluorescence lifetime	Constant	Variable
Fluorescence polarizing	Constant	Variable
Absorption spectrum	Variable	Constant
Temperature coefficient of quenching	Negative	Positive

The General Quenching Phenomenon

(a) the Thermal Quenching
(b) the Concentration Quenching : ${}^1M^* + M \Leftrightarrow {}^1(M \cdot M)^*$
(c) the Quenching by Oxygen : ${}^1M^* + O_2 \rightarrow (M \cdot O_2)^* \rightarrow {}^3M^* + O_2$

Exciplex Fluorescence Method

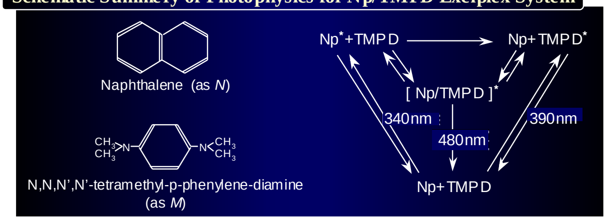
$${}^1M^* + N \Leftrightarrow {}^1(M\cdot N)^*$$

${}^1M^*$: monomer ⟶ vapor

N : quencher

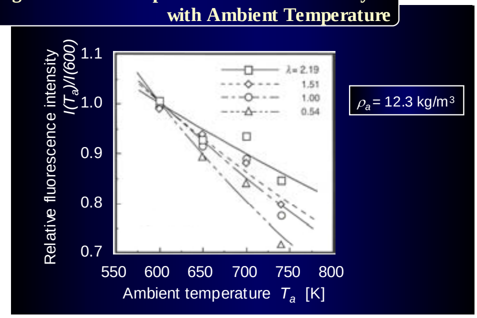
${}^1(M\cdot N)^*$: exciplex ⟶ liquid

Schematic Summery of Photophysics for Np/TMPD Exciplex System



The Change of the Vapor Fluorescence Intensity caused by the Ambient Temperature and Vapor Concentration

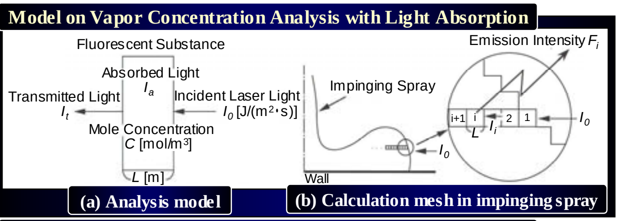
Change in Relative Vapor Fluorescence Intensity with Ambient Temperature



Spray and Combustion Science Laboratory, DOSHISHA Univ.

Quantification of the Vapor Concentration – 1

Model on Vapor Concentration Analysis with Light Absorption



The Calculation of Vapor Concentration by Lambert-Beer Low

$$I_t = I_0 \exp(-\varepsilon CL) \quad (3\text{-}1)$$

$$I_a = I_0 - I_t = I_0\{1-\exp(-\varepsilon CL)\} \quad (3\text{-}2)$$

$$I_i = I_0 \exp\left(-\varepsilon L \sum C_{i-1}\right) \quad (3\text{-}3)$$

$$F_i = A\cdot K\cdot I_0 \exp\left(-\varepsilon L \sum C_{i-1}\right)\{1-\exp(-\varepsilon C_i L)\} \quad (3\text{-}4)$$

ε : molar absorptivity [m³/mol·m]

C : concentration of fluorescence material [mol/m³]

A : constant of optical apparatus

K : probability of luminous transition

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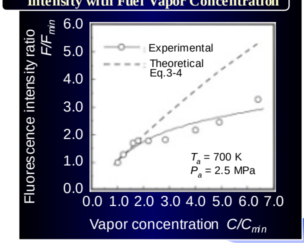
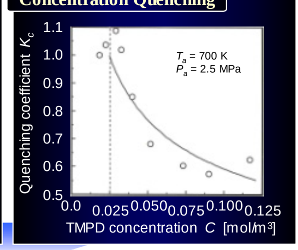
Quantification of the Vapor Concentration – 2





Eq.3-4 ⟶ $$F_i = A\cdot K\cdot K_C I_0 \exp\left(-\varepsilon L \sum C_{i-1}\right)\{1-\exp(-\varepsilon C_i L)\} \quad (3\text{-}5)$$

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The Correction of the Vapor Concentration with Mixture Temperature

Mixture Mean Temperature

$$T_r = \frac{-C_v\{c_{fl}(T_{sat}-T_{l0})+h_f\}+\rho_a c_a T_{ent}+C_v c_{fv} T_{sat}}{C_v c_{fv}+\rho_a c_a} \quad (3\text{-}6)$$

C_v : concentration of the fuel vapor [kg/m³] , ρ_a : density of the ambient gas [kg/m³]

c : specific heat [J/(kg·K)] , h_f : latent heat of vaporization [J/kg]

T_{sat} : saturation temperature of the fuel [K] , T_{l0} : initial temperature of the fuel [K]

T_{ent} : temperature of the entrainment ambient gas [K]

Relation Between Temperature and Relative Fluorescence Intensity

$$\frac{F(T_r)}{F(T_0)} = K_{qa}\exp(-K_{qb}T_r) \quad (3\text{-}7)$$

K_{qa}, K_{qb} : coefficient of temperature quenching

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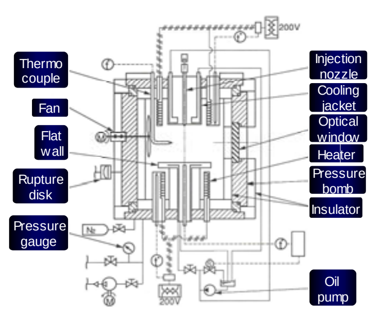
The Schematic Diagram of the Experimental Apparatus

High Temperature and Pressure Constant Volume Chamber



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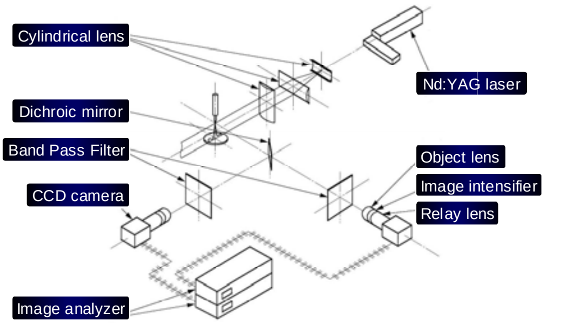
The Schematic Diagram of Laser Sheet Optical System and Photography System



The Experimental Condition

Injection nozzle	Type : Hole nozzle DLL-p		
	Diameter of hole	d_n [mm]	0.2
	Length of hole	L_n [mm]	1.0
Ambient gas			N_2 gas
Ambient temperature	T_a	[K]	700
Ambient pressure	p_a	[MPa]	1.04, 1.70, 2.55
Ambient density	ρ_a	[kg/m^3]	5.0, 8.2, 12.3
Temperature of wall surface	T_w	[K]	550, 600, 650
Injection pressure	p_{inj}	[MPa]	22, 42, 72, 112
Injection quantity	Q_{inj}	[mg]	12.0
Injection duration	t_{inj}	[ms]	2.82, 1.98, 1.54, 1.20
Impingement distance	Z_w	[mm]	24, 30, 34, 40

† Parameter   † Standard condition

The Analysis Process in Every Parameter

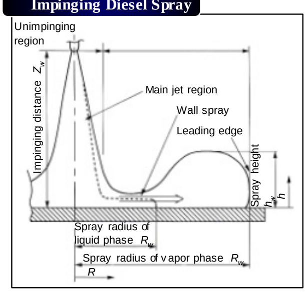
The impinging spray image
(a) Vapor concentration
(b) Mixture temperature
(c) Liquid fluorescence intensity

The spray radius & height

The relative fuel vapor volume

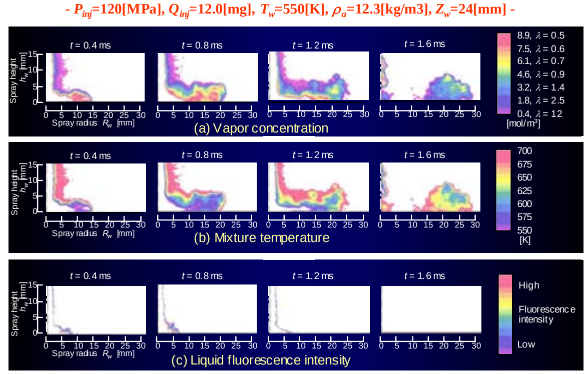
Radial distribution of fuel vapor

Model on Vaporizing Impinging Diesel Spray



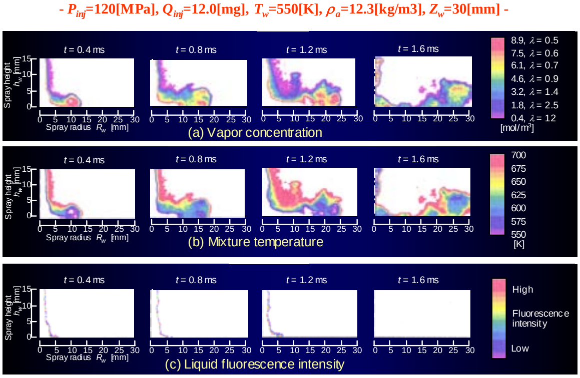
Temporal Change in the Impinging Spray Image with Exciplex Fluorescence Method

- P_{inj}=120[MPa], Q_{inj}=12.0[mg], T_w=550[K], ρ_a=12.3[kg/m3], Z_w=24[mm] -



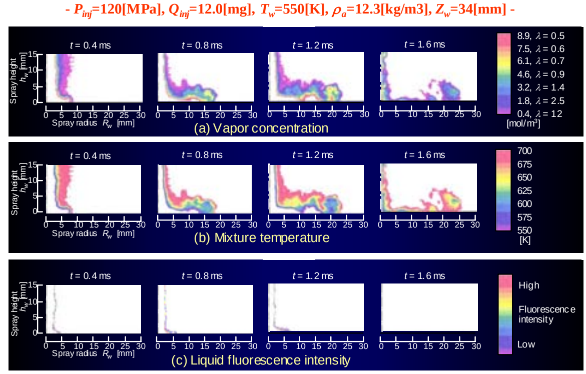
Temporal Change in the Impinging Spray Image with Exciplex Fluorescence Method

- P_{inj}=120[MPa], Q_{inj}=12.0[mg], T_w=550[K], ρ_a=12.3[kg/m3], Z_w=30[mm] -



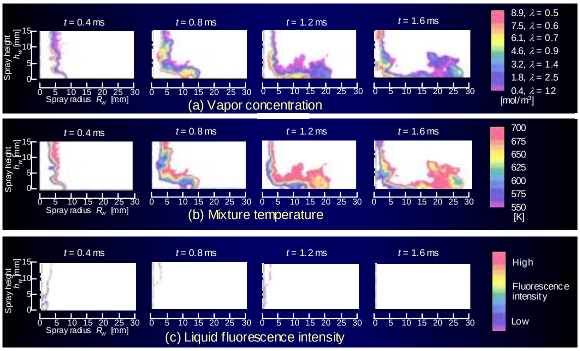
Temporal Change in the Impinging Spray Image with Exciplex Fluorescence Method

- P_{inj}=120[MPa], Q_{inj}=12.0[mg], T_w=550[K], ρ_a=12.3[kg/m3], Z_w=34[mm] -

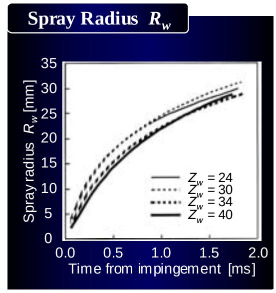


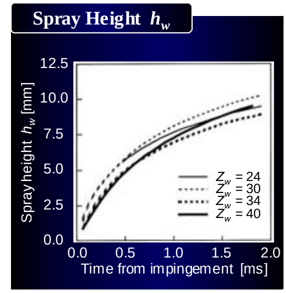
TempToral Change in the Impinging Spray Image with Exciplex Fluorescence Method

- P_{inj}=120[MPa], Q_{inj}=12.0[mg], T_w=550[K], ρ_a=12.3[kg/m3], Z_w=40[mm] -



Temporal Change in the Spray Radius and Height





The END - 完 -

Thank you for your kind attention

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