# Optimization of the NOx reduction condition in the combustion furnace for the combustion of "heavy-oil - $NH_3$ system" using CFD

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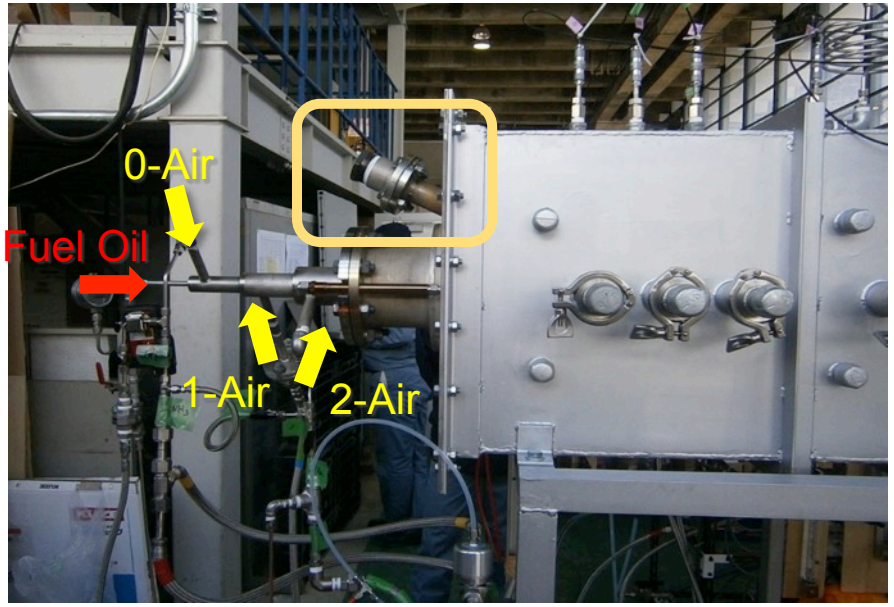
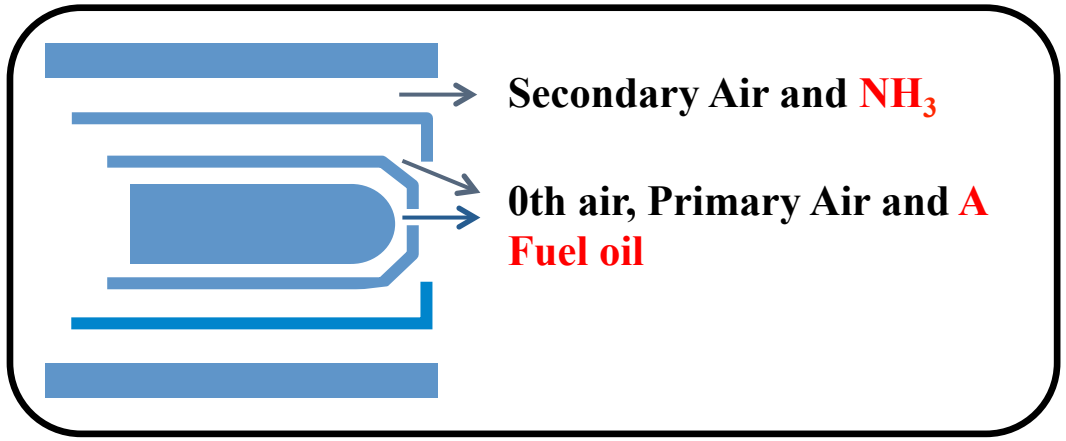
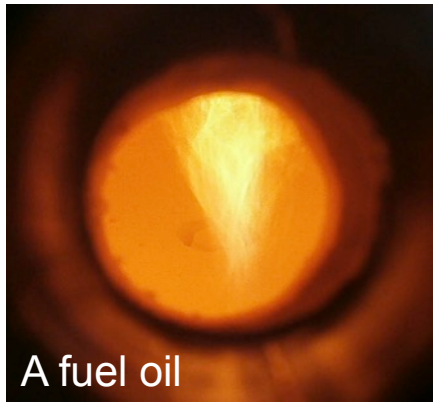
# A Fuel Oil-$NH_3$ co-combustion experiments

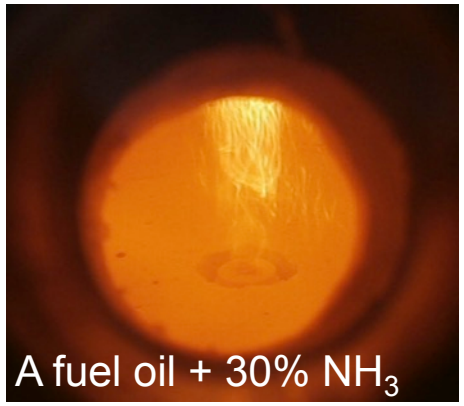
**10kW Furnace (Inner : L.1200 mm×H.300mm×W.300mm)**




***Oil burner dimension***




**λ(total air/theoretical air for Fuel)=1.05-1.3**

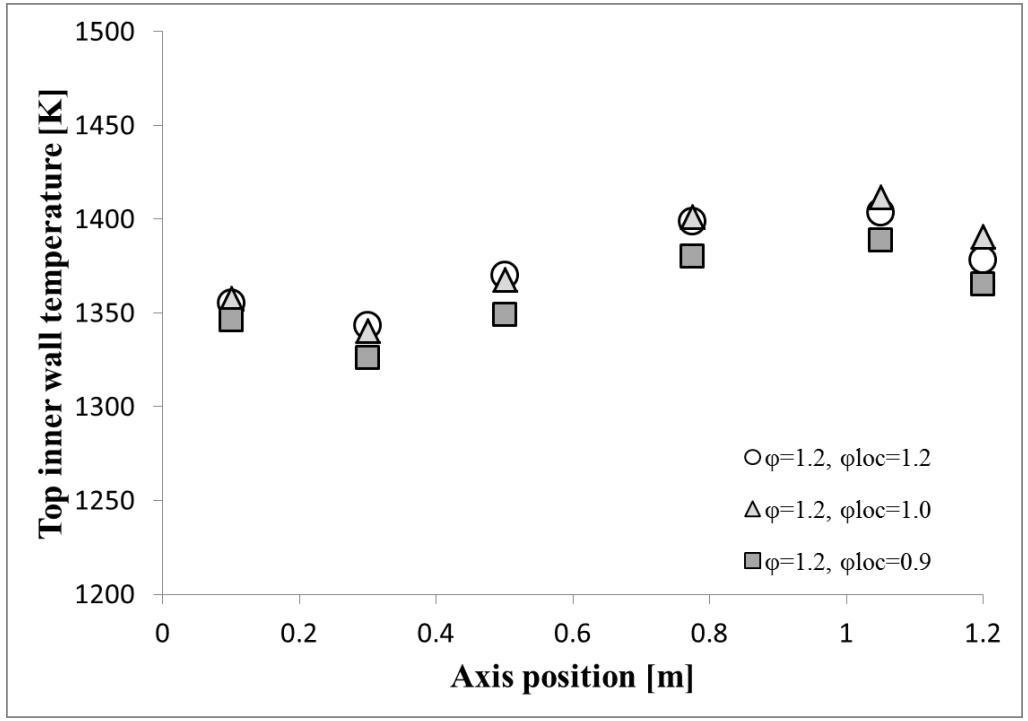
**$\lambda_{loc}$ (secondary air/theoretical air for NH3)=0.6-1.4**

**<u>$\lambda_{loc}$ is most important parameter for NOx reduction.</u>**

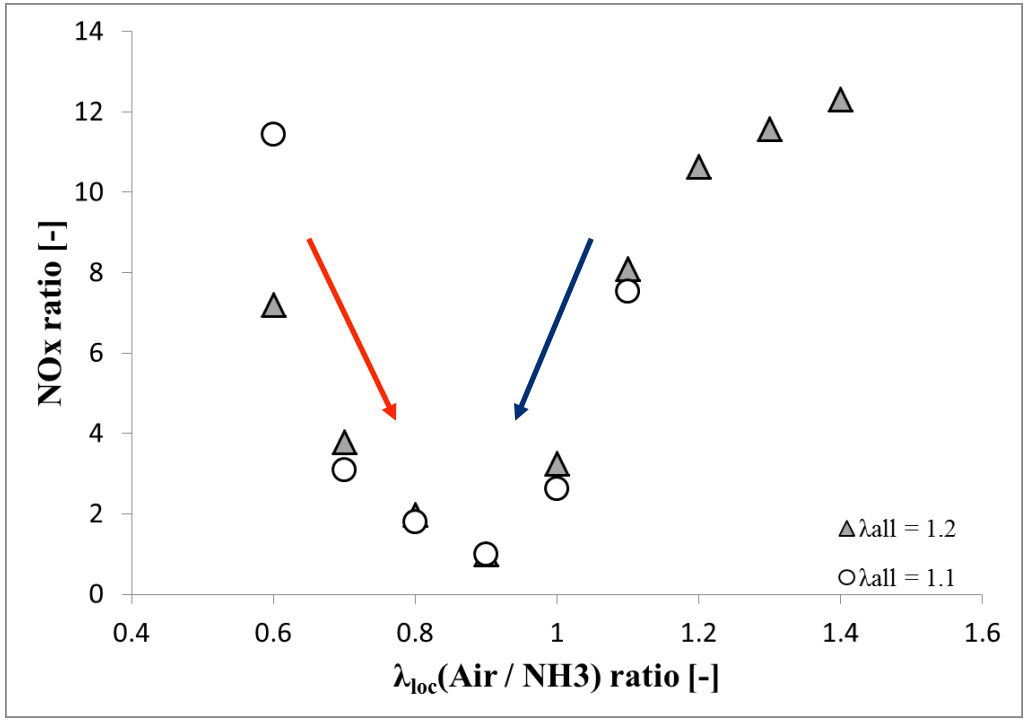
# Experimental results

When $NH_3$ mixing rates increased in this study, the temperature distribution in the furnace decreased. $N_2$ increase in exhaust gas composition and a decrease in $CO_2$ influence it.

In addition, we discovered that there was a NOx reduction effect when we regulated transportation atmosphere for an NH3 supply line to show it in the right figure.




Inner wall temperature distribution [K]




NOx ratio for $\lambda_{loc}$[-]

# Turbulence Combustion Model （EDC）

Species transport equations

$$\partial/\partial t\,(\rho Y_i)+\nabla\cdot(\rho \boldsymbol{v} Y_i)=-\nabla\cdot \boldsymbol{J}_i+R_i$$

$$Y_i^{*}=Y_i+\int_0^{\tau^{*}} \dot{M}_{w,i}\sum_{r=1}^{N_R}\dot{R}_{i,r}\,/\rho\,dt$$

Chemical reaction equations

$$\sum_{i=1}^{N}\dot{\nu}'_{i,r}\mathcal{M}_i \Leftrightarrow k_{f,r}/k_{b,r}-\sum_{i=1}^{N}\dot{\nu}''_{i,r}\mathcal{M}_i$$

Volume fraction constant:

$$\xi^{*}=C_{\xi}(\nu\varepsilon/\kappa^2)^{1/4},\ C_{\xi}=2.1377$$

Time scale constant:

$$\tau^{*}=C_{\tau}(\nu/\varepsilon)^{1/2},\ C_{\tau}=0.4082$$

Net reaction rates [1]

$$R_i=\rho(\xi^{*})^2/\tau^{*}\,[1-(\xi^{*})^3]\,(Y_i^{*}-Y_i)$$

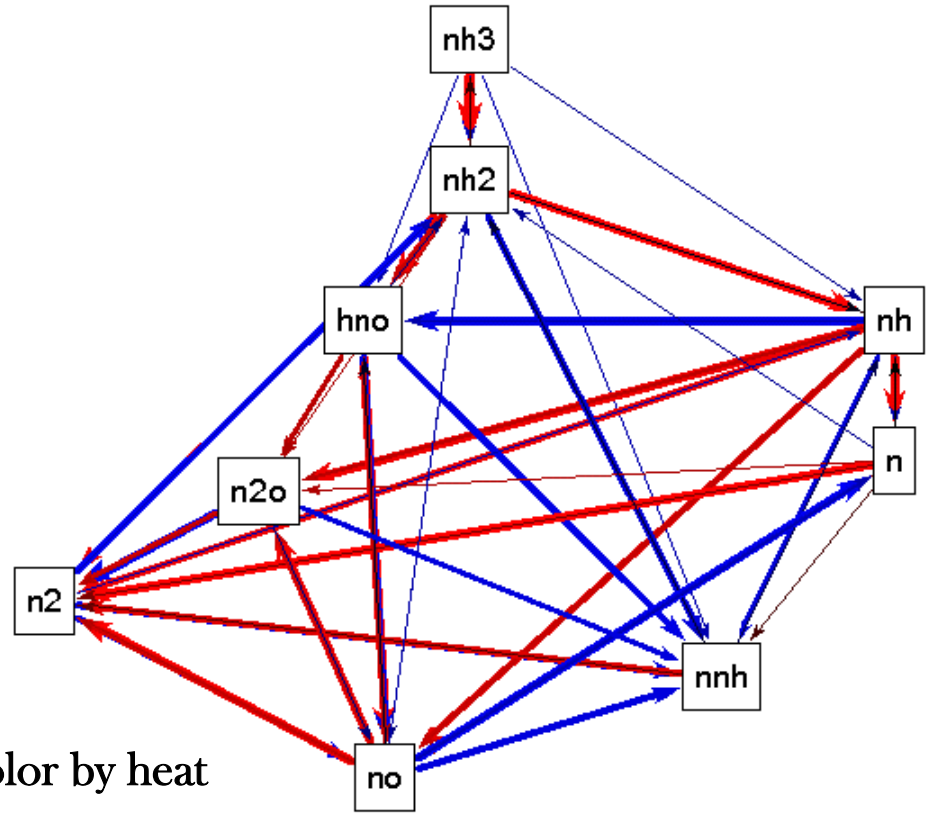
kinematic viscosity : $\nu=\mu/\rho\ [\mathrm{m}^2/\mathrm{s}]$

Because some slow reactions exists, it is difficult to solve the reaction term.
By the direct integration for Fine scales, it is considered chemical reaction and turbulence mixing at the same time.

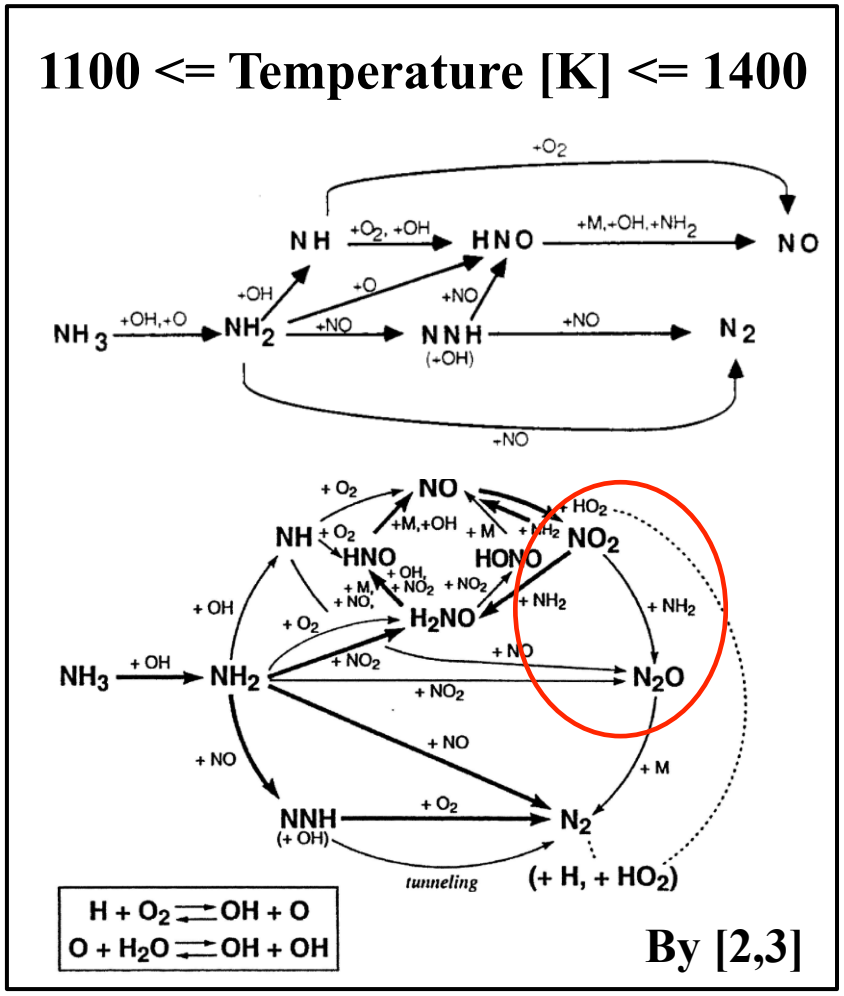
[1] Magnussen : On the structure of Turbulence and a generalized Eddy Dissipation Concept for chemical reaction in turbulent flow (1981)

# $NH_3$ Combustion & Fuel NOx (Simplified Miller's Mechanism)

Reaction path for the oxidation of ammonia in flames.




Color by heat



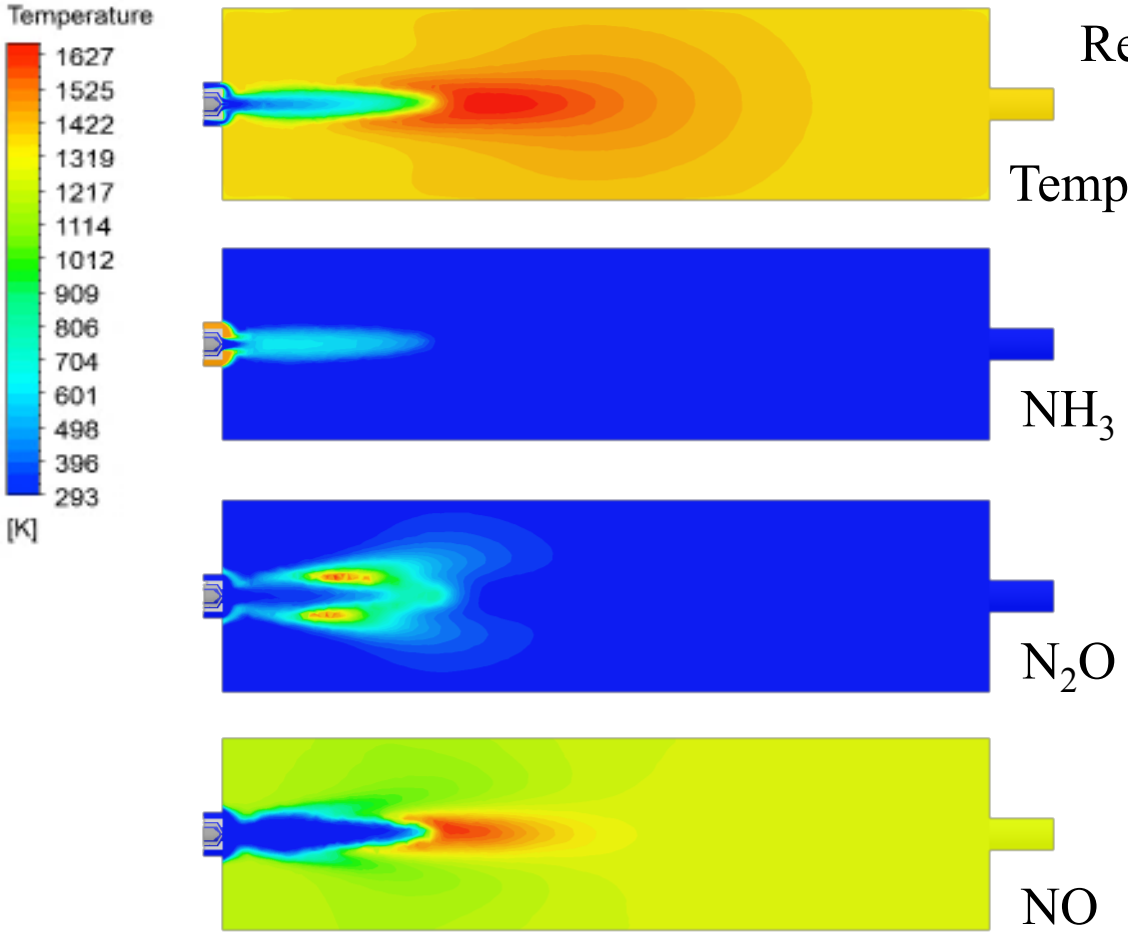


**[2]** James A. Miller : Mechanism and Modeling of Nitrogen Chemistry in Combustion(1989)

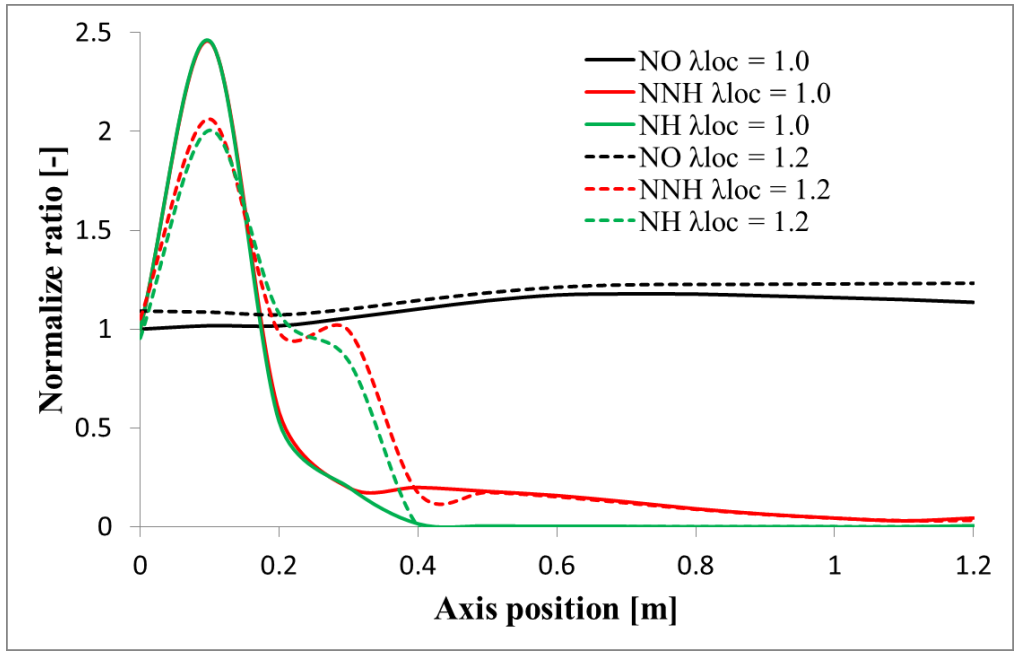
**[3]** James A. Miller : Modelling the Formation of $N_2O$ and $NO_2$ in the Thermal De-NOx Process (1996)

# CFD results

A difference became less than the experimental results in the $NH_3$ reaction mechanism which I used in this study. I am inspecting how there is influence of the reaction mechanism that I simplified.

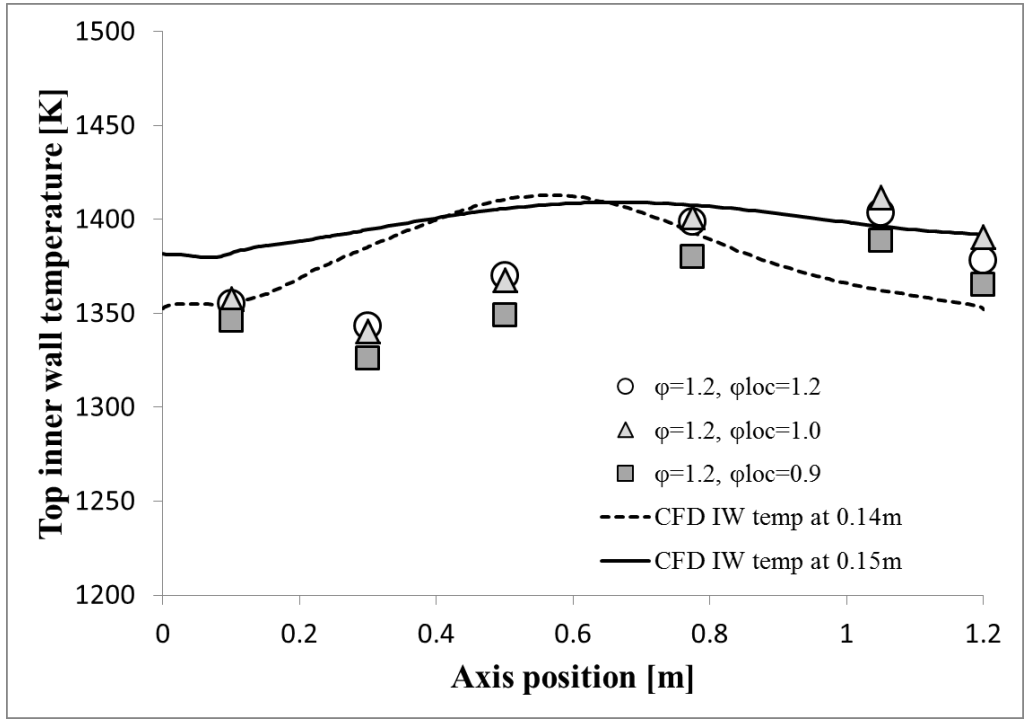



Results of contour for $\lambda$=1.2, $\lambda_{loc}$=1.2

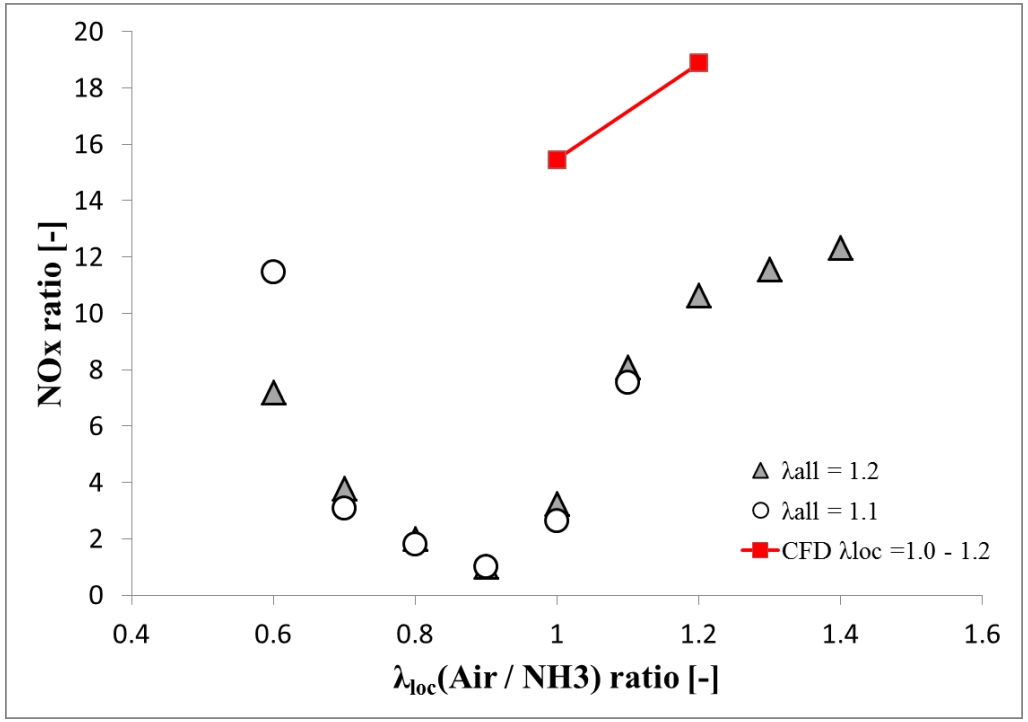


# Conclusion

We inspected it about NOx behavior of A Fuel oil–$NH_3$ co-combustion by experiment and CFD. We understood that there was a local minimum of the NOx by the experiment. On the other hand, the analysis result by CFD became higher in NOx concentration than some experiments. According to the precision of simplification of the reaction mechanism and the analysis model, this is thought about. We will do the study continuously in the future to raise precision more.




Inner wall temperature distribution [K]




NOx ratio for $\lambda_{loc}$[-]

*Thank you for your attention.*

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