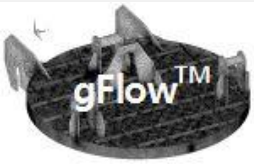
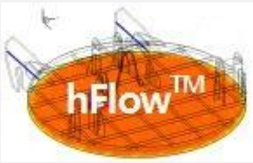
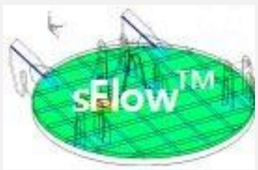
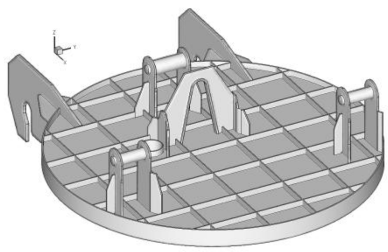
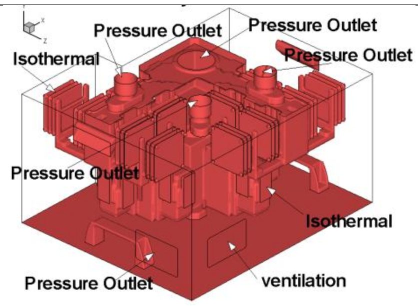
Industrial Machinery Facility Optimization Solution Provider

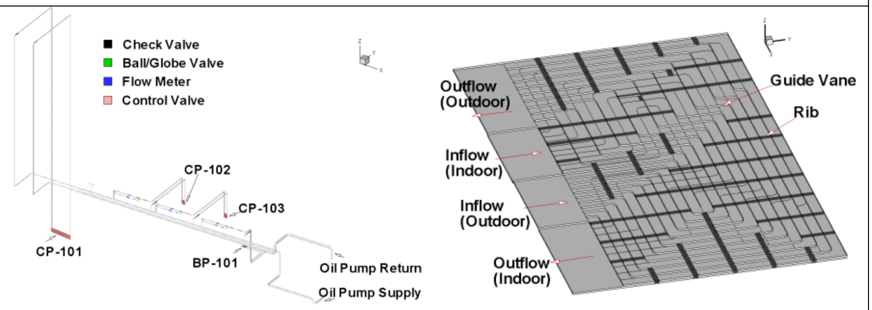
1. Products

Classification	Contents and Descriptions
 격자생성	● **Grid Generation Code** ⇒ Using finite difference method ⇒ Structured(including block structured) grid ⇒ Unstructured(including tetrahedral element) grid ⇒ Moving Grid ⇒ Adaptive grid
 열유동해석	● **Heat and Fluid Flow Analysis Solver Code** ⇒ Combined finite volume with element method ⇒ General coordinate system(body fitted) ⇒ Using iteration method(TDMA matrix solver) ⇒ Central differencing scheme for 2nd order partial derivatives ⇒ 2nd order upwind and QUICK(Quadratic Upstream Interpolation for Convective Kinematics) scheme for 1st order partial derivatives
 응력해석	● **Stress Analysis Solver Code(including thermal stress)** ⇒ Combined finite difference with element method ⇒ General coordinate system(body fitted) ⇒ Using iteration method(TDMA matrix solver) ⇒ Central differencing scheme for 2nd order partial derivatives ⇒ Central differencing scheme combined with element integration for 2nd order mixed partial derivatives
 최적설계	● **Design and Process Optimization Code** ⇒ Combined gFlow™, hFlow™, sFlow™ with optimization algorithms ⇒ Using ADS(Automated Design Synthesis) optimization code ⇒ Finding single or multi objective value by minimizing error function ⇒ Solving stochastic optimization problem by using the weighted sum approach method

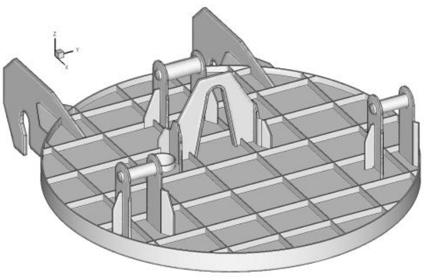
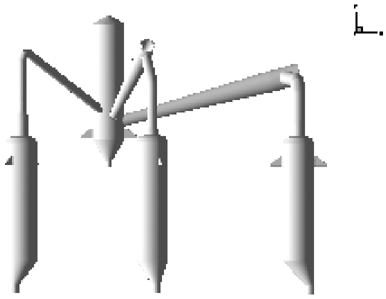
1.1 gFlow™

Classification	Basic Equations and Descriptions
Elliptic Grid Generation Eqn.	$\alpha_{11}x_{\xi\xi} + \alpha_{12}x_{\xi\eta} + \alpha_{13}x_{\xi\phi} + \alpha_{22}x_{\eta\eta} + \alpha_{23}x_{\eta\phi} + \alpha_{33}x_{\phi\phi} = -I^2\left(Px_\xi + Qx_\eta + Rx_\phi\right)$ $\alpha_{11}y_{\xi\xi} + \alpha_{12}y_{\xi\eta} + \alpha_{13}y_{\xi\phi} + \alpha_{22}y_{\eta\eta} + \alpha_{23}y_{\eta\phi} + \alpha_{33}y_{\phi\phi} = -I^2\left(Py_\xi + Qy_\eta + Ry_\phi\right)$ $\alpha_{11}z_{\xi\xi} + \alpha_{12}z_{\xi\eta} + \alpha_{13}z_{\xi\phi} + \alpha_{22}z_{\eta\eta} + \alpha_{23}z_{\eta\phi} + \alpha_{33}z_{\phi\phi} = -I^2\left(Pz_\xi + Qz_\eta + Rz_\phi\right)$
Jacobian	$I = x_\xi\left(y_\eta z_\phi - y_\phi z_\eta\right) - x_\eta\left(y_\xi z_\phi - y_\phi z_\xi\right) + x_\phi\left(y_\xi z_\eta - y_\eta z_\xi\right)$
Matrix Tensor	$\alpha_{11} = \beta_{11}^2 + \beta_{21}^2 + \beta_{31}^2$, $\alpha_{12} = \beta_{11}\beta_{12} + \beta_{21}\beta_{22} + \beta_{31}\beta_{32}$ $\alpha_{13} = \beta_{11}\beta_{13} + \beta_{21}\beta_{23} + \beta_{31}\beta_{33}$, $\alpha_{22} = \beta_{12}^2 + \beta_{22}^2 + \beta_{32}^2$ $\alpha_{23} = \beta_{12}\beta_{13} + \beta_{22}\beta_{23} + \beta_{32}\beta_{33}$, $\alpha_{33} = \beta_{13}^2 + \beta_{23}^2 + \beta_{33}^2$
Invariants	$\beta_{11} = y_\eta z_\phi - y_\phi z_\eta$, $\beta_{12} = y_\phi z_\xi - y_\xi z_\phi$, $\beta_{13} = y_\xi z_\eta - y_\eta z_\xi$ $\beta_{21} = x_\phi z_\eta - x_\eta z_\phi$, $\beta_{22} = x_\xi z_\phi - x_\phi z_\xi$, $\beta_{23} = x_\eta z_\xi - x_\xi z_\eta$ $\beta_{31} = x_\eta y_\phi - x_\phi y_\eta$, $\beta_{32} = x_\phi y_\xi - x_\xi y_\phi$, $\beta_{33} = x_\xi y_\eta - x_\eta y_\xi$
Control Function Thomas & Middlecoff	$P = x_{\xi\xi} + x_{\eta\eta} + x_{\phi\phi}$, $Q = y_{\xi\xi} + y_{\eta\eta} + y_{\phi\phi}$, $R = z_{\xi\xi} + z_{\eta\eta} + z_{\phi\phi}$
Case Analysis	 

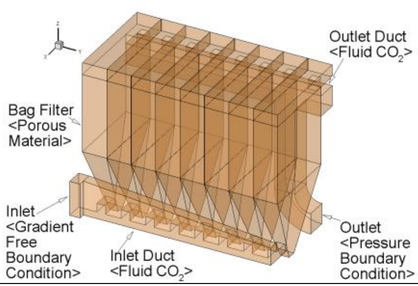
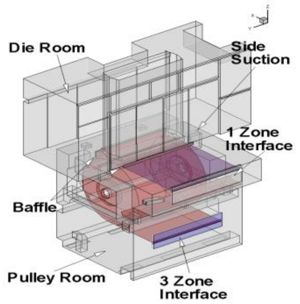
1.2 hFlow™

Classification	Basic Equations and Descriptions
Continuity Eqn.	$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x_j}\left(\rho u_j\right)=0$
Momentum Eqn.	$\frac{\partial}{\partial t}(\rho u_i)+\frac{\partial}{\partial x_j}\left(\rho u_j u_i\right)=\rho f_i-\frac{\partial p}{\partial x_i}+\frac{\partial \tau_{ij}}{\partial x_j}$ $f_i=\text{body force}$
Energy Eqn.	$\frac{\partial}{\partial t}(\rho H-p)+\frac{\partial}{\partial x_j}\left(\rho u_j H\right)=-\frac{\partial q_j}{\partial x_j}+\frac{\partial}{\partial x_j}\left(u_i \tau_{ij}\right)$ $H=C_p T+\frac{1}{2}\left(u_1^2+u_2^2+u_3^2\right)$, $q_j=-k\frac{\partial T}{\partial x_j}$
2-eqns. Turbulence Model	$\frac{\partial}{\partial t}(\rho \Phi)+\frac{\partial}{\partial x_i}(\rho u_i \Phi)=\frac{\partial}{\partial x_i}\left(\Gamma_\Phi \frac{\partial \Phi}{\partial x_i}\right)+R_1+R_2$ $R_1=\Pi$ or $\frac{C_1 \varepsilon \Pi}{k}$, $R_2=-\left(\frac{C_\mu \rho^2 k^*}{\mu_t}\right)k$ or $-\left(\frac{C_2 \rho \varepsilon^*}{k^*}\right)\varepsilon$ $\Pi=\left[\mu_t\left(\frac{\partial\langle u_i\rangle}{\partial x_j}+\frac{\partial\langle u_j\rangle}{\partial x_i}\right)-p\delta_{ij}\right]\frac{\partial\langle u_i\rangle}{\partial x_j}$, $\mu_t=\frac{C_\mu f_\mu \rho \kappa^2}{\varepsilon}$
Stress Tensor	$\tau_{ij}=\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}-\frac{2}{3}\delta_{ij}\frac{\partial u_k}{\partial x_k}\right)$, $\delta_{ij}=\text{Kronecker's Delta}$
Case Analysis	

1.3 sFlow™

Classification	Basic Equations and Descriptions
Equilibrium Eqn.	$(\lambda+G)\frac{\partial}{\partial x_i}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}\right)+G\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)=\frac{\alpha E}{1-2\nu}\frac{\partial T}{\partial x_i}-X_i$
Modulus of Elasticity	$G=\frac{E}{2(1+\nu)}\ ,\ \lambda=\frac{\nu E}{(1+\nu)(1-2\nu)}$
Strain Rates	$\varepsilon_x=\frac{\partial u}{\partial x}\ ,\ \varepsilon_y=\frac{\partial v}{\partial y}\ ,\ \varepsilon_z=\frac{\partial w}{\partial z}\ ,\ \varepsilon=\varepsilon_x+\varepsilon_y+\varepsilon_z$ $\gamma_{xy}=\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\ ,\ \gamma_{xz}=\frac{\partial u}{\partial z}+\frac{\partial w}{\partial x}\ ,\ \gamma_{yz}=\frac{\partial v}{\partial z}+\frac{\partial w}{\partial y}$
Stresses	$\sigma_x=\frac{\nu E}{(1+\nu)(1-2\nu)}\varepsilon+\frac{E}{1+\nu}\varepsilon_x\ ,\ \tau_{xy}=G\gamma_{xy}$ $\sigma_y=\frac{\nu E}{(1+\nu)(1-2\nu)}\varepsilon+\frac{E}{1+\nu}\varepsilon_y\ ,\ \tau_{yz}=G\gamma_{yz}$ $\sigma_z=\frac{\nu E}{(1+\nu)(1-2\nu)}\varepsilon+\frac{E}{1+\nu}\varepsilon_z\ ,\ \tau_{zx}=G\gamma_{zx}$
Principal Stress	$\sigma^3-I_1\sigma^2+I_2\sigma-I_3=0$ $I_1=\sigma_x+\sigma_y+\sigma_z=\sigma_1+\sigma_2+\sigma_3$ $I_2=\sigma_y\sigma_z+\sigma_z\sigma_x+\sigma_x\sigma_y-\tau_{yz}^2-\tau_{xz}^2-\tau_{xy}^2=\sigma_2\sigma_3+\sigma_3\sigma_1+\sigma_1\sigma_2$ $I_3=\begin{vmatrix}\sigma_x & \tau_{yx} & \tau_{zx}\\ \tau_{xy} & \sigma_y & \tau_{zy}\\ \tau_{xz} & \tau_{yz} & \sigma_z\end{vmatrix}=\sigma_1\sigma_2\sigma_3$
Failure Criteria **Von Mises & Hencky**	$\tau_0=\left(\frac{1}{9}\left[(\sigma_x-\sigma_y)^2+(\sigma_x-\sigma_z)^2+(\sigma_z-\sigma_x)^2+6\tau_{xy}^2+6\tau_{xz}^2+6\tau_{yz}^2\right]\right)^{\frac{1}{2}}$ $=\frac{\sqrt{2}}{3}Y$
Fatigue Life **(Basquin)**	$\frac{\Delta\sigma}{2}=\sigma_f\left(2N_f\right)^b$ $\frac{\Delta\sigma}{2}=$ true stress amplitude , $2N_f=$ the number of reversals to failure , $\sigma_f=$ fatigue strength coefficient , $b=$ fatigue strength exponent
Case Analysis	 

1.4 aFlow™

Classification	Basic Equations and Descriptions
Single Objective Function	$Minimize \quad f(x)$ $f(x)=w_1 f_1(x)+w_2 f_2(x)\ldots+w_m f_m(x)$ $Subject to \quad g_j(x)\le 0, \quad j=1,2,\ldots,J$ $h_k(x)=0, \quad k=1,2,\ldots,K$ $x_i^{(L)} \le x_i \le x_i^{(U)}, \quad i=1,2,\ldots,N$
Multi-Objective Function	$Minimize \quad (f_1(x), f_2(x),\ldots, f_M(x))$ $Subject to \quad g_j(x)\le 0, \quad j=1,2,\ldots,J$ $h_k(x)=0, \quad k=1,2,\ldots,K$ $x_i^{(L)} \le x_i \le x_i^{(U)}, \quad i=1,2,\ldots,N$ $Feasible Solution \quad f_i^a \le f_i^b \; for\ all\ i=1,2,\ldots,M$ $f_i^a \le f_i^b \; for\ at\ least\ one\ i \in \{1, M\}$
Stochastic Optimization Problem	$Minimize \quad f_m(\mu_{ym}(x), \sigma_{ym}(x)), \quad m=1,2,\ldots,M$ $Subject to \quad g_j(\mu_{yj}(x), \sigma_{yj}(x))\le 0, \quad j=1,2,\ldots,J$ $h_k(x)=0, \quad k=1,2,\ldots,K$ $x_i^{(L)} + n\sigma_{xi} \le x_i \le x_i^{(U)} - n\sigma_{xi}, \quad i=1,2,\ldots,N$ $Constraints \quad \mu_y - n\sigma_y \ge Lower\ Limit$ $\mu_y + n\sigma_y \ge Upper\ Limit$
Optimizing Algorithms	● One dimensional search ● Fletcher-Reeves algorithm for unconstrained minimization ⇒ Davidon-Fletcher-Powell variable metric method for unconstrained minimization ⇒ Broydon-Fletcher-Goldfarb-Shanno variable metric method for unconstrained minimization ● Method of Feasible Direction for constrained minimization
Case Analysis	 

2. Case Analysis

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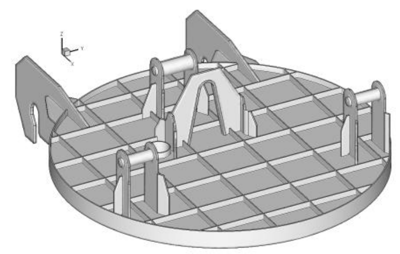
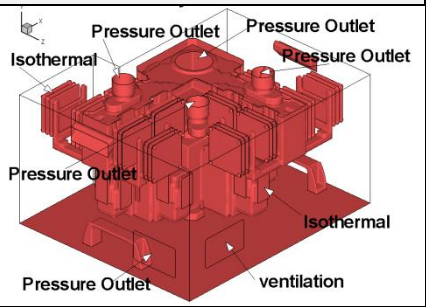
<tr><td rowspan="2">Grid Generation</td><td></td><td>
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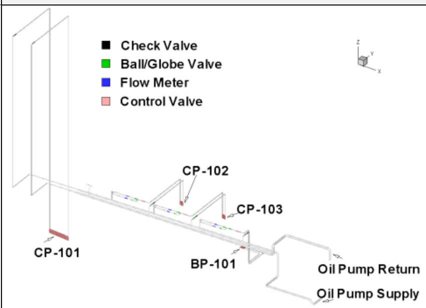
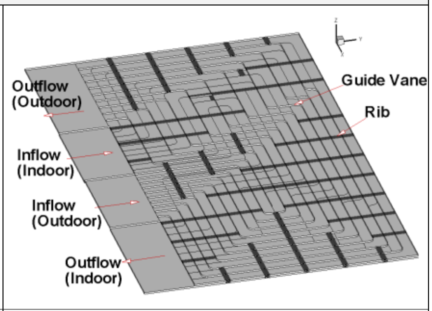
<tr><td colspan="2">Tetrahedral Adaptive Mesh</td></tr>
<tr><td rowspan="2">Heat and Fluid Flow</td><td>
</td><td>
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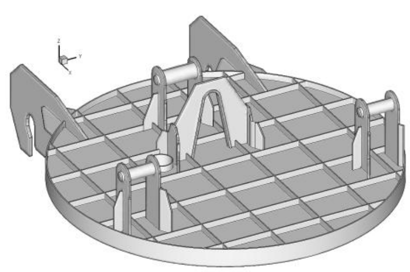
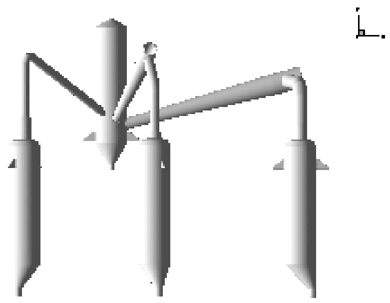
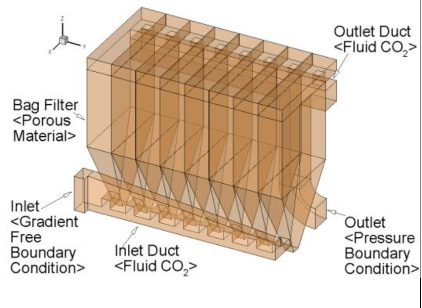
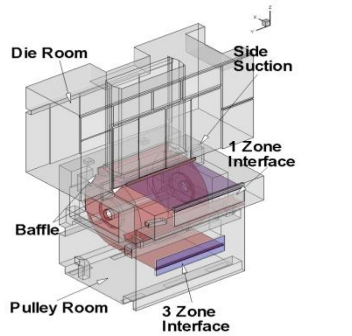
<tr><td>Fluid Flow</td><td>Heat and Fluid Flow</td></tr>
<tr><td rowspan="2">Thermal Stress</td><td></td><td></td></tr>
<tr><td>Fatigue Failure</td><td>Thermal Stress</td></tr>
<tr><td rowspan="2">Design Optimization</td><td>
</td><td>
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<tr><td>Design Optimization</td><td>Process Optimization</td></tr>
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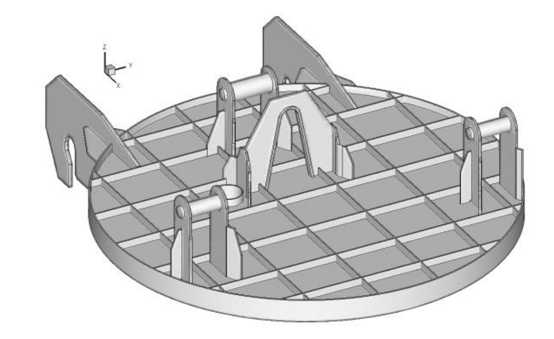
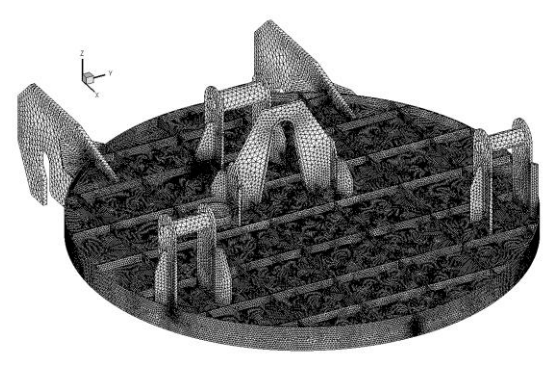
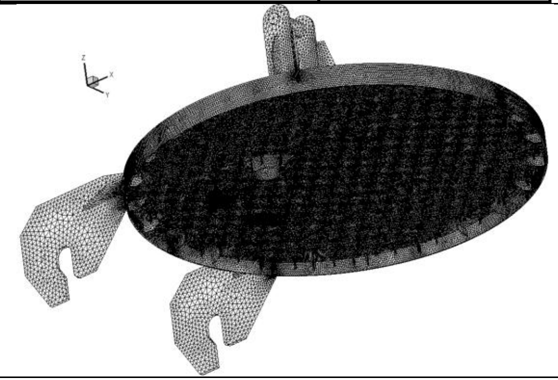
2.1 Grid Generation

Ladle Metallurgical Furnace Cover

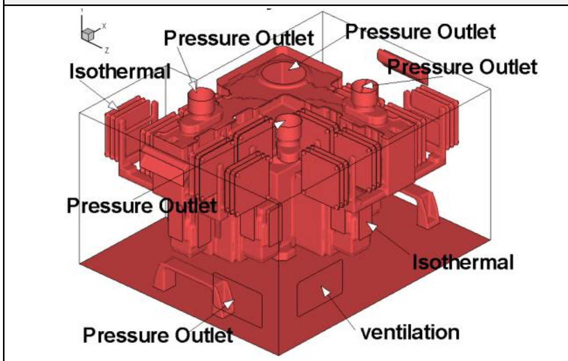


Temperature	℃
Design Temperature	℃
Heat Transfer Coef._1	W/m^2K
Heat Transfer Coef._2	W/m^2K
Density	kg/m^3
Specific Heat	J/kgK
Thermal Conductivity	W/mK

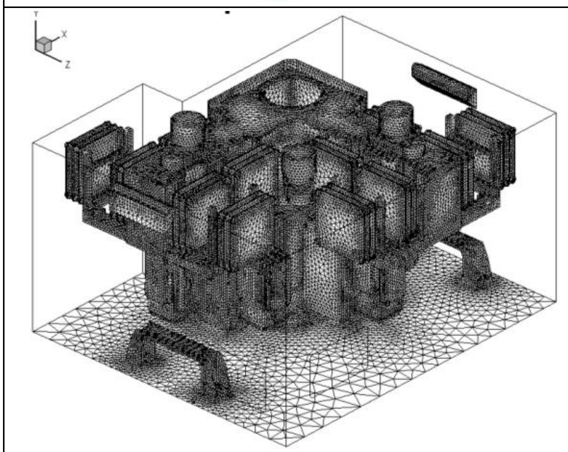


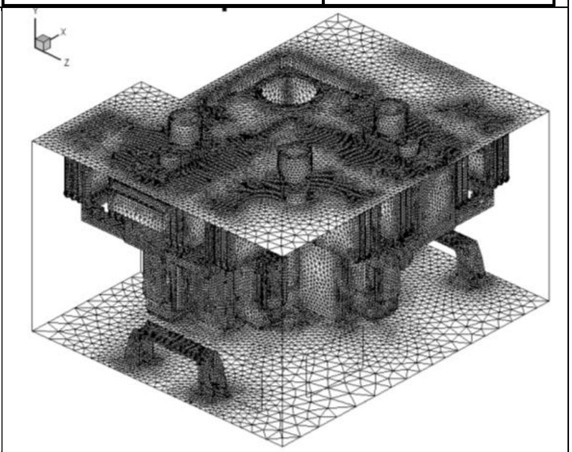


Vision Inspection Module



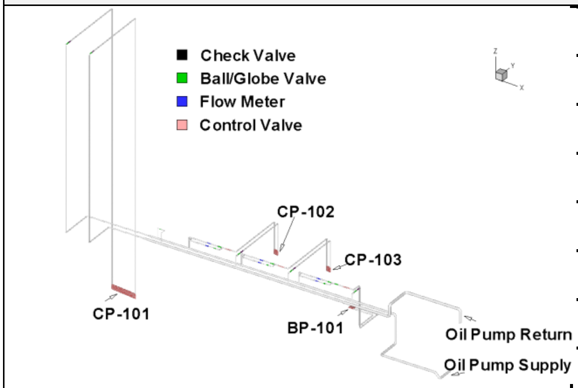
Design Condition	℃
Density_1	kg/m^3
Viscosity_1	kg/ms
Pressure Drop	Pa
Heat Source_1	℃
Heat Source_2	℃
Initial Condition	℃





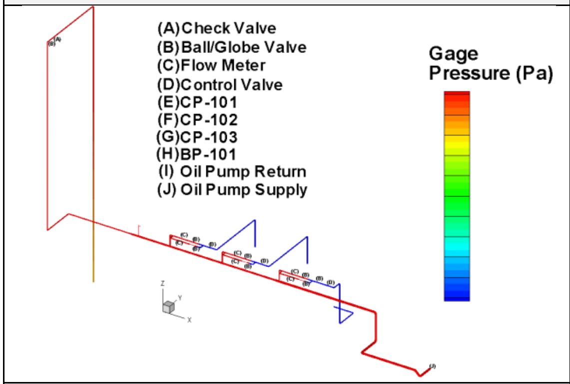
2.2 Fluid Flow Analysis

Chemical Plant Plumbing Fixture

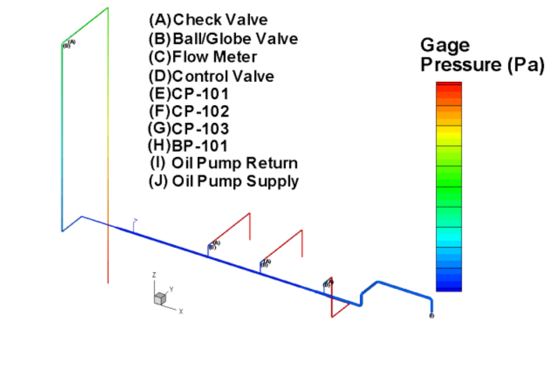


Flow Rate_1	m^3/hr
Pressure Drop_1	Pa
Pressure Drop_2	Pa
Density	kg/m^3
Viscosity	kg/ms
Valve Friction Factor_1	-
Valve Friction Factor_2	-
Valve Friction Factor_3	-

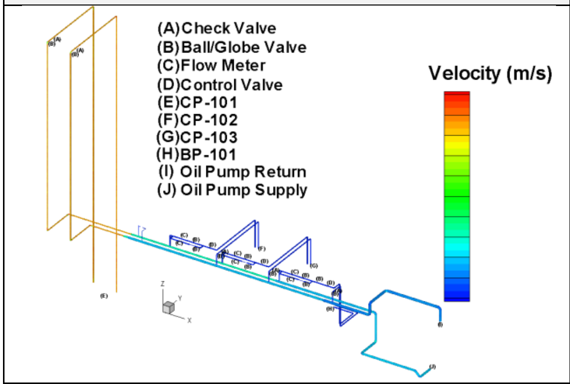
Pressure Distribution in Path 1



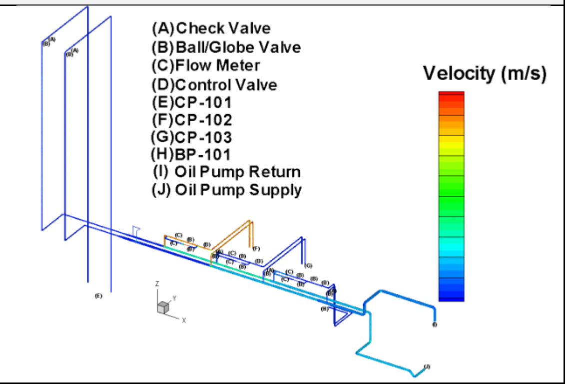
Pressure Distribution in Path 2



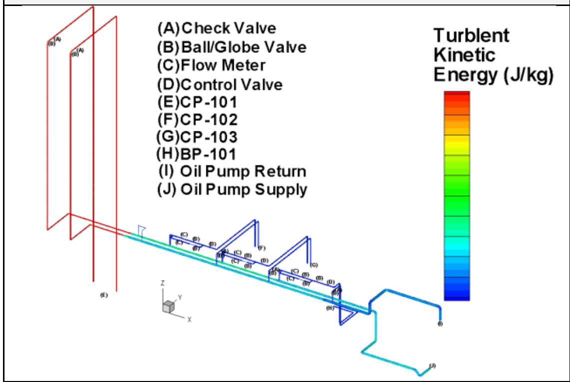
Velocity Distribution in Path 1



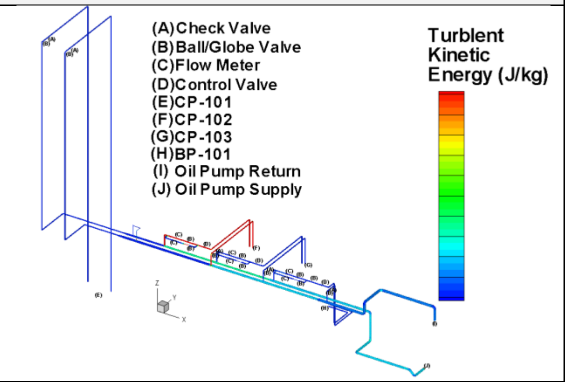
Velocity Distribution in Path 2



Turbulent Kinetic Energy in Condition 1

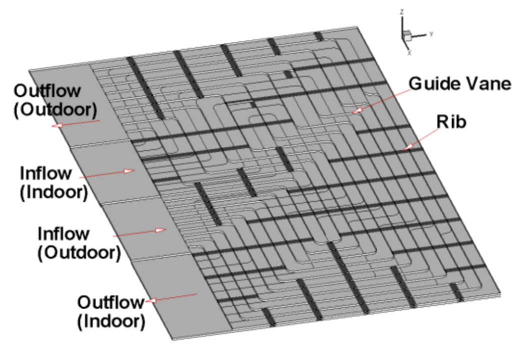


Turbulent Kinetic Energy in Condition 2



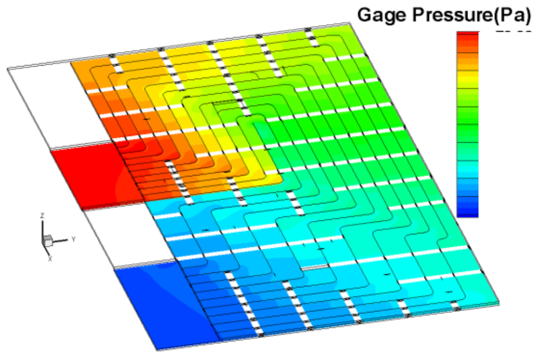
2.3 Heat and Fluid Flow Analysis

Flat Plate Type Heat Exchanger

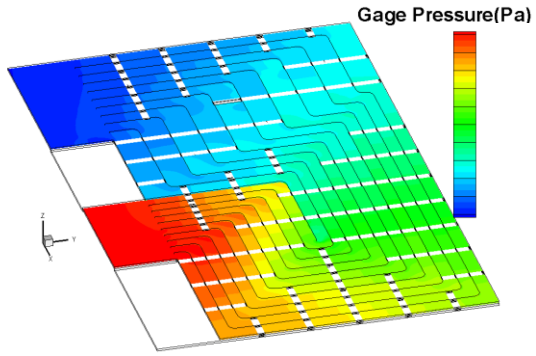


Flow Rate	m^3/hr
Density_1	kg/m^3
Specific Heat_1	J/kgK
Thermal Conductivity_1	w/mK
Viscosity	kg/ms
Density_2	kg/m^3
Specific Heat_2	J/kgK
Thermal Conductivity_2	w/mK

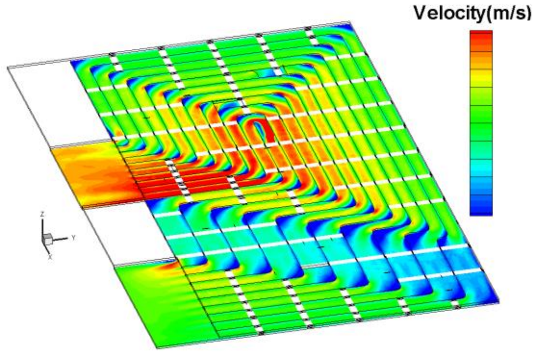
Pressure Distribution in Path 1



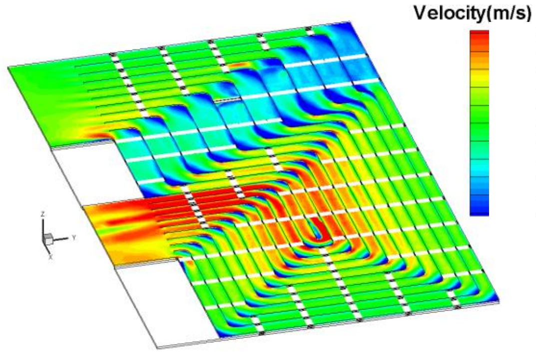
Pressure Distribution in Path 2



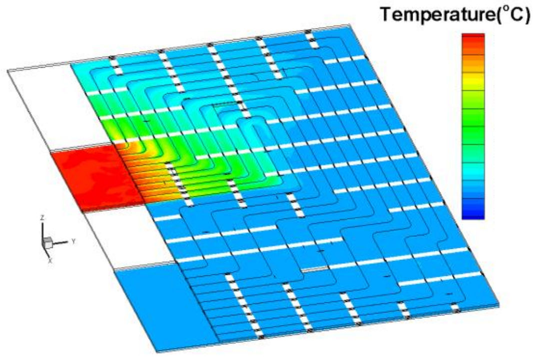
Velocity Distribution in Path 1



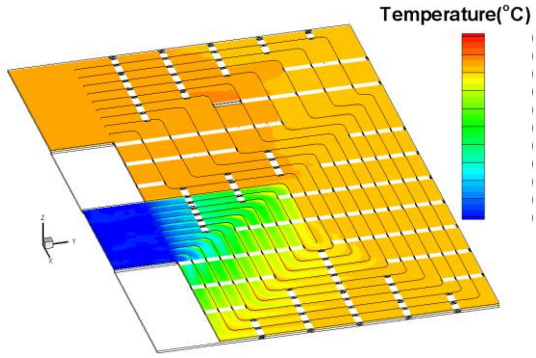
Velocity Distribution in Path 2



Temperature Distribution in Path 1

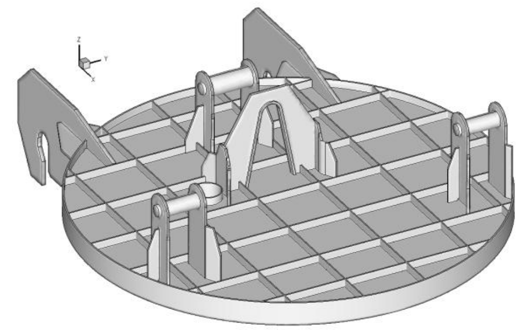


Temperature Distribution in Path 2



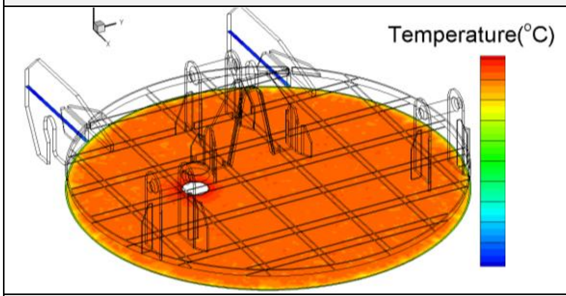
2.4 Fatigue Failure and Life Analysis

Ladle Metallurgical Furnace Cover

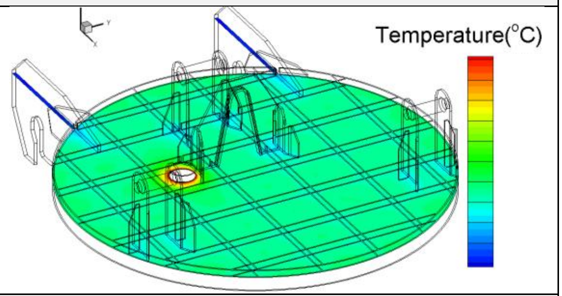


Specific Heat	J/kgK
Thermal Conductivity	W/mK
Thermal Expansion Rate	1/K
Young's Modulus	GPa
Poisson's Ratio	-
Allowable Yield Stress	MPa
Fatigue Strength Coef.	MPa
Fatigue Strength Expo.	-

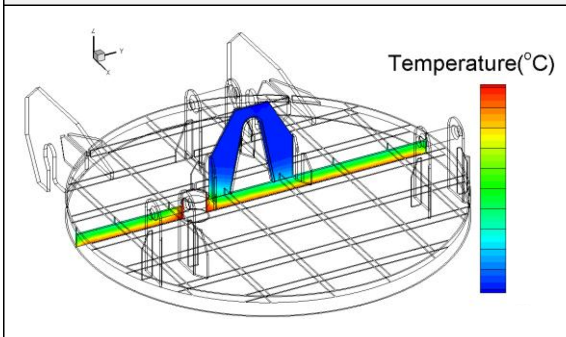
Temperature Distribution at Lower Side



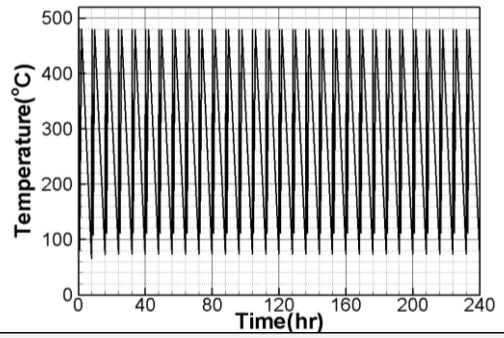
Temperature Distribution at Upper Side



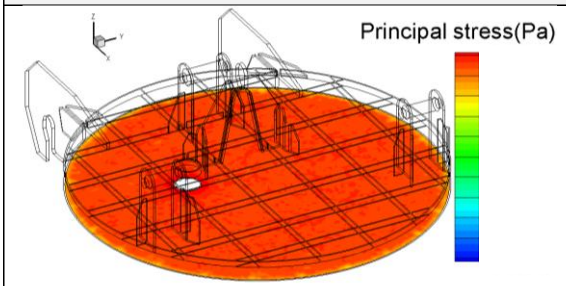
Temperature Distribution in Cross Section



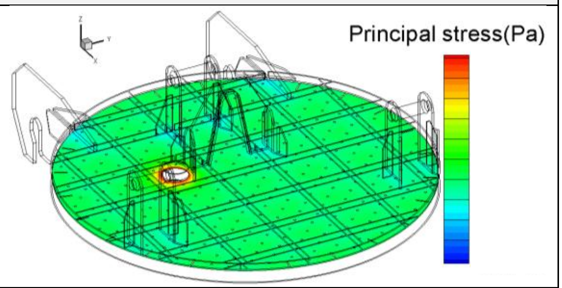
Temp. Fluctuation in Progress of Time



Thermal Stress Distribution at Lower Side

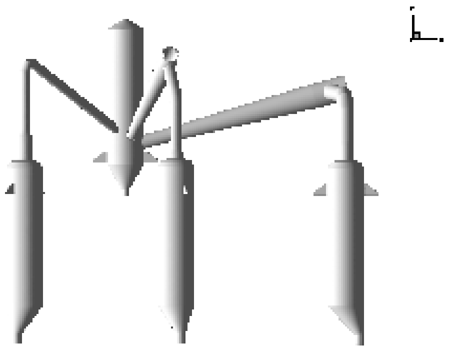


Thermal Stress Distribution at Upper Side



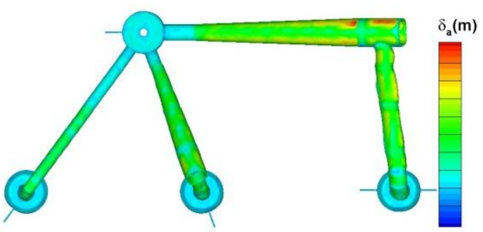
2.5 Thermal Stress Analysis

Chemical Plant Concentric Pipe

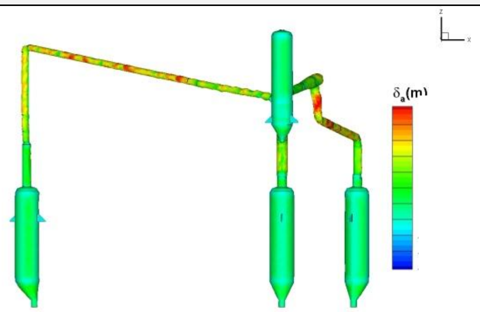


Conv. Heat Transfer Coef.	W/m²K
Density	kg/m³
Specific Heat	J/kgK
Thermal Conductivity	W/mK
Thermal Expansion Rate	1/K
Young's Modulus	GPa
Poisson's Ratio	-
Allowable Yield Stress	MPa

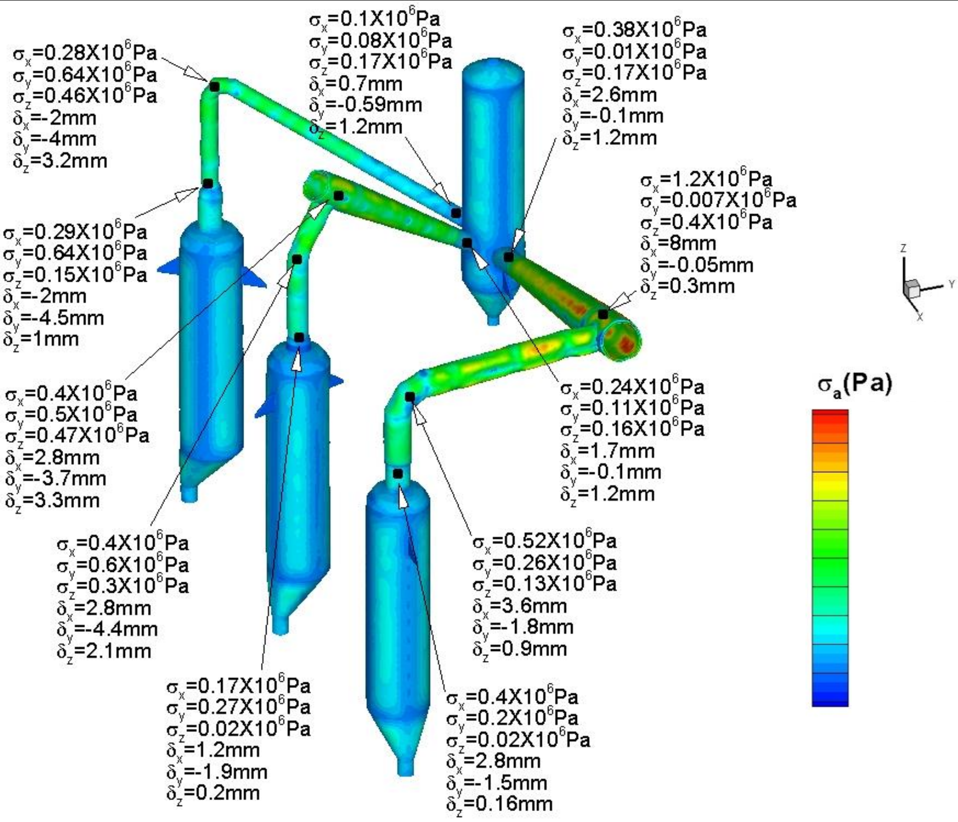
Displacement Due to Thermal Expansion



Displacement Due to Thermal Expansion

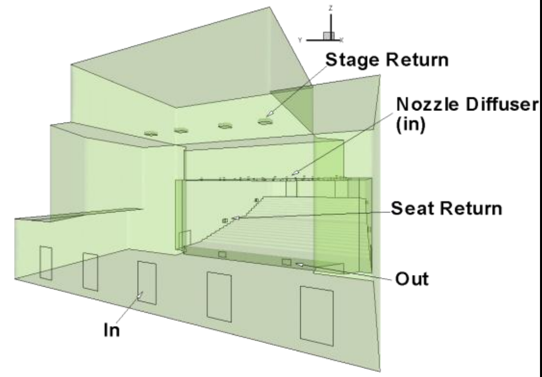


Principal Stress and Displacement Due to Thermal Expansion



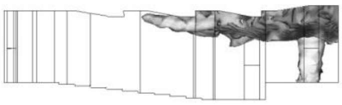
2.6 Mass Transfer Analysis

Flame Propagation

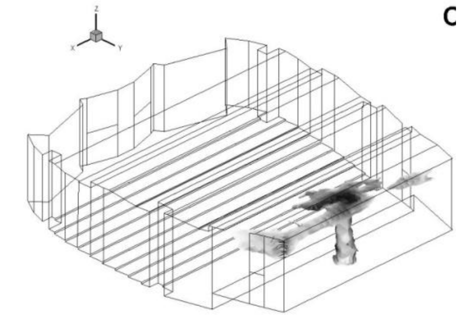


Flow Rate	m^3/hr
Density_1	kg/m^3
Specific Heat_1	J/kgK
Thermal Conductivity_1	w/mK
Viscosity	kg/ms
Density_2	kg/m^3
Specific Heat_2	J/kgK
Thermal Conductivity_2	w/mK

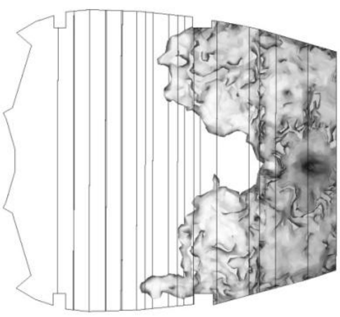
65℃ Iso-Thermal Surface at ** sec.



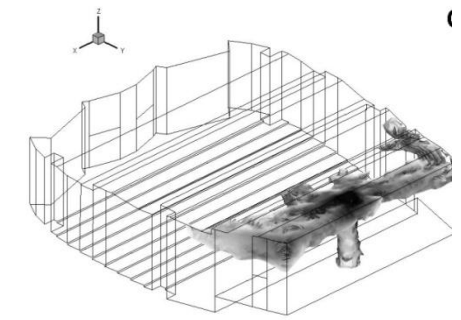
CO Concentration Distribution at ** sec.



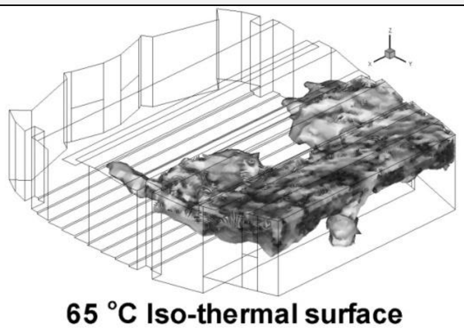
65℃ Iso-Thermal Surface at ** sec.



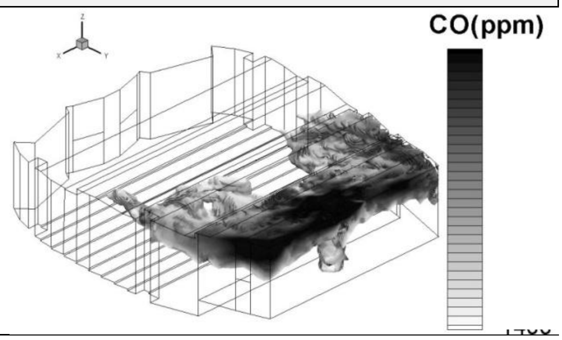
CO Concentration Distribution at ** sec.



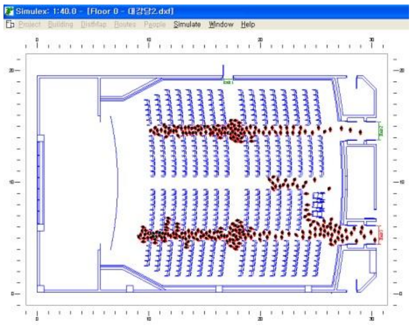
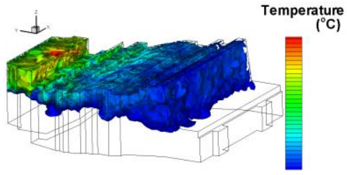
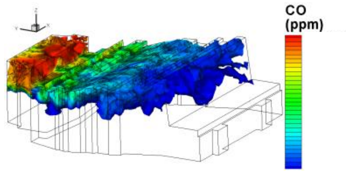
65℃ Iso-Thermal Surface at ** sec.



CO Concentration Distribution at ** sec.



2.7 Fire Emission and Evacuation

<table>
<tr><th>진행</th><th>피난시뮬레이션</th><th colspan="2">화재시뮬레이션</th></tr>
<tr><td rowspan="2">*분
**초</td><td rowspan="2"></td><td>연기층
(65℃ 등온면)</td><td></td></tr>
<tr><td>CO 농도
(1400 ppm)</td><td></td></tr>
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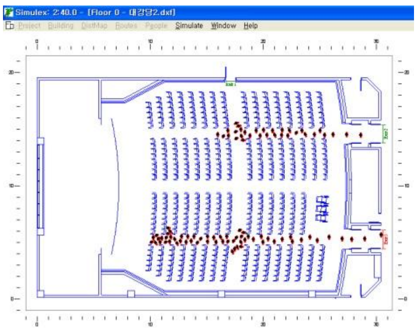
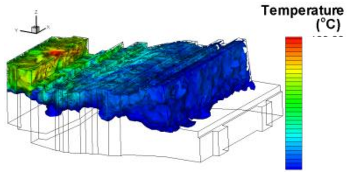
**초</td><td rowspan="2"></td><td>연기층
(65℃ 등온면)</td><td></td></tr>
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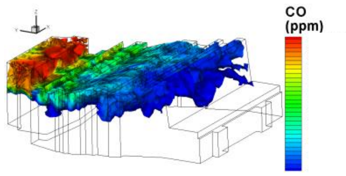
(1400 ppm)</td><td></td></tr>
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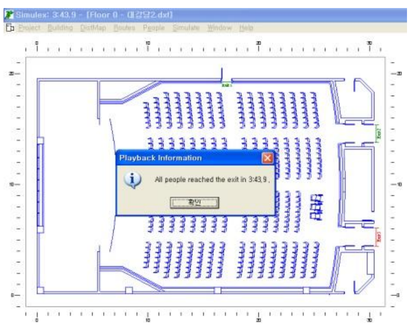
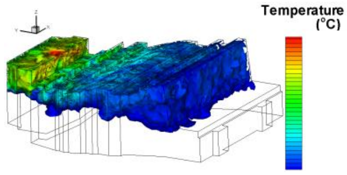
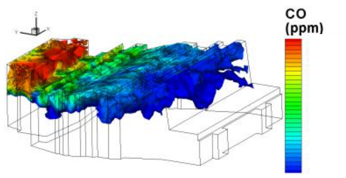
**초</td><td rowspan="2"></td><td>연기층
(65℃ 등온면)</td><td></td></tr>
<tr><td>CO 농도
(1400 ppm)</td><td></td></tr>
<tr><td>검토 결과</td><td colspan="3">. 재실인원이 모두 피난 완료할 때까지 연기층(65℃) 위치가 피난출구 바닥면에서 2m 높이에 도달하여 피난안전성 확보함.
. CO 가스 농도(1400ppm)의 위치도 피난 완료시까지 피난출구 바닥면에서 2.3m 높이에 도달하여 피난안전성 확보함.</td></tr>
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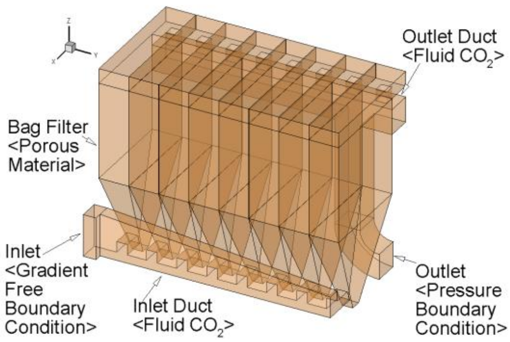
<table>
<tr><th rowspan="3">구 분</th><th rowspan="3">피난 인원 (명)</th><th colspan="3">피난 및 화재시뮬레이션</th><th rowspan="3">판 정</th></tr>
<tr><th rowspan="2">피난소요시간 (RSET)</th><th colspan="2">피난가능시간(ASET)</th></tr>
<tr><th>연기층(65℃)</th><th>CO 농도 1400ppm</th></tr>
<tr><td>000 화재</td><td>000</td><td>0 분 00 초</td><td>0 분 00 초</td><td>0 분 00 초</td><td>안전</td></tr>
</table>

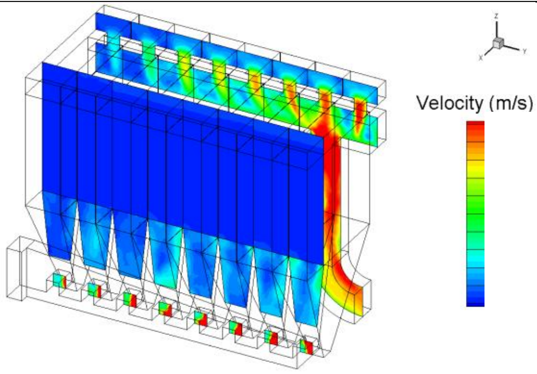
2.8 Design Optimization

Bag Filter Duct Fixture Optimization(Uniform Flow Rate)

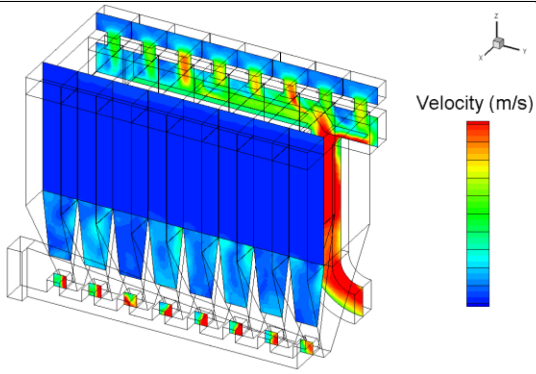


Design Condition	m/s
Density	kg/m^3
Viscosity	kg/ms
Pressure Drop	Pa
Inlet duct Pressure	Pa
Outlet duct Pressure	Pa
Bag Filter Porosity	-
Bag filter Permeability	-

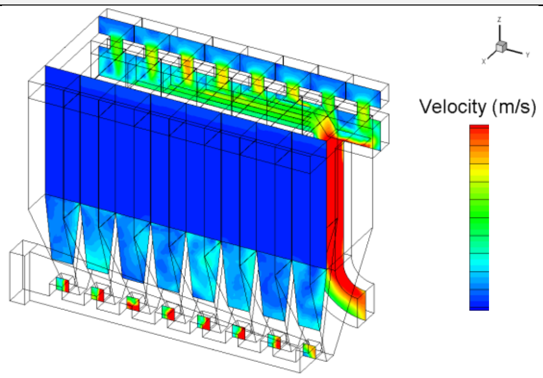
Velocity Distribution in Design 1



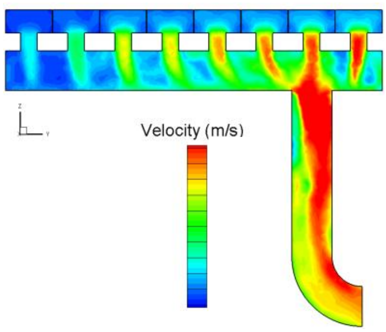
Velocity Distribution in Design 2



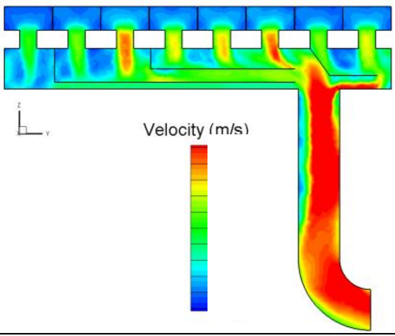
Velocity Distribution in Design 3



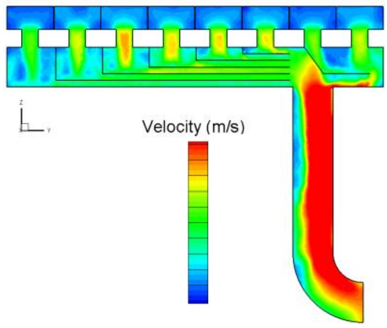
Velocity Distribution in Duct Design 1



Temp. Distribution in Duct Design 2

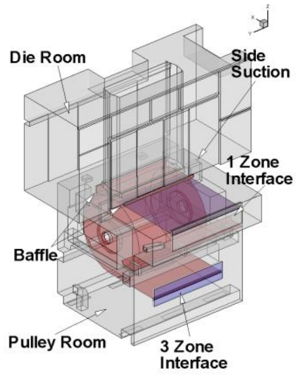


Temp. Distribution in Duct Design 3



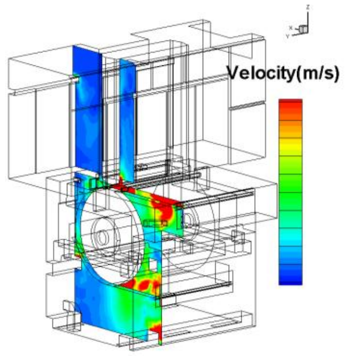
2.9 Process Optimization 1

Chemical Film Making Process Optimization

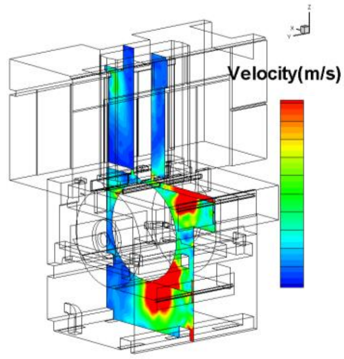


Flow Rate	m^3/hr
Density_1	kg/m^3
Specific Heat_1	J/kgK
Thermal Conductivity_1	w/mK
Viscosity	kg/ms
Density_2	kg/m^3
Specific Heat_2	J/kgK
Thermal Conductivity_2	w/mK

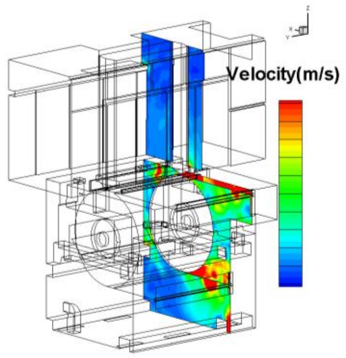
Velocity Distribution in West



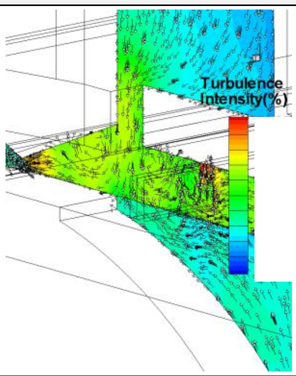
Velocity Distribution in Middle



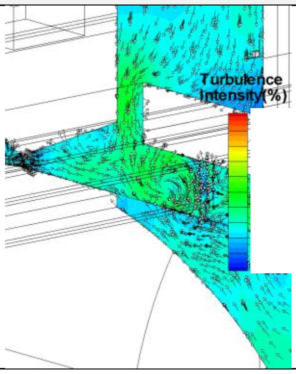
Velocity Distribution in East



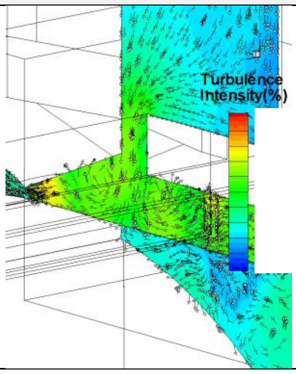
Turbulence Intensity in West



Turbulence Intensity in Middle

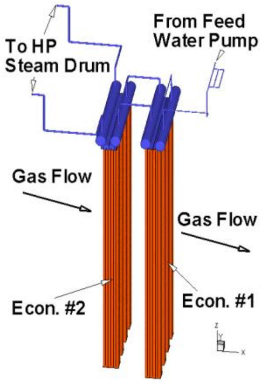


Turbulence Intensity in East



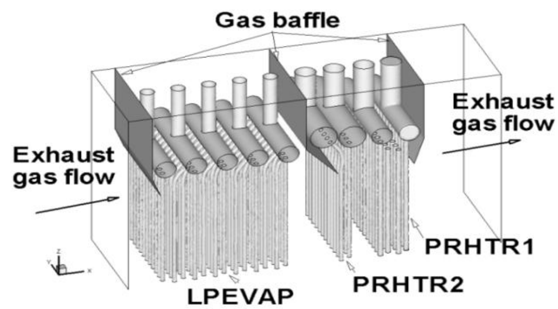
2.10 Process Optimization 2

HRSG(Heat Recovery Steam Generators) Plant

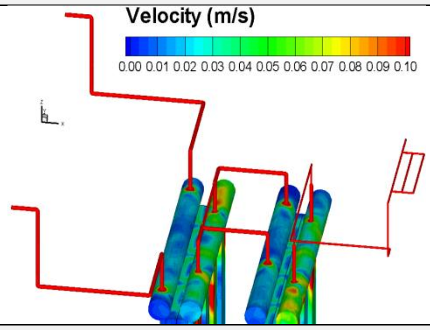


Flow Rate	m^3/hr
Density_1	kg/m^3
Specific Heat_1	J/kgK
Thermal Conductivity_1	w/mK
Viscosity	kg/ms
Density_2	kg/m^3
Specific Heat_2	J/kgK
Thermal Conductivity_2	w/mK

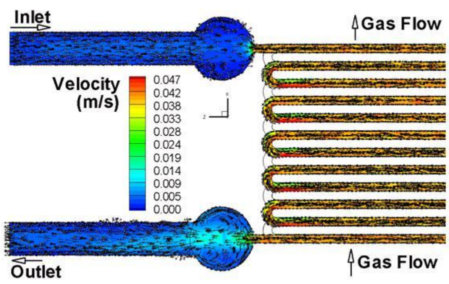
Calculation Domain



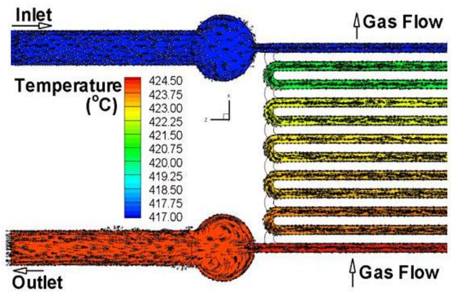
Velocity Distribution in Drum



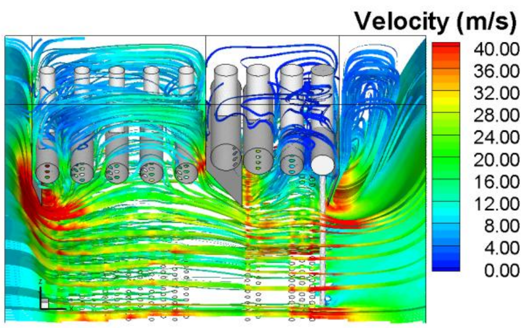
Velocity Distribution in Fin Tube



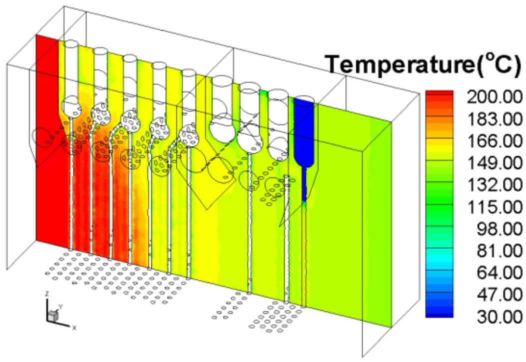
Temperature Distribution in Fin Tube



Particle Trackings in Fin Tube Bundle



Temperature Distribution in Tube Bundle



3. CONTACT US

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Https://yyyoonjung.wixsite.com/hflow

2026 년 월 일

hFlow CFD Solution Group

대표 김 소 영

공학박사 윤 정 배