Study of Nitrogen Leakage Impact on Operator Safety Using CFD

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Abstract

Stantec Consulting Ltd. was retained by a client to evaluate the potential risk to the life safety of operators from an accidental release of a large volume of nitrogen being stored under high pressure.

The objectives of the assignment were to:
1. Determine the expected distribution of the large scale nitrogen leak, and specifically consider the potential to displace the life sustaining oxygen atmosphere in the pit area where operators carry out their duties.
2. If a potential for displacing the life sustaining oxygen atmosphere in the pit area exists, determine recommended modifications to prevent such an occurrence.

To meet these objectives, Stantec chose to use CFD modeling validated with field gathered data and observations of the operation.

This presentation will summarize the analysis carried out, and the methods used in the application of CFD techniques. The major conclusion from the investigation was that a leak could result in an atmosphere with a reduced oxygen content. Another interesting conclusion was that the high pressure release could result in windstorm like conditions that would impact on any attempts by operators to leave the area via the available stairwells. The proposed action plan developed as a result of this investigation to ensure operator safety will be reviewed.
Executive Summary

The client retained Stantec Consulting Ltd. (Stantec) to assess the effect of nitrogen leakage from the forge press accumulators in the press pit area of the two forge press operation. The objective of this assignment was to determine the expected distribution of a large scale nitrogen (N\textsubscript{2}) leak from the accumulators, assess if a potential for displacing a life sustaining oxygen atmosphere in the pit area exists, and recommend modifications to prevent such an occurrence.

After a site visit to observe the operation and collect background information and data, Stantec used Computational Fluid Dynamic (CFD) modelling to predict the leak distribution. The modelling was also used to assess the effectiveness of potential solutions.

Per client safety standards, an acceptable safe atmosphere was defined as 20% oxygen (O\textsubscript{2}).

Nitrogen was found to enter the press pit area, and reduce the O\textsubscript{2} content to below 20%. The lowest concentration in the pit area predicted by the model was nominally 18% O\textsubscript{2}. The lowest concentration elsewhere (other than directly in the jet) was nominally 16% O\textsubscript{2}.

The high pressure associated with the N\textsubscript{2} leak was found to induce a strong disturbance in the press pit and accumulator area. The velocities that would be expected in the area as a result of the leak would exceed 100 mph in some locations in the press pit.

The present ventilation system concept cannot have any significant impact in the overpowering flow regime created by the N\textsubscript{2} leak scenario.

We recommend the implementation of a nominally 5'-0" high deflector wall just beside and below the accumulators to significantly reduce any potential of N\textsubscript{2} accumulating in the press pit area. This deflector wall must be of substantial design to withstand the forces involved with the N\textsubscript{2} and associated water leak, but it need not be gas or water tight. Its prime objective is to redirect or deflect any leak, and not to provide an exceptionally tight seal.

With implementation of the deflector wall, personnel access to the low pressure side of the accumulators and press pit appears acceptable. Access to the area directly below the accumulators remains at risk of a reduced O\textsubscript{2} atmosphere in the event of a leak. Further detail of our modelling assessment in completing this project is contained in this report.

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ATTACHMENT 1  Presentation Slides
1.0 INTRODUCTION

The client retained Stantec Consulting Ltd. (Stantec) to assess the effect of nitrogen leakage from the forge press accumulators in the press pit area of the two forge press shop. The objective of this assignment is to investigate the impact of an unexpected nitrogen leak on the atmosphere in the press pit area. Should such a leak occur, no one anywhere in the press pit area is to be exposed to an oxygen deficient atmosphere.

The client’s plant operates several large forge presses. The two press systems require the use of twelve large accumulators charged with nitrogen. Each accumulator vessel is nominally 3'-0" diameter and 80'-0" high with an internal pressure of 5,000 psi. The accumulators operate on a manifold system, and are interconnected. If there is a leak, the entire volume of contained nitrogen is potentially available for discharge. A "worst case" leak scenario involving a valve failure in the high pressure side of the system was selected as the leak orifice. A valve failure on the high pressure side of the one press system occurred recently. The entire accumulator charge was lost during an offshift. This event demonstrated that a system wide, nitrogen loss is possible.

The objectives of this assignment were to:

1. Determine the expected distribution of a large scale nitrogen leak from the accumulators, specifically considering the displacement of a life sustaining oxygen atmosphere in the press pit area.

2. If a potential for displacing the life sustaining oxygen atmosphere in the press pit area exists, determine recommended modifications to prevent such an occurrence.

To meet these objectives, Stantec carried out the following steps:

- observe the typical operation of the press system
- establish a computational fluid dynamic (CFD) model of the press pit area
- use the model to predict the impact of a leak
- provide recommendations as to concepts to minimize the creation of any oxygen deficient atmosphere.

This report provides a concise summary of the work we carried out and our recommendations. It is not detailed documentation of all modelling runs, modelling output and assessments we have carried out in completing this assignment.

A set of presentation slides is included in Attachment 1.
2.0 DATA COLLECTION AND ANALYSIS

2.1 FIELD DATA AND OBSERVATIONS

During our field observations, Stantec recorded the airflow patterns in the press pit and accumulator area using video recording of smoke tracers, observation of smoke tracers, as well as air flow measurements.

Two ventilation systems supply the press pit area. The operating conditions and parameters of the press pit ventilation are summarized below. Two man cooler style axial fans are continuously in operation below the accumulators (both these fans have the same performance characteristics).

<table>
<thead>
<tr>
<th>Press Pit</th>
<th>Total Air Movement (actual cfm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Press 1</td>
<td>8,400 cfm</td>
</tr>
<tr>
<td>Press 2</td>
<td>9,400 cfm</td>
</tr>
<tr>
<td>Mancooler Fans</td>
<td>7,500 cfm each (Two (2) blowers)</td>
</tr>
</tbody>
</table>

While the press pits have separate make up air supply systems, they are connected by openings into the central access stairwell that serves both pits.

Drawings of the press pit area construction and obstructions were obtained for dimensional data. Field measurements and observations were also used to include the major equipment “blockages” that were not shown on drawings. Temperatures of equipment surfaces and press equipment conditions were also field measured.

2.2 DISCUSSION OF MODEL SET-UP AND VALIDATION

The leak parameters identified to be the worst case scenario was a severed 7.75” ID pipe, with release to the north west.

The leak properties of the N₂ gas were investigated. Discussions with the N₂ supplier were confirmed with investigation of the properties of N₂ gas. A leak temperature of 5°F based on 5000 psi accumulator pressure was used.

Ambient air temperature was 70°F. Wall and equipment surface temperatures were measured during the field investigation.

In carrying out the model set up and assessment, the objective is to assess correlation of the model with actual observations and measurements. Sensitivity
assessments of the modelling output to input parameters are also made. Many different underlying assumptions are reviewed and the impact on predicted results is assessed. This analysis of the model set up and predicted results gives us insight into the behaviour of the flow regime, and allows us to develop valid options for proposed solutions. These valid options receive more in depth predictive assessment.

The validation focused model run was the base case no leak condition in steady state. The model showed good correlation with the smoke tracer release observations. Based on review of the modelling runs and observation data, it was concluded that the model was sufficiently robust and representative to enable assessment of the leak scenario outcome.

The model geometry and set up can be generally seen in Figure 1, Model Geometry.

The ventilation path lines shown by the model can be seen in Figure 2. These illustrate the typical distribution of the air supplied to the pits and circulated under the accumulators with the existing ventilation system.

2.3 INTERPRETING THE CFD OUTPUT PLOTS

Attached in this report are several exhibits of CFD output. This section contains key information to successfully interpret the output results.

Geometry plots – plot to familiarize reader with elements of geometry included in the modelling. Note that some detail must be switched off in 2-D plots to enable a view of the interior of model area. Colour is used to distinguish different model elements.

Streamline or Pathline plots – these plots are intended to illustrate flow patterns within the model space. Colour of streamline trace lines is not significant in plots presented in this study.

N₂ Concentration plots – these plots present the isosurface and internal slices of N₂ Concentration. The colour scale on the left of each plot represents N₂ mass fraction. Note that the air atmosphere is assumed to be 21% O₂ and 78% N₂. The leak release is pure N₂. Base on the N₂ mass fraction, the O₂ level can be determined from the table below.

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Table 2.3

<table>
<thead>
<tr>
<th>Colored Scale</th>
<th>Colored Scale</th>
<th>N\textsubscript{2} levels (from leak only)</th>
<th>Air levels (21% O\textsubscript{2}; 78% N\textsubscript{2})</th>
<th>O\textsubscript{2} levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>RED</td>
<td>1.00</td>
<td>100%</td>
<td>0%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
<td>90%</td>
<td>10%</td>
<td>2.1%</td>
</tr>
<tr>
<td></td>
<td>0.80</td>
<td>80%</td>
<td>20%</td>
<td>4.2%</td>
</tr>
<tr>
<td></td>
<td>0.70</td>
<td>70%</td>
<td>30%</td>
<td>6.3%</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>60%</td>
<td>40%</td>
<td>8.4%</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>50%</td>
<td>50%</td>
<td>10.5%</td>
</tr>
<tr>
<td></td>
<td>0.40</td>
<td>40%</td>
<td>60%</td>
<td>12.6%</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>30%</td>
<td>70%</td>
<td>14.7%</td>
</tr>
<tr>
<td></td>
<td>0.20</td>
<td>20%</td>
<td>80%</td>
<td>16.8%</td>
</tr>
<tr>
<td></td>
<td>0.10</td>
<td>10%</td>
<td>90%</td>
<td>18.9%</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>5%</td>
<td>95%</td>
<td>20.0%</td>
</tr>
<tr>
<td></td>
<td>0.04</td>
<td>4%</td>
<td>96%</td>
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<td>0.03</td>
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<td>97%</td>
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<tr>
<td></td>
<td>0.02</td>
<td>2%</td>
<td>98%</td>
<td>20.6%</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>1%</td>
<td>99%</td>
<td>20.8%</td>
</tr>
<tr>
<td>BLUE</td>
<td>0.00</td>
<td>0%</td>
<td>100%</td>
<td>21.0%</td>
</tr>
</tbody>
</table>
Fig 1- Model Geometry
Fig 2-Base Case CFD pit ventilation system (fresh air) pathlines
3.0 PREDICTIVE CFD RESULTS – RUNS AND ANALYSIS

In carrying out the predictive case runs, the overall objective was to develop insight into the flow pattern behaviour and N\textsubscript{2} atmosphere distribution with the leak scenario. For discussion purposes, we have broken the major types of runs into the following classifications:

- Base case with leak (Steady State)
- Base case with leak (Transient Case)
- Modified geometry - 5' deflector wall (Transient Case)
- Modified geometry – 10’ deflector wall (Transient Case)

After discussion with client personnel, it was agreed that when N\textsubscript{2} reduces the atmosphere to less than 20 % oxygen, it should be considered a potentially hazardous atmosphere. During our assessment, we selected output with either 19 or 20 % oxygen makeup in the atmosphere and discuss the specifics involved with our criteria with each case.

3.1 BASE CASE – WITH LEAK (STEADY STATE)

Review of this output demonstrated that in the event of the leak scenario, N\textsubscript{2} will enter the pits below both the two presses. Figure 3 illustrates the typical steady state pathlines of N\textsubscript{2} distribution into the pit area.
Fig 3- Steady State N\textsubscript{2} pathlines
3.2 BASE CASE – WITH LEAK (TRANSIENT CASE)

The use of transient analysis allows the prediction of the distribution and spread of a N₂ “leak cloud” over time.

The high pressure leak creates a high pressure zone in front (push zone), as well as a low pressure zone behind the leak front (suction zone). This results in a radical change to the ventilation and air movement patterns observed without a leak. The suction zone has a large impact because it draws the flow field in behind the leak front. The large pressure difference causes rapid air mixing and rapid depletion of the O₂ levels in the pit basement area.

The relatively enclosed geometry around the two press areas (this refers to the extensive checkerplate on top of grating used for equipment access purposes) prevents the upward escape of N₂ that has entered the pit, effectively trapping the N₂.

For illustration of the N₂ leak dispersion Figures 4, 5, 6, 7 were plotted. The leak “cloud” is represented by an isosurface of nominally 19% O₂ concentration in the plots. The plots represent the cloud evolution at 0.25, 1.0, 10 and 60 second intervals after the start of the leak, respectively. The oxygen concentration in the cloud is less than the isosurface value (19% O₂).
Fig 4 and 5

Contours of Mass fraction of n2 (Time=2.5761e-01)

Contours of Mass fraction of n2 (Time=1.0476e+00)
Fig 6 and 7

Contours of Mass fraction of n2 (Time=1.0198e+01)

Contours of Mass fraction of n2 (Time=6.0198e+01)
Note that in a three dimensional space, the “leak cloud” will not be of a fixed concentration. It will instead be a variation of concentrations depending on exact location. Figure 8 illustrates several sections of interest around the pit areas showing the range of concentrations that correspond with fig 6, 10 seconds after the start of leak.

In addition to the concentration of N\textsubscript{2} present, some appreciation of the conditions to be expected in the pit area can be developed with Figures 9a and 9b Base Case leak velocity profiles. The high pressure, catastrophic failure creates the velocity profiles shown. Note that the high velocities present (100 mph+) will create a windstorm like environment right down to the bottom of the press pits. The high velocities would be a secondary challenge to personnel in this area, the primary challenge is the deficient oxygen atmosphere.
Fig 8

Contours of Mass fraction of N2 (Time=1.0210e+01)
Fig 9a, 9b

Base case N2 leak
Contours of Velocity Magnitude (mph) (Time=1.8921e+02) Mar 19, 2002
FLUENT 5.5 (3d, segregated, spe2, ke, unsteady)
3.3 **Scenario 1 – 5’ Deflector Wall – (Transient Case)**

The use of a wall has been discussed as a potential solution to prevent the N₂ release from the high pressure accumulator system side entering the press pit area. As any leak on the high pressure side will likely be preceded by a release of some amount of water, the wall will need to be substantial to withstand the associated force. Detail assessment of the forces and required wall designs were outside the scope of this project.

The leak scenario chosen involves a leak located at the valve elevation which is nominally 2’ to 3’ above the accumulator basement level (elevation 134’ to 135’). For a preliminary assessment of the success of a physical wall barrier the height was chosen to be above the leak point. This is a nominal 5”-0” height (elevation 137’). The N₂ leak, which should be considered to behave as a discharge jet, was effectively directed upward by the deflector wall. This height of deflector wall provided effective redirection of the N₂ release. The redirection of the N₂ flow field also resulted in a significantly altered flow pattern when compared with the non wall situation.

Figures 10, 11, 12 and 13 that follow provide several snap shots of the distribution of the N₂ leak cloud as time advances with the 5’ high wall in place. The isosurface concept illustrates the evolution of the leak over time. The time frame chosen is similar to the base case, at 0.25, 1.0, 10 and 60 second intervals after the start of the leak, respectively. Figures 10, 11 and 12 represent nominal 19% O₂ concentrations isosurface plots. Figure 13 represents nominal 20% O₂ concentrations isosurface plots.
Fig 10 and 11

Contour of Mass fraction of n2 (Time=2.4830e-01)

Mar 12, 2002
FLUENT 5.5 (3d, segregated, spec2, ke, unsteady)

Contour of Mass fraction of n2 (Time=1.0783e+00)

Mar 13, 2002
FLUENT 5.5 (3d, segregated, spec2, ke, unsteady)
Fig 12 and 13
Figure 14 illustrates sections of interest to assess the actual concentrations at specific points in the model.

Figure 15a and 15b shows plots of the corresponding atmosphere velocities in the pit and access areas. Note that the high velocities and windstorm like atmosphere will not occur anywhere other than under the accumulators with the deflecting wall in place.

Note that the area under the accumulators will continue to have an O₂ deficient atmosphere with the deflecting wall in place.
Fig 14
Fig 15a and 15b

N2 leak with deflector wall
Contours of Velocity Magnitude (mph)  (Time=2.3293e+02)  Mar 19, 2002
FLUENT 5.5 (3d, segregated, spe2, ke, unsteady)
3.4 **OTHER SCENARIOS**

We considered several other scenarios. Specific output from these has not been included for brevity. We have commented briefly on these approaches here.

Modifications to the existing press ventilation system (involving additional volume, redesigned delivery louvres, etc) was not effective in overcoming the high energy level associated with the leak discharge “jet”. Note, however that the condition and poor state of repair (large holes in ductwork) and poor distribution of air leave room for improvement of these systems.

Differing deflector wall heights (including up to 10’ high) were also examined. The objective of the wall is not to “seal” against leakage, but provide a deflection of the N₂ “jet” to prevent the N₂ becoming trapped in the pit area. The 5’ high deflector wall should be adequate for any high pressure leak scenarios we have discussed and envisaged. Note that this wall is really a deflector first, its objective is not to “seal” out the N₂ or water that will accompany a leak. Any openings to allow penetration of pipes and other interferences will not be required to be tightly sealed. Detail design of the deflector wall will require robust construction to withstand the forces associated with an unexpected leak.

Further assessment to predict the worst case atmosphere that would potentially exist with the present scenario were carried out. While such absolute predictions are “best guesses” with the qualitative modelling techniques used in our assessment, we predict that the lowest O₂ level that will exist is in the order of 18% in the actual pit area. The lowest O₂ level is estimated at 16% elsewhere (this is other than directly in the leak jet stream itself, which is approaching 0% O₂).
4.0 CONCLUSIONS

The following are the key conclusions from our assessment:

- Should a significant N₂ leak occur at the clients facility, the pit and access areas under the two presses will experience an atmosphere with oxygen content less than 20%.

- The main driving factor for N₂ to enter the pit area is the strength of the N₂ leak jet velocity toward the pit area. This is further compounded by the push-suction effect of the leak. The existing pit ventilation systems will be overpowered by those impacts with the present geometry.

- Other contributing, and important factors for N₂ migration into the pit area is the “enclosure” of the pit (especially the checkerplate covered floor gratings) and the N₂-Air temperature difference.

- Any reasonable increase in pit ventilation volume alone cannot solve the atmosphere quality risk in the pit during the leak.

- Should a leak occur with the existing geometry, a windstorm like environment would exist in the pit area, with air movement above 100 mph expected.

- The main objective of any wall configuration is to deflect the energy of an unexpected release. A 5’ high deflection wall is sufficient to deflect the N₂ leak jet we considered.

- During assessment of the deflector wall effect, an N₂ leak jet was deflected upward and back into the accumulator area. The accumulator area fills up quickly, mixes with air, warms and escapes upward. The push-suction pressure effect is now localized to the accumulator area with only a small effect on the pit atmosphere. With the deflector wall in place, we do not anticipate any large impact from N₂ accumulation on the operating floor level surrounding the accumulators (i.e. floor elevation 142”) as the N₂ quickly mixes and rises. Note however, that our model scope boundary did not extend a great distance past the pit area.

- In the model of the 5’ high deflector wall impact, the N₂ spilled to the basement area and towards the pits but quickly warmed and mixed with air without causing significant O₂ depletion during the first few critical minutes and during steady state.

- With the 5’ high deflector wall in place, the turbulent windstorm like atmosphere is not expected in the press pit itself or the access areas (stairwell).
With all modelled cases (including the recommended 5’ high deflector wall), the area under the accumulators themselves will have an oxygen deficient atmosphere.

In all modeled cases, after a few minutes into the \( \text{N}_2 \) leak, once the path lines were established, the whole area can be looked at as steady state since no major changes in concentration occur. \( \text{N}_2 \) was constantly warming, mixing with air and escaping upward.
5.0 RECOMMENDATIONS

- We recommend the construction of a deflection wall to channel any unexpected N₂ leaks away from the two presses in the press pit and access area. This will prevent the occurrence of an oxygen depleted, windstorm like atmosphere for any personnel who may be in this area at the time of the leak.

- A nominal 5' high emergency leak deflection wall (to elevation 137') will be effective in allowing safe personnel escape from the pit/basement area for a leak located up to nominal 3' (elev 135') above the accumulator floor level. The objective is to deflect the leak away from the pit and access area. A higher leak elevation requires a correspondingly higher deflector wall height.

- The basement area immediately below the accumulator vessels will have an oxygen depleted atmosphere, and should not be considered safe for personnel should an unexpected leak occur.
ATTACHMENT 1

Presentation Slides
Study of Nitrogen Leakage Impact on Operator Safety Using CFD

Allan E. Prits, P.Eng
May 15, 2006

Outline of Presentation

• Background and objective for project
• Why use CFD?
• Model set-up and validation
• CFD output results
• Conclusions for the project
• Comments on the use of CFD for this project
Background and Objectives

- Facility with large forge presses
- Nitrogen is stored in twelve 3’-0” diameter 80’ high accumulators at 5,000 psi
- A mechanical valve failure had occurred in the past releasing the complete $N_2$ charge
- Operators are typically located at work stations in the press pit
- The existing attitude amongst operations personnel was cavalier, and there was a refusal to acknowledge potential risk

Objectives

- Determine the distribution of a large scale nitrogen leak, and consider the potential to displace the life sustaining oxygen atmosphere.
- If a potential for displacing a life sustaining atmosphere exists, determine recommended modifications to prevent such an occurrence.
Background and Objectives

Why Use CFD?

- A challenging airflow problem
- Not possible to observe the actual leakage situation
- Important that the situation be addressed because of the aging of the equipment and history of a recent unexpected and serious failure
- Downtime on the forge press operations was not acceptable
Model Set-Up and Validation

• Field Data and Observations
  – Local ventilation systems of 8,400 cfm and 9,400 cfm
  – Two (2) mancooler type fans, each 7,500 cfm
  – Observation of smoke tracers and general crossdrafts
  – Scale drawings of press pit and accumulator base were obtained

• Additional Input Information
  – Worst case leak parameter severed 7.75” ID pipe
  – Leak properties of N₂ investigated! Leak temperature 5 °F based on 5000 psi accumulator pressure assumed.
  – Ambient air temperature of 70 °F
Model Set-Up and Validation

- Validation
  - Validation focused model run was a base case no leak condition in steady state.
  - Model showed good correlation with the smoke tracer release observations.
  - Model convergence and performance were sufficiently robust to enable agreement that base case model was representative.

- Evaluation Criteria
  - The at risk atmosphere defined to be when the release of $N_2$ reduces $O_2$ content to less than 20%.

CFD Output Results

Total Ventilation Pathlines
Note: This is Plan View looking down on presses and accumulators

Total ventilation
Path Lines Colored by Particle Id
CFD Output Results

Steady State N₂ Leak
Pathlines

Base Case N₂ Leak
19% O₂ Isosurface Cloud
Time = 0.25 sec
Contours of Mass fraction of n₂ (Time = 2.576e-01)

PRELIMINARY - STEADY STATE
Path Lines Colored by Particle Id
CFD Output Results

Base Case N2 Leak
19% O2 Isosurface Cloud
time = 1.0 sec

Contour of mass fraction of n2 (Time = 1.0196e+01)

CFD Output Results

Base Case N2 Leak
19% O2 Isosurface Cloud
time = 10 sec

Contour of mass fraction of n2 (Time = 1.0196e+01)
CFD Output Results

Base Case N2 Leak
19% O2 Isosurface Cloud
time = 60 sec

CFD Output Results

Base Case N2 Leak
Concentration at Sections
time = 10 sec
• Discussion of Base Case Results
  – The “leak cloud” will not be of a fixed concentration, but will be variation of concentrations based on exact location.
  – There is a potential for N₂ to displace the minimum acceptable 20% O₂ atmosphere.
  – The high pressure, catastrophic failure will result in a windstorm like environment down to the bottom of the press pits.

• Discussion of Options to Consider
  – Modifications to Ventilation Supply System
  – Barrier Wall
  – Eliminating Use of N₂
CFD Output Results

5'-0" Wall w N2 Leak
19 % O2 Isosurface Cloud
time = 0.25 sec

Contours of Mass fraction of n2 (Time=2.4830e-01)

CFD Output Results

5'-0" Wall w N2 Leak
19 % O2 Isosurface Cloud
time = 1.0 sec

Contours of Mass fraction of n2 (Time=1.0785e+00)
CFD Output Results

5'-0" Wall w N2 Leak
19 % O2 isosurface Cloud
time = 10 sec

Contours of Mass fraction of n2 (Time=1.0078e+01)

CFD Output Results

5'-0" Wall w N2 Leak
19 % O2 isosurface Cloud
time = 60 sec

Contours of Mass fraction of n2 (Time=6.0078e+01)
CFD Output Results

5'-0" Wall w N2 Leak
Concentration at Sections
time = 10 sec

Contours of Mass fraction of N2 (Time=1.0425e+01)

CFD Output Results

5'-0" Wall Case Velocity
High Range

N2 leak with deflector wall
Contours of Velocity Magnitude (mph) (Time=2.3293e+02)
Conclusions on Project

- Should a significant N\textsubscript{2} leak occur, the pit and operator access areas under the forge presses will have an atmosphere with oxygen content less than 20%.
- Driving factor for N\textsubscript{2} entry is the leak velocity toward the pit area. The relative velocity difference to the local ventilation system delivery will overpower its effect.
- Other factors for N\textsubscript{2} entry to the pit are enclosure (by overhead walkway) and the N\textsubscript{2} – ambient air temperature differential.
Conclusions on Project (Cont’d)

• No reasonable increase in pit ventilation volume alone can eliminate the infiltration by N₂
• A leak occurrence will create a windstorm like environment in the pit and access area, air movement above 100 mph is expected
• A deflector wall is a viable solution to the N₂ build up in the press pit area, and would limit the risk area to the unoccupied accumulator base

Conclusions on CFD

• CFD was a powerful tool that enabled operator appreciation of potential risks in the event of a leak or potential valve failure
• Visualization of the flow regime and likely outcomes were important
• The evaluation of the transient leak evolution enabled generation of a series of time step predictions and creation of an animation presentation of iso-surface propagation representing the leak
Conclusions on CFD (Cont’d)

• Without the use of CFD, changes in the facility operations would not have been implemented

Thank-you.

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Study of Nitrogen Leakage Impact on Operator Safety Using CFD

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