TECHNICAL EVALUATION REPORT FOR SAFETY BASIS AND CORRECTIVE ACTION PLAN LEADING TO RESTART

HONEYWELL METROPOLIS WORKS
UF_6 CONVERSION PLANT
METROPOLIS, ILLINOIS

SOURCE MATERIALS LICENSE SUB-526
DOCKET 40-3392

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EXECUTIVE SUMMARY

Honeywell is proposing to modify the Metropolis Works (MTW) facility to protect against seismic and tornado missile events. The U.S. Nuclear Regulatory Commission (NRC) staff reviewed the information in Honeywell's Safety Basis and Corrective Action Plan (SBCAP) and Emergency Response Plan (ERP) for these proposed modifications.

The NRC staff review is consistent with guidance in NUREG-1520, "Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility." NUREG-1520 was used because Honeywell provided an analysis in the form of an Integrated Safety Analysis (ISA).

Honeywell provided detailed analyses for credible seismic and tornado missile events, including the initiating event frequencies, the likelihood of equipment failures leading to release of liquid uranium hexafluoride (UF_6), and the consequences of releases to workers and the public. The staff evaluated the analyses and ERP and has reached the following conclusions:

- The staff finds that the modified Feed Materials Building (FMB), as proposed, is appropriately designed for the seismic loads equivalent to a 475-year return period earthquake, Honeywell's Design Basis Earthquake (DBE). Based on the seismic margin analysis, the staff finds that, as presented by Honeywell in this analysis, the modified building will perform beyond the design basis, up to seismic loads equivalent to a 1700-year return period earthquake. Building performance is the ability of the structure to withstand anticipated seismic loads without collapse and without exceeding Honeywell-specified deformation criteria that could contribute to release of hazardous material.
- The staff finds that the restraints for the process equipment and piping are appropriately designed to withstand seismic loads equivalent to a 1300-year return period earthquake.
- The staff has reasonable assurance that the structural performance of the modified building and equipment, as proposed, will adequately prevent a release of liquid UF_6 from piping, up through at least the 1300-year return period earthquake.
- The staff finds that the proposed building modifications for protection of large inventories of UF_6 against design basis tornado-generated missiles are adequately designed to prevent a release of liquid UF_6.
- The staff finds Honeywell's use and application of a consequence-likelihood risk matrix adequate to demonstrate that the risk levels associated with the proposed modifications to protect against seismic and tornado missile events are acceptable.
- The staff finds that Honeywell's approach to determining the facility risk levels is consistent with accepted ISA methods and guidance. Further, the staff finds that the risk levels presented by the facility (as modified), under credible seismic and tornado missile events, are acceptably low and consistent with the risk levels at other operating fuel cycle facilities.
- The staff finds that Honeywell's ERP is acceptable and conforms to regulatory requirements.

The staff concludes that the proposed modifications to the MTW facility, once implemented, and the ERP provide reasonable assurance of adequate protection to workers and public health and safety under credible seismic and tornado missile events.

ACRONYMS

AEGL	Acute Exposure Guideline Level
ACH	air changes per hour
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ASCE	American Society of Civil Engineers
AWS	American Welding Society
BOCA	Building Officials Code Administrators
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DCR	demand-to-capacity ratios
EPRI	Electric Power Research Institute
ERP	Emergency Response Plan
FEMA	Federal Emergency Management Agency
FMB	Feed Materials Building
HF	hydrogen fluoride
IBC	International Building Code
ICC	International Code Council
IEMA	Illinois Emergency Management Agency
ISA	Integrated Safety Analysis
LRFD	Load and Resistance Factor Design
MTW	Metropolis Works
NEHRP	National Earthquake Hazard Reduction Program
NH_3	anhydrous ammonia
NMSZ	New Madrid Seismic Zone
NRC	U.S. Nuclear Regulatory Commission
PAR	Protective Action Recommendation
PFAP	plant features and procedures
PSHA	probabilistic seismic hazard analysis
RAI	Request for Additional Information
SBCAP	Safety Basis and Corrective Action Plan
TER	Technical Evaluation Report
TI	Temporary Instruction

UBC	Uniform Building Code
UF_6	uranium hexafluoride
UHS	uniform hazard spectra
USGS	United States Geologic Survey

1.0 Introduction

Honeywell International Inc. holds NRC source material license number SUB-526, which was issued under Title 10 of the Code of Federal Regulations (10 CFR) Part 40, "Domestic Licensing of Source Material." Operations at the Honeywell MTW facility were first authorized in 1958. The NRC last renewed Honeywell's license in May, 2007, for a period of 10 years (NRC, 2007d). During the last renewal, the NRC added a condition to Honeywell's license incorporating a requirement for Honeywell to perform an ISA for the purposes of determining accident sequences and relevant hazards and to identify safety controls to prevent or mitigate those hazards. NRC amended the license condition to substitute the ISA Summary (Honeywell, 2008) for the full ISA in 2009 (NRC, 2009). At that time, as part of its ISA analysis, Honeywell determined that there were no high or intermediate consequences[1] to the public resulting from a seismic event.

In May, 2012, in response to the events at the Fukushima Daiichi site in Japan, the NRC staff inspected the MTW facility, in accordance with NRC Temporary Instruction (TI) 2600/015 (NRC, 2011). During the inspection, the staff identified concerns related to protection of liquid UF_6 from a seismic or tornado event and evaluation of Honeywell's UF_6 and hydrogen fluoride (HF) bounding source terms, which Honeywell used as the basis for the MTW facility's ERP.[2] During the May 2012 inspection, the NRC staff found that the process equipment in Honeywell's Feed Materials Building (FMB) lacked seismic restraints, supports and bracing to ensure equipment integrity during credible seismic events or tornadoes.

The NRC staff documented the results of this inspection in a letter to Honeywell dated August 9, 2012 (NRC, 2012a). In that letter, the staff identified two apparent violations of NRC regulations relating to the ERP. Honeywell, which was in a maintenance shutdown at the time, agreed to keep the MTW facility shut down until it addressed the issues raised by the NRC inspection. On October 15, 2012, in lieu of issuing a notice of violation and possible civil penalties for the two apparent violations, the NRC issued a Confirmatory Order (EA-12-157) to Honeywell. The Confirmatory Order formalized Honeywell's commitment to remain shut down until it took adequate corrective actions and those actions had been verified by the NRC (NRC, 2012b).

2.0 Confirmatory Order EA-12-157

The Confirmatory Order, in part, identified corrective actions needed to be completed at the MTW facility in order to provide reasonable assurance that public health and safety will be adequately protected. Under Section IV of the Confirmatory Order, Honeywell is required to provide an evaluation of external events at the MTW facility that clearly defines and provides the safety bases for the following:

- seismic and wind design
- structures, systems, or components relied on to protect workers and the public during both intermediate and high consequence events caused by seismic and wind hazards

[1] As part of Honeywell's ISA approach, accident sequences are categorized into one of the three consequence categories (high, intermediate, low) based on their expected radiological, chemical, and/or environmental impacts. Further explanation of the consequence categories is provided in Honeywell's ISA Summary (Honeywell, 2008).
[2] UF_6 is an NRC-licensed material which reacts with moisture in air to produce HF, a toxic gas.

- defining intermediate and high consequence events for non-radiological releases caused by these events
- defining "unlikely" and "highly unlikely" as the basis for determining acceptable limits for seismic and wind events[3]

Honeywell is also required to provide, to the NRC, a revised ERP and documentation of the design bases for the MTW facility and equipment as modified by Honeywell to meet the NRC order. Additionally, Honeywell must develop, implement, and have available for NRC inspection, the quality assurance measures that would be applied to the modifications needed for the facility to meet the requirements specified in the Order.

Honeywell must implement all modifications required by the Confirmatory Order before seeking to resume NRC-licensed operations at the MTW facility.

3.0 Purpose of Technical Evaluation Report

This Technical Evaluation Report (TER) describes the staff's review and evaluation of Honeywell's SBCAP and ERP, submitted in response to the Confirmatory Order. In order to determine whether Honeywell complied with the main objectives of the Confirmatory Order, the NRC staff performed an evaluation of seismic hazards, structural design and design margins, chemical consequences, integrated safety analysis and controls, and the potential risks from seismic and high wind events. The focus of the staff's evaluation was to determine whether Honeywell's SBCAP provides an adequate safety basis for the proposed modifications to the MTW facility. To make this determination, the staff evaluated whether the ISA demonstration provided by Honeywell meets acceptable risk performance criteria with an overall likelihood of "highly unlikely" for high consequence events and "unlikely" for intermediate consequence events. The staff also determined whether the corrective actions proposed by Honeywell meet the requirement of adequate protection of public health, as required by 10 CFR Part 40.

The staff's review focused on the likelihood and consequences of a liquid UF_6 release because this is the NRC-licensed material that has the potential for producing significant downwind chemical consequences as a result of the release and dispersion of UF_6 hydrolysis products (HF and uranyl fluoride [UO_2F_2]). The staff did not conduct a detailed review of the likelihood or consequences of HF or anhydrous ammonia (NH_3) releases from the MTW tank farm and piping because the staff concluded that releases from these areas would not affect Honeywell's ability to prevent or mitigate releases of licensed material during a seismic or tornado missile event. NRC's regulatory authority covers the storage and processing of HF and NH_3 only to the extent that the handling or release of other materials may affect the safety of NRC-licensed materials and in that way adversely affect workers or the public.

In addition, the staff reviewed the revised ERP to ensure compliance with 10 CFR 40.31(j)(1)(ii) as required by the Confirmatory Order.

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[3] As part of its ISA, Honeywell uses a risk matrix approach to identify accident sequences for which certain combinations of consequences and likelihoods yield an unacceptable risk index. Honeywell defines the permissible likelihood of occurrence of uncontrolled accident sequences, for different consequence categories. Accident sequences with impacts categorized as high consequence must be highly unlikely and accident sequences with impacts categorized as intermediate consequence accident sequences must be unlikely. If these permissible likelihoods are exceeded, Honeywell designates controls to prevent the sequence or to mitigate its consequences. In Honeywell's ISA, these controls are referred to as plant features and procedures (PFAP).

4.0 Overview of Honeywell's Submittal

On November 30, 2012, Honeywell submitted its SBCAP describing the corrective actions necessary to comply with the requirements described in Section IV of the Confirmatory Order (Honeywell, 2012). In the SBCAP, Honeywell defined the MTW facility's safety basis as a demonstration that the risk to the public of a high consequence event is highly unlikely and the risk of an intermediate consequence event is unlikely. The definitions and basis for these likelihood terms are provided by Honeywell as well as the limits used to define consequence levels. Honeywell provided analyses, including a risk matrix, to demonstrate that the corrective actions when implemented will reduce the overall likelihood of a high consequence hazardous release resulting from seismic or tornado missile events to acceptable risk performance limits. Honeywell also described the major improvements and the basis for building and component structural modifications that it proposes to put in place at the MTW facility to protect against or mitigate the consequences of these events. These proposed modifications include:

- strengthen the FMB structure, piping supports and vessel restraints to prevent releases of hazardous material that could result in unacceptable consequences to the public due to an earthquake or tornado missiles
- increase protection of the liquid UF_6 inventory and prevent releases of hazardous material by implementation of seismic actuated shutoff valves and tornado missile shielding
- provide additional measures to confine the distillation area to reduce the rate of any UF_6/HF releases

The submittal also provided Honeywell's justification of the adequacy of the design of these modifications and the actions and safety controls needed to assure adequate protection of the public.

On February 6 and February 20, 2013, to support its review, the staff issued Requests for Additional Information (RAIs) to Honeywell (NRC, 2013a and 2013b). Honeywell provided responses to these RAIs on February 25 and March 5, 2013 (Honeywell, 2013a and 2013b). In addition, by letter dated April 2, 2013, Honeywell revised the SBCAP to incorporate the information provided in response to the NRC's RAIs (Honeywell, 2013c). Honeywell submitted Revision 2 to the SBCAP (Honeywell, 2013d), by letter dated May 15, 2013, to incorporate additional information in response to the staff's comments. Honeywell also submitted Revision 3 to the SBCAP (Honeywell, 2013e), by letter dated May 22, 2013, to incorporate the results of additional seismic margin analyses in response to the RAIs.

On June 5, 2013, Honeywell submitted an updated ERP, which had been put into effect by Honeywell as of May 14, 2013 (Honeywell, 2013h).

5.0 Staff Evaluation of the Safety Basis

The Confirmatory Order required Honeywell to address the adequacy of the safety basis for seismic and tornado events at the MTW facility. Honeywell used its ISA methodology, as described in the ISA Summary (Honeywell, 2008), as the means to demonstrate, in a risk-informed fashion, that the safety basis for these events is acceptable. In addition to defining and demonstrating the safety basis for these events, Honeywell was also required to provide definitions of the terms "unlikely" and "highly unlikely" for the purpose of providing limiting risk performance criteria for acceptability of these external events. Honeywell used these definitions to demonstrate that its evaluation of these events meets their risk performance criteria for consequences and accident sequence likelihoods. The staff has previously approved similar definitions and limits for 10 CFR Part 70 licensees for risk-informed performance evaluation. Honeywell's overall conclusion is that potential high consequence events due to seismic or tornado missile hazards will be highly unlikely, thereby providing an acceptable demonstration of the safety basis for these events. The staff reviewed Honeywell's application of the ISA methodology and the results of the ISA evaluation, and determined that the corrective actions provide an acceptable level of safety for seismic and tornado missile hazards. The following is a summary of the staff's evaluation.

As described in Table 1 of the SBCAP, Honeywell proposes modifications to the MTW facility to provide fortification of pipes, equipment and components that contain liquid UF_6 (the hazardous material at risk for release). Honeywell also proposes modifications to the building structure. The purpose of these modifications is to prevent and/or mitigate the potential for release of UF_6 due to a seismic or tornado missile event.

In this TER, Honeywell's design basis earthquake (DBE) is the 475-year return period earthquake based on the 2002 USGS seismic hazard maps. Honeywell proposes modifications to the structure and piping and equipment restraints to this design basis. For the discussion of the seismic margin assessment, in Sections 7.0 and 8.0 of this TER, the Evaluation Basis Earthquake (EBE) is used. The EBE is the 475-year return period earthquake based on the 2008 USGS seismic hazard maps. Differences between the DBE and EBE are described in Section 7.0 of this TER.

Honeywell's safety basis includes modifications made to meet the design basis as well as additional modifications and controls to the MTW facility which provide additional margin to protect against earthquake ground motions that exceed the DBE and EBE.

The staff reviewed the SBCAP to evaluate the adequacy of these modifications and the controls Honeywell proposes to prevent an UF_6/HF release at the MTW facility or to mitigate the consequences of such a release. The staff systematically evaluated the structural impacts on various systems and components and the possible UF_6/HF releases associated with these expected impacts. The staff also evaluated the assumptions and justifications made by Honeywell in reaching their overall conclusion that potential high consequence events due to a seismic or tornado missile event will be highly unlikely. Key information reviewed by the staff included the seismic impact on the facility and structures; the associated frequency of the seismic event; the structural response of systems and components, including the building structure and the analytical conservatisms and margins associated with the structural analyses; the design of tornado missile barriers, the quantities and locations of liquid UF_6 at risk; various parameters associated with the modeling of releases and determination of impact to the public including the expected reactions and release rates of UF_6/HF; and the consequences of various UF_6/HF release scenarios resulting from a seismic event.

5.1 Staff Review of ISA Methodology for Seismic and Tornado Missile Events

As a condition in its current Part 40 license, Honeywell must perform an ISA to evaluate possible hazards to the MTW facility and identify safety controls needed to prevent or mitigate hazards that could result in intermediate or high consequences. The ISA analysis Honeywell conducted for the seismic and tornado missile events, as part of its response to the Confirmatory Order, is described in Honeywell's SBCAP. Honeywell's analysis follows the general methodology described in its current ISA Summary referenced in Honeywell's license (Honeywell, 2008). The ISA analysis as performed by Honeywell evaluates hazards and their credibility, determines or estimates the likelihood of events including failures, evaluates the consequences of hazards and their level (high, intermediate, or low), and determines safety controls needed to prevent or mitigate accidents and designates them as plant features and procedures (PFAPs). PFAPs are the safety controls identified and credited by Honeywell in their ISA analysis demonstration of acceptable risk performance. The staff finds that evaluating seismic and tornado missile events by a method that uses a consequence-likelihood risk matrix is consistent with currently approved practices and is acceptable for the analysis provided by Honeywell to support their safety basis.

For determining the process hazards associated with the analyzed events, Honeywell followed the process hazards analysis method described in its current ISA summary. In general, this method follows the guidance provided in NUREG-1513, "Integrated Safety Analysis Guidance Document" (NRC, 2001). The staff review of the results of the analyses concluded that the hazards analyses were reasonable because Honeywell identified potential materials at risk and the interactions among materials considered, determined the inventories of these materials, evaluated the design aspects of the proposed modifications to the facility and the potential impacts from a seismic event, and considered the safety controls available to prevent or mitigate possible consequences.

5.2 ISA Analysis for Seismic Hazard

5.2.1 Definitions of Likelihood for Seismic Hazard

For seismic risk mitigation, Honeywell provided revised definitions for the risk performance categorization of likelihoods in Table 4 of the SBCAP. For the seismic evaluation, Honeywell defined the following accident sequence criteria:

Not unlikely	More than 10^{-3} per event, per year
Unlikely	Between 10^{-3} and 10^{-4} per event, per year
Highly unlikely	Less than 10^{-4} per event, per year

Honeywell stated that these definitions are consistent with definitions used by other fuel cycle facilities licensed by the NRC for external event evaluations. The staff finds these definitions are reasonable and consistent with definitions used by other fuel cycle facilities (e.g., GNF-A, 2012) and current guidance for performing ISA-related analyses. These definitions are therefore acceptable for use by Honeywell for this safety basis demonstration for seismic events.

5.2.2 Definitions of Consequence Severity for Seismic Hazard

In Table 5 of the SBCAP, Honeywell provided definitions of consequence severity categories and the limits associated with those categories. These definitions for consequence categories and limits are consistent with the current ISA method being used by Honeywell. As such, the staff finds it is acceptable to use these definitions for consequence performance evaluation for Honeywell's safety demonstration as provided in the SBCAP.

5.2.3 Consequence-Likelihood Risk Matrix for Seismic Hazard

Honeywell provided a risk matrix (Table 6 of the SBCAP) for seismic event evaluation that is consistent with the definitions above but which is a revision of the matrix referenced in the current Honeywell license and used for evaluation of tornado events. As discussed later in this section of the TER, the staff finds that the use of the risk matrix provides reasonable assurance of acceptable risk to the health and safety of the public.

5.2.4 Honeywell Seismic Safety Basis Documentation

As described in the SBCAP, Honeywell determined that the unmitigated release of all material at risk during processing operations -- approximately [redacted] liquid UF_6, the total inventory in the FMB building-- dispersed at ground level, could result in a possible high or intermediate consequence to the public given various assumptions concerning release rates and meteorological conditions. Therefore, designation of PFAPs is required to meet risk performance limits.

In evaluating the seismic initiated accident sequence, Honeywell assumed that the product of the frequency of the initiating seismic event and the probability of failure of all credited PFAPs must be less than 1 x 10^{-4}/year. Equation 1 illustrates this calculation.

Equation 1:

Frequency of initiating seismic event	*	Probability of failure of the PFAPs	$<10^{-4}$/year

Honeywell's ISA analysis of the accident scenario related to a seismic event (SBCAP, p. 20) assumes probabilistic ground motions with a 10 percent (%) probability of exceedance in 50 years (i.e., effective return period of 475-years), based on the USGS 2002 hazard maps. A discussion of the staff review of the use of this assumption for ground motions to initiate earthquake-induced event sequences is provided in Section 7.0 of this TER, Seismic Hazard Assessment.

Based on an initiating event with a return period of 475-years, Honeywell assumed the probability of the initiating seismic event to be 2.0 x 10^{-3} and the probability of failure of the PFAPs to be 1.0 x 10^{-2}. Honeywell assumes the PFAPs for this event are composed of systems of seismic structural features and supports that can be represented for evaluation purposes by a single passive engineered control in terms of the designation of a single probability of failure. The PFAPs for this accident sequence assumed by Honeywell in their analysis include:

- Structural upgrades to the FMB building structure
- Equipment restraints for vessels containing liquid UF_6
- Piping support upgrades for pipes containing liquid UF_6

Honeywell states that the assumed failure rate of 1.0 x 10^{-2} is conservative and that its use is consistent with guidance provided in NUREG-1520, "Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility," (NRC, 2010). Honeywell did not identify any specific modes of failure for pipes, vessels or other components nor the release rates that would be associated with the failures resulting from a seismic event with a 475-year return period. The overall likelihood of the accident sequence is calculated as the product of the frequency of the initiating event and the probability of failure of the PFAPs, resulting in a mitigated risk likelihood value of 2.0 X10^{-5}, demonstrating that the risk performance for high consequence events meets the risk performance limit for highly unlikely.

In addition to evaluating this accident sequence, Honeywell conservatively considered, beyond its determination that a release would be prevented, various failures of piping and piping components and the impact of these failures on both the consequences and likelihood of the accident scenario. Honeywell used general categories to estimate the risk impacts based on their assignment of fragility values to pipes in the building that contained the liquid UF_6. Honeywell estimates that even with all pipe inventories assumed to be released due to failures associated with the containment of liquid UF_6/HF in the pipes, the consequences would not reach intermediate or high limits. This scenario is addressed by the staff review as discussed in TER Section 9.0, Chemical Consequences.

5.2.5 Staff Evaluation of Seismic Safety Basis

In evaluating Honeywell's analysis, the staff considered the overall likelihood of the accident sequence to be the product of the frequency of the initiating seismic event; the probability of release of the material at risk (i.e., UF_6 is in the liquid state); the probability of failure of the PFAP that could result in a high consequence release; and the probability that a member of the public could receive an exposure resulting in a high consequence (a probability that takes into account distance to the nearest resident and prevailing wind direction).

Equation 2:

Frequency of initiating seismic event	*	Probability that the material at risk is available for release	*	Probability of failure of the PFAPs resulting in a possible high consequence	*	Probability that public experiences high consequence	$<10^{-4}$/year

To evaluate a range of credible events, the staff considered the possible accident sequences associated with the level of an earthquake in three ranges: (1) the range of seismic loads impacting the facility up to the 475-year return period; (2) the range of seismic loads beyond the 475-year return period, up to the estimated design safety margin limit for the FMB piping supports and vessel restraints, a 1300-year return period earthquake; and (3) the range of seismic loads beyond the 1300-year return period. The staff chose these ranges based on the analysis that Honeywell provided regarding the seismic performance of the FMB and the restraints for the process equipment and piping. Section 8.0 of this TER provides a description and evaluation of the seismic performance. The following is a discussion of the staff's evaluation of the accident sequences for each of these three ranges.

For the mitigated accident sequence initiated by a 475-year return period earthquake, no release of UF_6/HF is expected to occur. The staff makes this finding based on Honeywell's evaluations supporting the ability of the proposed MTW facility modifications and PFAP controls to withstand the 475-year seismic event without damage to these safety features, as well as their ability to perform their safety functions and prevent unacceptable consequences

The Honeywell analysis and the staff review did not attempt to quantify the probability of a failure of the PFAPs, for this particular scenario. Based on the Honeywell evaluations and staff review of the structural modifications, no significant release of UF_6/HF is expected to occur. Therefore, the staff finds that any estimate of the probability of failure of the PFAPs is likely to result in a value that would conservatively assure meeting the highly unlikely criteria for the accident sequence. The staff makes this finding based on its review of the structural analysis of the building and the seismic modifications supporting the components that contain material at risk. As a general technical practice, the failure rate that should be used for the PFAP when assuming a single value would be either a conditional probability of failure value based on the assumed seismic event and not one constant value, or a value based on the individual failure rates of the numerous components and a limiting or representative single value. The example failure frequencies and probabilities in NUREG-1520 and used by Honeywell are not conditional seismic failure probabilities, and so are not applicable for use in the Honeywell demonstration. The staff concludes that even though the assumed probability of failure that could lead to a high consequence event is difficult to determine and highly variable, there is reasonable assurance that the assumption provided by Honeywell is reasonable and conservative and that the overall likelihood of the accident sequence acceptably meets the risk performance limit.

In addition to demonstrating that the PFAPs provide acceptable prevention or mitigation of the consequences to highly unlikely, Honeywell also proposes other layers of protection that prevent or mitigate a high consequence event to the public. These layers include seismically activated isolation valves on all tanks that contain liquid UF_6 and modifications to the distillation area of the building to create confinement of possible releases to the first three floors. For the areas with large quantities of liquid UF_6, the isolation valves and confinement provide additional layers of protection against large offsite releases. In Section 9.0 of this TER, Chemical Consequences, the staff discusses the benefits of these additional layers of protection. The staff agrees with Honeywell that these additional protections, although not precisely quantifiable, support a finding that the overall likelihood of a release resulting in high consequences would be at or below the value demonstrated by Honeywell for the ISA analysis of a seismic event with a 475-year return period and conservatively below the performance requirement for highly unlikely.

The staff also considered the contribution of the probability that the material is at risk (i.e. UF_6 in the liquid state) and the probability that a member of the public experiences a high consequence event (taking into account distance to the nearest resident and prevailing wind direction)—factors not directly considered by Honeywell in its analysis. Honeywell's evaluation of the likelihood of a release is based on conservatively assuming that all material at risk has a probability of 1.0 of being available for release when, in fact, certain large amounts are only available for small periods of time (probability <1.0). In addition, Honeywell's evaluation assumes that the probability of meteorological conditions that could result in a high consequence is 1.0 when, in fact, more extreme meteorological conditions that may be needed to result in high consequence events have probabilities up to two orders of magnitude lower. These conservative assumptions provide additional assurance that the likelihood of the accident resulting in high consequences to the public as a result of the 475-year return period event will be reasonably below the performance requirement for highly unlikely.

In addition to the 475-year return period earthquake, the staff evaluated the credible scenarios associated with frequencies of earthquakes beyond the 475-year return period. In its submission dated May 22, 2013, Honeywell provided information regarding the response of the modified FMB for forces beyond the assumed ground accelerations of the seismic accident sequence (Honeywell, 2013e). Although Honeywell provided this information to estimate the design margin in the FMB structure for the 475-year earthquake, the staff used this information to make qualitative evaluations of risk for other credible seismic events with ground accelerations greater than those assumed for the 475-year return period. This evaluation is consistent with current staff ISA guidance requiring that all credible events be analyzed as part of the ISA.

Based on the staff's review of the information provided by Honeywell, as discussed in Section 8.0 of this TER, Design of Structures, Systems, and Components, the median seismic capacity of the FMB is expected to be 2.51 times the EBE, indicating that the structure has the capability to meet structural performance requirements for seismic loads equivalent to an earthquake with a 1700-year return period. In Section 8.0 of this TER, the staff also finds that the restraints for the UF_6 process equipment and piping are appropriately designed to meet structural performance requirements for seismic loads equivalent to an earthquake with a 1300-year recurrence interval. Because the sequences of equipment and piping failures and the associated extent of damage are complex to characterize, but are closely related to possible releases, the staff has assumed, for the purposes of evaluating risk, that the initiating frequency of an earthquake resulting in significant releases of UF_6 from damaged equipment or piping is the more conservative value of the 1300-year return period.

For return periods greater than 475 years and less than 1300 years, the staff looked at possible accident sequences and qualitatively estimated probabilities of releases based on structural analyses and determinations provided by Honeywell. The 1300-year return period represents Honeywell's assumed design basis for the piping supports and vessel restraints for those components that contain liquid UF_6. For select combinations of pipe and equipment failures the staff also performed consequence estimates as described in Section 9.0 of this TER, Chemical Consequences. For this range of possible sequences, the staff finds that the likelihood of failures resulting in a high consequence release will increase as the earthquake return period increases. Honeywell has shown, via calculations and evaluations of modifications to tanks, pipes and other components, that the likelihood of failure for these components up to the design basis 1300-year return period is well below that needed to demonstrate acceptable risk performance. The staff has reviewed Honeywell's calculations of building response and equipment modifications, as discussed in Section 8.0 of this TER, Design of Structures, Systems, and Components, and finds the assumption that the likelihood of failure for up to the 1300-year return period is supportable by a finding that there is acceptable performance of the building and components and that there is reasonable assurance that proposed accident sequences in this range could be demonstrated to be highly unlikely. Honeywell has demonstrated that the FMB structure has the capacity to withstand up to the 1700-year return period earthquake without major damage, so the initiating event frequency that could be assumed for a high consequence event may be lower, further supporting the staff determination that the 1300-year event design basis of the components is acceptable. The staff determination is also supported by additional measures of protection or mitigation for the overall likelihood of failure resulting in a major release. Also, similarly conservative assumptions as stated above regarding the availability of material at risk and the meteorology could be credited for this analysis. Although not quantified, these layers of protection and conservative assumptions provide additional assurance that the consequences of events with initiating frequencies up to the 1300-year return period are reasonably below the performance requirement for highly unlikely.

For return periods greater than 1300-years, the staff considered the frequency of the initiating event resulting in a high consequence to be the frequency of the 1300-year return period earthquake ($8x10^{-4}$). The staff considered the probability that the public experiences a high consequence to be the probability of prevailing winds in the direction of the nearest residence. The product of these two probabilities alone is less than 1.07×10^{-4} which nominally meets the likelihood criteria of highly unlikely without consideration of other factors. However, given that the likelihood criterion is only nominally met with the ISA-type demonstration, assuming no additional credit for other factors, the staff further explored a conservative risk evaluation for an individual member of the public. Subsection 5.2.4 of this TER provides further discussion of this evaluation and conclusions regarding adequate protection.

5.2.6 Staff Quantitative Risk Evaluation for Seismic Hazard

The staff conducted an evaluation of risk to individuals from seismic events at the MTW facility with the proposed modifications. This evaluation used results of the seismic structural analyses submitted by Honeywell, but assessed risk and used criteria that are independent of Honeywell's methods and definitions. The purpose was to establish a realistic quantitative basis for an understanding of how risk is limited. The staff finds that, given the circumstances of this facility, limitation of seismic risk to individuals is one element that needs to be considered to support a finding of adequate protection of public health and safety. The risk to individuals arises from the possibility that seismic structural failures could cause releases of UF_6. The evaluation here uses the results of the licensee's analysis of the behavior of structures in response to seismic events and quantitative seismic hazards established by USGS. This analysis has been evaluated as establishing bounding frequencies for failures that could release UF_6. The staff has independently evaluated the magnitude of exposures to individuals offsite that could result from such UF_6 releases (see Section 9 of this TER, Chemical Consequences).

The risk results from the staff's evaluation will be compared to quantitative risk guidelines. There are no quantitative risk guidelines in NRC guidance directly applicable to this case. Therefore the staff used guidelines from international authorities (HSE, 2005; ICRP, 1993; ICRP, 1991) that are consistent with NRC qualitative discussions of risk criteria (NRC, 2008; and NRC, 2004). These risk guidelines are expressed as frequencies below which risk of the specified health effect is considered acceptably limited. These guidelines are not risk or safety goals, which are typically described as "insignificant" or "negligible" risk, but higher values for judging acceptability (see NRC 2008, Chap. 4):

1) Risk to public of minor health effects: $< 1x10^{-2}$ /year
2) Risk to public of serious long-lasting health effects: $< 1x10^{-3}$ /year
3) Risk to public of fatality: $< 1x10^{-4}$ /year
4) Risk to workers of fatality: $< 1x10^{-3}$ /year

The evaluation below presents bounding frequencies of seismically induced UF_6 release scenarios whose consequences have been determined to fall in the above categories. These evaluations are based on information provided by Honeywell in its SBCAP and supplemented by the NRC staff's independent calculations of realistic consequences to persons offsite.

For worker risk, any large release of UF_6 could result in fatality, if the worker were unprotected and could not escape the plume. However, the frequency of the seismic event is less than 1/1300-years = $7.7x10^{-4}$/year, because Honeywell's safety analyses shows that piping failures will not occur for seismic loads up to this frequency. This frequency value meets the $1x10^{-3}$/year guideline 4 for workers.

The staff also calculated the consequences and bounding frequencies to a member of the public. The individual selected for this evaluation was at the closest offsite residence, and hence at highest risk. If the risk to this individual meets the above guidelines, then the risk to all other individuals also meets it. In evaluating this risk, the staff considered the previously mentioned probability equation for each of these guidelines (see Equation 2 of this TER). The staff identified that, for the MTW facility, the individual at greatest risk is located at the nearest residence, a distance of 1850 feet (ft) in a north northeast (NNE) direction from the FMB. This direction also has the highest wind frequency (wind rose value from the SSW) and so is bounding on other individuals.

As described in Section 9.0 of this TER, Chemical Consequences, the staff evaluated the consequences and likelihood of a range of equipment failure scenarios, such as releases of UF_6 from tanks and piping, for different weather conditions. The likelihood of resulting consequences to the bounding individual offsite for a given scenario was compared to the above-mentioned guidelines. In the likelihood evaluations referred to below, the frequencies of limiting values of the seismic structural analysis were used to evaluate releases of UF_6 from tanks and piping. Specifically, tank failures were associated with the 1/1700-year condition, a frequency of $5.9x10^{-4}$ /yr, and piping failures with the 1/1300-year frequency ($7.7x10^{-4}$/yr). The number and location of tank and piping failures determines the amount of UF_6 that could be released. The frequencies (of $5.9x10^{-4}$ /yr and $7.7x10^{-4}$/yr) used here are upper bounds on the frequency of the tank and piping failures for which chemical consequences were evaluated. Thus, since these frequencies are below the above risk guidelines, the frequencies of actual tank or piping failures would be well below the guidelines. Health consequences resulting from releases depend on weather conditions as well as amount released. Weather frequencies used were based on actual data.

For more frequent weather conditions, unstable and turbulent atmospheric conditions bounded by stability class D, and SSW wind direction, the staff found that the consequences for all possible release scenarios, including the release of the total inventory of liquid UF_6, were below the airborne concentration of HF associated with irreversible or serious health effects and that the likelihood of occurrence was below $5.4x10^{-5}$/year. Thus, for this case, the consequence severity is well below the life threatening airborne concentration and the frequency of occurrence is below the risk guidelines for both the risk of serious health effect ($1x10^{-3}$) and the risk of fatality ($1x10^{-4}$). Therefore, the staff found reasonable assurance that the risk to individuals offsite, associated with release scenarios for seismic events at or beyond the 1300-year event under normal weather conditions, is limited to an acceptable level.

For less frequent weather conditions characterized by the very stable, hence concentrated, plume, for stability class F, and SSW wind direction, the staff found a range of consequences, depending on the quantity released and the release rate from the building. For example, in the scenario of the loss of liquid UF_6 from the process piping, the consequences were below the irreversible or serious health effects and the likelihood of occurrence about $2x10^{-5}$/year, much less than the 10^{-3}/year guideline. However, for release scenarios involving the loss of larger quantities of liquid UF_6 from additional vessels, including up to the total inventory of liquid UF_6, the consequences were found to cover a wide range of consequences, with some cases above the airborne concentration of HF associated with life-threatening health effects. The likelihood of this range of scenarios was well below $2x10^{-5}$/year. Thus, for this range of scenarios, while the consequence severity ranged from serious health effects to life-threatening, the frequency of occurrence is estimated to be well below the above-mentioned guideline for fatality of $1x10^{-4}$. Therefore, the staff finds that the risk to individuals offsite, from scenarios when weather conditions are stable, hence producing higher concentrations offsite, is also limited to an acceptable level.

In conclusion, the staff reviewed Honeywell's demonstration of highly unlikely for the seismic scenarios. Also, the staff independently determined that, with the proposed modifications, the quantitative seismic risk to individuals is acceptably limited and adequate to protect public health, including for seismic events with a return period greater than 1700 years.

5.3 Consequence-Likelihood Risk Matrix for Tornado-Generated Missile Hazards

In Table 13 of the SBCAP, Honeywell defines the likelihood of events associated with tornado-generated as follows:

Not unlikely	More than 10^{-4} per event, per year
Unlikely	Between 10^{-4} and 10^{-5} per event, per year
Highly unlikely	Less than 10^{-5} per event, per year

The staff finds these definitions are reasonable and consistent with definitions previously used by Honeywell for ISA analysis and approved by the staff for use by other facilities for similar applications and are applicable for evaluation by Honeywell for tornado-related events based on current guidance.

Honeywell also used the definition of consequence severity categories from Table 5 of the SBCAP. These definitions for consequence limits are consistent with the current ISA method being used by Honeywell, current guidance, and definitions previously approved by the staff for similar applications and are acceptable for use for Honeywell's safety demonstration as provided in the SBCAP.

Honeywell provided a risk matrix (Table 14 of the SBCAP) for tornado missile event evaluation that is consistent with the definitions above. The staff finds that the use of the risk table for tornado events provides reasonable assurance that the risk to public health and safety is acceptable.

In evaluating the tornado initiated accident sequence, Honeywell assumed that a tornado missile event would be a high consequence event and that the product of the frequency of the initiating tornado missile event and the probability of failure of the PFAPs must be less than 1×10^{-5}/year. Equation 3 illustrates this calculation.

Equation 3:

$$\text{Frequency of initiating tornado missile event} * \text{Probability of failure of the PFAPs} < 10^{-5}/\text{year}$$

Honeywell's ISA analysis assumed an initiating tornado event of 10^{-3}/year and provided two PFAPs: an administrative control to implement safe shutdown procedures and a passive engineered control consisting of armor plate shielding to prevent possible consequences. For the administrative control, Honeywell assumed a likelihood of failure of 10^{-1}/year. For the passive controls, a likelihood of failure 10^{-2}/year was assumed. The overall likelihood for the accident sequence is therefore determined to be 10^{-6}/year, resulting in acceptable risk performance. Section 8.0 of this TER, Design of Structures, Systems, and Components, includes the staff's review and evaluation of the missile prevention controls, the assumptions used in the analysis of the tornado-generated missile events, and the staff's determination of acceptability.

In conclusion, the staff reviewed Honeywell's demonstration of highly unlikely for tornado missile scenarios and verified that the corrective actions will adequately prevent consequences to the public from the release of hazardous chemicals for the design basis tornado.

6.0 Technical Evaluations to Support Evaluation of the Safety Basis

As described in Section 5.0 of this TER, Evaluation of the Safety Basis, the staff evaluated whether the risk to individuals offsite has been adequately limited. In considering this risk, the staff evaluated Honeywell's assessment of the seismic and tornado hazards; the adequacy of studies that Honeywell conducted to develop proposed seismic corrective actions for the FMB structure, major process equipment, and piping systems; the adequacy of Honeywell's tornado design bases; and Honeywell's assessment of the hazards, consequences, and characterization of risk to individuals offsite. The following sections of this TER describe the staff's evaluation in each of these areas: Seismic Hazard Assessment; Design of Structures, Systems, and Components; Chemical Consequences; and Other Considerations.

7.0 Seismic Hazard Assessment

In Section III.A of the SBCAP (Honeywell, 2013e), Honeywell provided a description of the seismic hazard assessment for the FMB site used to develop the seismic design basis and the design of the facility modifications. The staff reviewed this information to confirm the adequacy of Honeywell's seismic hazard assessment. The following is a discussion of the staff's review and evaluation.

7.1 Seismic Hazard

The MTW facility is located within the New Madrid Seismic Zone (NMSZ), which is the most active seismic zone east of the Rocky Mountains (Honeywell, 2013e). The NMSZ produces an average of 200 earthquakes each year with moment magnitudes greater than M1.5 (Williams, 2011).[4] According to the United States Geologic Survey (USGS) Earthquake Catalog, there have been more than 150 earthquakes with magnitudes equal to or greater than M3.0 since

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[4] M is the standard symbol for earthquake magnitude. It was originally derived by Charles Richter and Beno Gutenberg (hence the term "Gutenberg-Richter scale" or simply "Richter scale") as a way to quantify the sizes of earthquakes based on a measurement of ground motion amplitude recorded on a specific type of seismograph. Today, the limitations of this approach are well known, principally that the Richter scale saturates at about M7 and magnitude estimates may not be reliable if the epicenter is more than 600 km from the recording. In modern seismology, earthquakes magnitudes are recorded as a "moment magnitude," which is sometimes abbreviated as Mw but more commonly just denoted as M. Moment magnitude is based on Keiiti Aki's theory that the energy released from an earthquake is proportional to the area of fault rupture. The magnitudes reported in the TER represent moment magnitudes, consistent with current USGS practice and USGS earthquake information.

G force is a unit of force equal to the force exerted by the Earth's gravity (g) per unit of mass of the object as the object is accelerated. For example, a 200 kg object undergoing 2g experiences 400 kg of force as it accelerates. The standard units of gravity are defined as a percentage of the earth's gravitation force (g), which is equal to 9.80665 meters per second squared or equivalently 9.80665 newtons of force per kilogram of mass. The accelerations (g) that are produced by an earthquake depend on the relative location of the site to the epicenter, the size of the earthquake, how efficiently the earthquake energy is transmitted through the earth from epicenter to the site, and how the site conditions amplify or de-amplify the earthquake energy when it reaches the site.

installation of regional seismic networks in 1973.[5] These include the 1968 M5.4 Southern Illinois earthquake, and a 1976 M5.0 earthquake that occurred in Poinsett County, Arkansas, at the southern end of the NMSZ.

The source of earthquakes in the NMSZ is a series of thrust and dip-slip faults that form a restraining step-over in a right-lateral strike-slip fault zone (e.g., Russ, 1982). In 1811 and 1812, at least three large earthquakes resulted from ruptures on strike-slip and thrust faults within the NMSZ. The first of these major earthquakes occurred on December 16, 1811, near present-day Blytheville, Arkansas. The second earthquake in the NMSZ sequence occurred on January 23, 1812, but the location of its epicenter is not certain. This earthquake is thought to have resulted from a rupture on a strike-slip fault segment somewhere in the Missouri Bootheel (e.g., Johnston, 1996b). However, using instrumentally recorded aftershock locations and models of elastic stress change, Mueller et al., (Mueller, 2004) suggest that this earthquake may have actually occurred well to the northeast of the Missouri Bootheel, somewhere in the Wabash Valley of southern Indiana and Illinois and northeast of the MTW site. The third, and probably the most widely felt of the three earthquakes, occurred on February 7, 1812, very near the small town of New Madrid, Missouri.

Shaking from these earthquakes was felt across most of the eastern United States (U.S.), from Massachusetts to Texas. Although uncertain, the moment magnitudes of the three earthquakes are estimated to be equal to or greater than M7.0, and possibly as high as M8.0 (e.g., Nuttli, 1981 and Johnston, 1996b). In addition to the three main shock earthquakes, there were numerous magnitude M6.0 or larger aftershocks in the region, including one on December 16, 1811, with an estimated magnitude of up to M7.0. This large aftershock, which occurred on the same day as the initial New Madrid earthquake, is considered by some seismologists as another main shock to the NMFZ sequence (e.g., Hough, 2009). These magnitude estimates are derived from the areal distribution of observed shaking intensity and related damage to infrastructure recorded in personal journals, newspaper reports, and other historical accounts (Bakun, 2003 and Hough, 2000). In addition, the earthquakes produced widespread liquefaction features, especially sand blows. Based on comparisons to modern analogs, the size and spatial distribution of the sand blows support the M7.0 to M8.0 estimates (Tuttle, 2002).

Geological evidence suggests that similarly intense earthquakes ruptured the NMFZ several times prior to the 1811-1812 sequence. Paleoseismic studies of older sand blows indicate several prehistoric earthquakes with moment magnitudes and epicenter location similar to the 1811-1812 New Madrid sequence (Tuttle, 2002; 2005; 2006). Archeology and radiocarbon dates of material in and around the sand blows indicate prior earthquakes at approximately 1450 AD (± 150 years), 900 AD (± 100 years), 300 AD, and possibly in 2350 BC (± 200 years). These data suggest an average recurrence interval of about 500 years for the large magnitude NMSZ earthquakes.

7.2 USGS Survey Probabilistic Seismic Hazard Analysis

Since 1996, the USGS has been developing probabilistic seismic hazard maps of the U.S. that contour earthquake ground motion intensity levels across the U.S. as part of the National Earthquake Hazard Reduction Program (NEHRP). The maps are based on a probabilistic seismic hazard analysis (PSHA) approach (e.g., McGuire, 2004) and they essentially report the mean ground motion intensity values from the resulting distributions. The USGS maps are

[5] Global Earthquake Search available at http://earthquake.usgs.gov/earthquakes/eqarchives/epic/

drawn for three exceedance probability levels (2, 5, and 10% exceedance probability in 50 years).

The USGS maps are applied in seismic provisions of building codes, insurance rate structures, risk assessments, and other public policies. The maps are updated every six years based on improved hazard assessment methodologies and new seismological, geophysical, and geological information. Honeywell cites results from both the 2002 (Frankel, 2002) and 2008 (Peterson, 2008) updates to support their seismic design basis and supporting seismic analyses for the FMB at the MTW facility. The next sub-section of this TER, Section 7.3, Seismic Design Basis, provides detailed information about the MTW facility's seismic design basis and Honeywell's supporting seismic analyses.

Although the 2002 and 2008 USGS maps are similar in many regards, there are some important differences with regard to the NMSZ. According to Peterson et al., (Peterson, 2008), the most significant differences between the 2002 and 2008 maps regarding the NMSZ are: (i) reduced magnitude estimates (by 0.2 magnitude units) for rupture of the northern NMSZ, (ii) inclusion of a logic-tree branch to account for a recurrence interval of 750 years in addition to the more favored recurrence interval of 500 years, (iii) inclusion of a clustered model for simultaneous rupture of three New Madrid fault segments rather than a single rupture, and (iv) updated attenuation relationships for the central and eastern U.S. The result of these updates is that the 2008 USGS ground motion levels for southern Illinois are lower than the 2002 USGS levels by approximately 5 to 10%. There are several reasons for the reduction in the 2008 hazard. One is the smaller magnitudes assigned to the northern New Madrid fault zone branch in the probabilistic seismic hazard assessment logic tree. In the 2002 model, the distribution of magnitudes and weights were M7.3 (0.15), M7.5 (0.2), M7.7 (0.5), and M8.0 (0.15). In the 2008 model, the magnitudes were reduced by 0.2 magnitude units and the resulting distribution of magnitudes and weights were M7.1 (0.15), M7.3 (0.2), M7.5 (0.5), and M7.8 (0.15). This reduction in magnitude was based on general acceptance by the USGS hazard analysts that the second of the three main-shock earthquakes, which is considered to have ruptured a fault in the northern part of the NMSZ, was about 0.2 magnitude units smaller than the December and February earthquakes (Johnston, 1996b; Hough, 2000; and Bakun, 2004). A second reason for the decrease is that more recent ground motion attenuation models for the central and eastern U.S. generally produce lower estimates of ground motions than the ones used in USGS, 2002.

7.3 Seismic Design Basis

As described in Section III of Honeywell's SBCAP (Honeywell, 2013e), the design basis for seismic design of the FMB at the MTW facility are probabilistic earthquake ground motions based on the 10% probability of exceedance in 50 years (i.e., effective return period of 475-years) from the 2002 USGS map (Frankel, 2002). According to the Seismic Calculations Feed Materials Building Seismic Retrofit, Revision 1 (ABS Consulting, 2013b), this design basis earthquake has a Peak Ground Acceleration (PGA) = 0.31g, spectral acceleration with a period of 0.2 seconds ($S_{0.2}$) = 0.58g, and spectral acceleration with a period of 1 second ($S_{1.0}$) = 0.13g. These hazards levels are mean values from the probabilistic seismic hazard curves, and are based on firm rock site condition, i.e., Site Class B (assumed shear wave velocity averaged over the top 30 meters (m) [98.4 ft] equal to 760 m/second [2493.6 ft/sec]).

The MTW site sits atop significantly softer soil than the firm rock condition assumed in the USGS hazard maps. According to the geotechnical investigations performed by Leighton and Associates (Leighton, 1991), the soils beneath the FMB have shear wave velocities as low as 200 m/sec [about 650 ft/sec], which characterizes the soils as Site Class D soils within the

USGS NEHRP classification scheme (FEMA, 2003). This characterization is consistent with USGS estimates based on USGS V_S^{30} interactive map server, which implements the methodology of Allen and Wald (Allen, 2007). The presence of Site Class D soils requires that site correction factors be applied to the USGS hazard to account for site-response amplification of seismic energy. Honeywell's application of site adjustment factors was made according to American Society of Civil Engineers (ASCE)-07-10 (ASCE, 2010). The adjusted design basis ground motions are PGA = 0.36g, $S_{0.2}$ = 0.78g, $S_{1.0}$ = 0.27g. Honeywell notes in the SBCAP (Honeywell, 2013e) that using the USGS 2002 maps adds additional safety margin above the current design basis because the ground motions in USGS 2002 are higher than those in USGS 2008.

7.4 Seismic Margin Assessment

Honeywell contracted MXA Associates to perform a structural margin analysis of the FMB to determine the median seismic capacity of the facility. The results of the analysis provide an assessment of the ability of the FMB to withstand seismic ground motions beyond the 475-year return period earthquake. This information is used in four aspects of Honeywell's response to the Confirmatory Order as documented in the SBCAP (Honeywell, 2013e) and in NRC Staff's technical evaluation: (1) It supports the adequacy of seismic design basis; (2) It is used to identify additional seismic modifications that improve the ability of the FMB to withstand damage due to a design basis seismic event; (3) It is used to evaluate the performance of FMB in the event of an earthquake that produces ground motions beyond the design basis; and (4), it provides information about the overall capacity of the modified FMB to resist ground shaking.

The seismic margin assessment was conducted based on ground motions from the USGS 2008 seismic maps (10% probability of exceedance in 50 years). Details of the seismic ground motions used in these analyses are provided in the MXA Associates report (MXA Associates, 2013). According to this report, the input ground motions from the USGS 2008 seismic maps are PGA = 0.27g, $S_{0.2}$ = 0.48g, $S_{1.0}$ = 0.11g, assuming Site Class B soil. This report also provides uniform hazard spectra (UHS), defined by seven spectral accelerations and PGA. The values for the UHS were extrapolated from the suite of USGS interactive hazard curves application (http://geohazards.usgs.gov/hazardtool/). These hazard values were corrected for the Site Class D soil conditions at the site using the amplification factors Fa (0.2 seconds) and Fv (1.0 second) specified in ASCE 7-10 (ASCE, 2010). For the periods between 0.2 and 1.0 seconds, the soil amplification factors were assumed to vary linearly between factors Fa and Fv. The amplification factor at Fa was applied to all spectral accelerations with a period smaller than 0.2 seconds. The adjusted margin assessment ground motions are PGA = 0.36 g, $S_{0.2}$ = 0.69g, $S_{1.0}$ = 0.27g. This 475-year return period earthquake is referred to as the EBE (MXA Associates, 2013). The information provided in the MXA Associates report (MXA Associates, 2013) also includes development of the full response spectrum based on the UHS following the guidance in NUREG/CR-6728 (McGuire, 2001).

The results of the seismic margin analysis show that the natural frequency of the FMB is approximately 1.0 Hertz (Hz) (1.0 second) and that the median seismic capacity of the FMB is 2.51 times the EBE. This capacity is equivalent to the demand of an earthquake with a 1.0 Hz spectral acceleration of 0.679g. According to the USGS seismic hazard curve (Table 3 and Figure 13; MXA Associates, 2013), this earthquake has an annual exceedance probability of 0.59×10^{-3}, which is equivalent to a 1700-year return period. Based on extrapolation of the USGS hazard results, the 1700-year return period ground motions have a PGA of 0.834g. A detailed evaluation of the Seismic Margin Analysis is provided in Section 8.0 of this TER.

7.5 Staff Evaluation

- The staff reviewed the information provided in the SBCAP (Honeywell, 2013e) and the supporting documentation submitted by Honeywell and finds that information regarding the seismic hazard assessment is adequate. Staff finds that Honeywell adequately described and summarized the geological information needed to support evaluations of the seismic hazards. The information relied on by Honeywell is consistent with the staff's understanding of the seismic hazard potential the NMSZ based on information provided by Honeywell as well as information available from the geologic literature.

- The staff verified that the 475-year return-period ground motions provided in these reports matches those provided by the USGS 2002 and 2008 maps and interactive web-based hazard tools. Table 7.1 of this TER summarizes ground motions from both USGS 2002 and 2008 for the site as well as ground motions corrected for site soil conditions.

Table 7.1. Summary of Ground Motion Values Cited in the TER for the FMB

	2002 Site Class B (g)	2002 Site Class D (g)	2008 Site Class B (g)	2008 Site Class D (g)
PGA	0.31	0.36	0.27	0.36
5 Hz (0.2 seconds)	0.58	0.78	0.48	0.69
1 Hz (1 second)	0.13	0.27	0.11	0.27

- The staff finds that the application of the USGS 2002 and 2008 hazard values for the design basis and performance review are adequate, consistent with the application of these tools for licensing of other fuel cycle facilities (e.g., NRC 2012c, and 2012d).

- The staff finds that correction of the USGS hazard values for the site soil conditions and development of a uniform hazard spectrum are adequate because they are based on standard engineering practices described in ASCE 7-10 (ASCE, 2010) and the procedures detailed in NUREG/CR-6728 (McGuire, 2001).

- The staff does not find that using the USGS 2002 ground motions rather than the USGS 2008 values for the seismic design basis adds conservatism to the assessment. The USGS ground motions are based on essentially mean values from probability distributions of ground motion intensities derived from the PSHA. Although the uncertainties about those mean values are not published by the USGS, typical 1-sigma uncertainty bands from site specific PSHA curves for the central U.S. at these hazard levels are on the order of ± 0.1g. Similar uncertainties probably exist for the site response assessment, which also relies on averaged amplification factors that are derived from a distribution of amplification factors not a discrete value. Thus, while the USGS 2008 ground motions are slightly lower than the USGS 2002 values, this difference may not be statistically significant and is too uncertain to be credited in the safety assessment.

- The staff finds that the 1.0 Hz spectral acceleration of 0.679g, which corresponds to the median capacity of the FMB as determined by the seismic margin analysis, is approximately equal to an earthquake with a return period of 1700 years based on the soil Site Class D hazard PSHA curves.

8.0 <u>Design of Structures, Systems, and Components</u>

Section III.C.2.c of the SBCAP (Honeywell, 2013e) describes the studies that Honeywell conducted to develop proposed seismic corrective actions for the FMB structure, major process equipment, and piping systems. These corrective actions were implemented in order to meet the conditions for operation required by the NRC Confirmatory Order. Section IV of the SBCAP describes how Honeywell developed measures to protect the FMB from missile strikes caused by a tornado. The following is a description of staff's review and evaluation of Honeywell's methodology for analysis of the structural design associated with the modifications for the Honeywell facility.

8.1 Description of Structure

The FMB is a steel-braced frame structure with flexible diaphragms composed of six stories plus a below-grade basement [ABS Consulting, 2013a]. The building dimensions are approximately 72 ft in the north-south direction and 168 ft in the east-west direction. The original building was constructed in 1957, with a six-story, two-bay addition added to the west side of the original structure in1969. In 1995, two stories were added above the lower UF_6 loading area at the east end of the building. The roof vertical load carrying system is composed of metal deck system with horizontal angle bracings. There is no evidence that the original construction considered earthquake loads.

8.2 Seismic Modifications

8.2.1 Seismic Design Basis

In Section III of the SBCAP (Honeywell, 2013e), Honeywell describes the seismic design basis of the FMB prior to the issuance of the Confirmatory Order. As explained in Section 7.0 of this TER, the MTW facility is located in the seismic-prone area known as the NMSZ. As a result of the propensity to seismic activity, in 1991, Honeywell hired Leighton & Associates to analyze the seismic vulnerability of the MTW facility. Leighton & Associates (Leighton, 1991) calculated a site-specific mean PGA of 0.26g (Section III.A.2; Honeywell, 2013e) for firm rock site condition, i.e., Site Class B, for an earthquake with a 10% probability of exceedance in 50 years (475-year mean return period). The Leighton report identified structural deficiencies in the FMB and the internal components and recommended that Honeywell complete modifications. In 1993, EQE Engineering & Design (EQE, 1993) designed retrofits for the FMB building structure using the 1990 Building Officials Code Administrators International (BOCA) National Building Code (BOC, 1990) and 1991 Uniform Building Code (UBC) (UBC, 1992). Although the retrofits were implemented in 1997 for the building structure, the deficiencies in the internal components were not addressed.

Section III.C.2 of the SBCAP (Honeywell, 2013e), provides the seismic design bases for the currently proposed modifications to the MTW facility. The methodology used to evaluate the seismic risk of the Honeywell facility is documented in "FMB Structural Seismic Evaluation Report" (ABS Consulting, 2013a). The bases for the modifications to the MTW facility are defined by Honeywell as a design basis earthquake obtained from the 2002 USGS seismic hazard mapping with a 10% probability of exceedance in 50 years, which is approximately equal to an earthquake with a mean return period of 475 years. According to the 2002 USGS seismic hazard results, the 475-year return period earthquake has a PGA of 0.31g (Section III.C.2.a; Honeywell, 2013e). The corresponding spectral acceleration with a period of 0.2 seconds is

0.58g and a spectral acceleration with a period of 1 second is 0.13g. These ground motions are based on an assumed Site Class B. However, as discussed in Section 7.0 of this TER, the MTW site sits atop significantly softer soil conditions that correspond to Site Class D. Honeywell used soil amplification factors (Tables 3-5 & 3-6; ASCE, 2003) and (Tables 1-4 & 1-5; ASCE, 2007) to derive spectral accelerations for MTW site (Figure 2; Honeywell, 2013e). The MTW site spectral accelerations for Site Class D; the values of PGA, the spectral acceleration with a period of 0.2 second, and the spectral acceleration with a period of 1 second are 0.36g, 0.78g, and 0.27g, respectively. The uniform hazard response spectrum curve for 475-year return period earthquake for Site Class D of FMB is provided by ABS Consulting (ABS Consulting, 2013b) and MXA Associates (Figure C2; MXA Associates, 2013).

8.2.2 Design Methodology for Seismic Modifications

ABS Consulting, hired as a contractor by Honeywell, performed a seismic risk assessment of the as-built condition of the FMB prior to issuance of the Confirmatory Order in accordance with the American Society of Civil Engineers (ASCE) Standard, “Seismic Evaluation of Existing Buildings” (ASCE 31-03) (ASCE, 2003). The assessment assumed an “Immediate Occupancy Performance Level” as the seismic performance criteria for the FMB based on the designated Occupancy Category criteria defined in ASCE 31-03. The Immediate Occupancy level expresses the potential damage that a building and its non-structural components would be expected to experience. As the title implies, a building designed with Immediate Occupancy criteria is expected to withstand the design basis seismic loads with minor reparable damage allowing immediate use of the building after the earthquake. Selection of the Immediate Occupancy level results in a building that is expected to experience less deformation for a specified seismic demand than the Life Safety Performance level. The Life Safety criteria implies that the building is expected to withstand the design basis seismic loads with a state of permanent deformation that results in very costly repairs but still allows the users to safely evacuate the building. The results of the seismic risk assessment for the FMB showed that the existing condition of the structure did not satisfy the performance criteria for Immediate Occupancy for the design basis ground motions and identified structural deficiencies in the FMB.

ABS Consulting performed its seismic risk assessment of the FMB structure using the tier process described in ASCE 31-03, “Seismic Evaluation of Existing Buildings” (ASCE, 2003). A Tier 1 process consists of screening using simplified analyses to identify potential vulnerabilities in the structure (ASCE, 2003). Because the Tier 1 results identified vulnerabilities at the FMB and because the FMB is located in an area of high seismicity, ABS Consulting used a Tier 2 process (ABS Consulting, 2013a) to further evaluate the deficiencies of the structure against the requirements of ASCE 31-03. A Tier 2 evaluation was completed for the FMB structure and a three-dimensional computer model of the “full structure” was developed using the commercial computer code ETABS. A linear dynamic seismic analysis was performed by subjecting the model of the building to the design spectral accelerations and by using factors and load combinations from ASCE 41-06, “Seismic Rehabilitation of Existing Buildings,” (ASCE, 2007). The results of the linear dynamic seismic analysis provided the demand-to-capacity ratios (DCR) of members of the structure. Members with DCRs over 1.0 are expected to respond inelastically to the earthquake ground shaking. For the FMB, the modeling showed that without modifications multiple horizontal braces and columns exceeded DCRs of 1.0. ABS Consulting designed the modifications for these sections of the FMB to ensure the structure will meet the Immediate Occupancy performance objective of ASCE 41-06 at the 475-year return period ground motion. ABS Consulting used American Institute of Steel Construction (AISC) 341-02 (AISC, 2002), AISC Load and Resistance Factor Design (LRFD) Specification (AISC, 1999), AISC Manual (AISC, 1949), American Welding Society (AWS) Welding Code (AWS, 2010), American Concrete Institute (ACI) 318-02 (ACI, 2002), and other related design codes and standards for structural design of the FMB modifications.

8.2.3 Staff Evaluation

The NRC staff reviewed the design bases and proposed modifications to the MTW facility. The staff performed independent calculations to verify that the spectral accelerations used by Honeywell as the design basis for the facility were consistent with the USGS 2002 seismic hazard data and in conformance with ASCE 31-03 standards. The staff performed reviews at the Honeywell facility to verify that the “as-built” condition of the structure was adequately characterized in the computer model used to evaluate and design the modifications for the FMB. The staff reviewed existing drawings of the facility and performed walk-downs of a sample of building structural elements to verify that the drawings were representative of the “as-built” structure. During walk-downs, the staff also reviewed whether the masses of heavy equipment or items that may impact the seismic performance of the FMB were adequately considered in its computer model. Based on this review, the NRC staff concludes, with reasonable assurance, that Honeywell has met the requirements of Section IV.1 of NRC Confirmatory Order EA-12-157 because the safety bases, structural design criteria, and methods it proposed for the seismic modification of the FMB structure are based on industry-accepted codes, standards, and procedures.

8.2.4 Seismic Margin Assessment

Honeywell hired MXA Associates as a contractor to perform a structural seismic margin analysis of the FMB. The purpose of the seismic margin analysis is to identify the median seismic capacity of the FMB after the implementation of design modifications for a 475-year design earthquake and complemented by additional modifications that will further increase the median capacity of FMB (MXA Associates, 2013).

As described in Section 7 of this TER, the design basis earthquake used for the FMB modifications is based on 2002 USGS seismic hazard maps (10% probability of exceedance in 50 years, i.e., 475-year return period earthquake) assuming Site Class B. The EBE used in the margin analysis is defined by the 2008 USGS seismic hazard mapping (10% probability of exceedance in 50 years) for Site Class B amplified (Table A2; MXA Associates, 2013) for FMB Site Class D. The USGS 2008 seismic hazard curve for Site Class D for 10% probability of exceedance in 50 years is given in Table 3 and Figure 13 (MXA Associates, 2013). The corresponding values for the PGA, the spectral acceleration with a period of 0.2 second, and the spectral acceleration with a period of 1 second are 0.36g, 0,69g, and 0.27g, respectively. The uniform hazard response spectrum curve for a 475-year return period earthquake for 2008 seismic hazard for Site Class D is provided in Figure C1 (MXA Associates, 2013). In addition to considering the main shock earthquake, the median capacity determination of FMB included the effects of aftershocks on FMB (Section 3.3.2.2; MXA Associates, 2013).

8.2.4.1 Methodology for Seismic Margin Assessment

MXA Associates used the computer program ABAQUS to conduct the pushover analysis (MXA Associates, 2013). The analysis process includes three sets of ABAQUS analyses. First, an elastic model was developed to conduct response spectrum analyses to verify the adequacy of the model conversion from the ETABS model (ABS Consulting, 2013b) used for DBE design analysis to the ABAQUS model. The model conversion was verified by comparison of the natural frequencies of the FMB and seismic base shear generated in the FMB by the 2002 USGS seismic ground motion for Site Class D (Figure C2; MXA Associates, 2013), that were calculated by the ETABS model (ABS Consulting, 2013b) and the ABAQUS elastic model (MXA Associates, 2013). Second, an elastic model was developed to conduct response spectrum analyses of the FMB to develop a seismic load vector for the pushover analyses. The ABAQUS elastic model, verified in the first set of analyses, was used to conduct the 2008 USGS seismic ground motion response spectrum analysis. The ground motion was for a 475-year return period earthquake and Site Class D (Figure C1; MXA Associates, 2013). Third, a nonlinear ABAQUS pushover model was used to determine the seismic capacity of the FMB under 2008 USGS seismic ground motion for Site Class D (MXA Associates, 2013). The nonlinear static pushover analyses were conducted for eight load combination cases (MXA Associates, 2013). The eight load combination cases were selected out of 24 possible seismic load combination cases (Section 3.2.2; MXA Associates, 2013) and the load combinations used the ASCE 4 "100-40-40 rule" (ASCE, 2000). MXA Associates performed the seismic margin assessment in three phases: (i) a nonlinear ABAQUS pushover analysis to determine the capacity of the braced frame, (ii) an evaluation of all members in the seismic load path to ensure that the capacity can be developed, and (iii) a determination of the median seismic capacity of FMB and development of the annual probability of failure for the FMB.

The pushover analysis assumes that the nonlinear behavior is limited to brace elements of FMB. The remaining elements of the FMB in the seismic load path are evaluated using the demands from the nonlinear pushover analysis to ensure that these components have sufficient strength and ductility to develop the median seismic margin scale factor, FM. The FM is defined by the product of median capacity factor, FC, and a best estimate of inelastic response factor, Fu. The median capacity factor is calculated by increasing the scaled seismic load vectors in the ABAQUS nonlinear model of FMB until the best estimate story drift corresponding to unacceptable performance is reached at any location of the FMB structure. Unacceptable performance is defined by MXA Associates (Section 2.1.3; MXA Associates, 2013) as the drift limit based on a 10% loss of lateral load capacity. The inelastic response factor is calculated using the approaches provided by Electric Power Research Institute (EPRI) (EPRI, 1991) and NUREG/CR-3805 (NRC, 1984). The mean seismic risk, PF, which is the annual probability of failure is obtained by numerical convolution of the mean seismic hazard curve and mean fragility curve (Section 4.3 & Appendix R; MXA Associates, 2013).

MXA Associates specified the assumptions and idealizations that it used in the ABAQUS models, input data, seismic mass distribution, material properties, effective frequency, effective damping, elastic response spectrum analyses, and nonlinear static pushover analyses. Honeywell used guidance in Regulatory Guide 1.92, Combining Modal Responses and Spatial Components in Seismic Response Analyses (NRC, 2006) to perform response spectrum analysis.

8.2.4.2 Results of Seismic Margin Assessment

MXA Associates provided a comparison of the natural frequencies and seismic base shear of FMB calculated by the ETABS model (ABS Consulting, 2013b) and the ABAQUS model (MXA Associates, 2013) that shows that the ABAQUS and ETABS elastic models are similar with the ABAQUS model having slightly higher frequencies (Section C.12; MXA Associates, 2013). The ABAQUS natural frequency is 0.17 Hz higher in the North-South direction and 0.1 Hz higher in the East-West direction. In the East-West and North-South directions, the ABAQUS model has a base shear that is 3% to 17% higher than the base shear in ETABS model.

The seismic base shear obtained from response spectrum analyses conducted by the ABAQUS elastic model is given for each load case in Table C8 (MXA Associates, 2013). The initial base shear that MXA Associates calculated for each load case by multiplying the accelerations from the response spectrum analyses by the corresponding seismic weight on a node-by-node basis and totaling them is also given in Table C8. A comparison of seismic base shear with the corresponding initial base shear in Table C8 shows that the initial base shear for each load case [Column 3, Table C8] is significantly larger than the corresponding seismic base shear (Column 2, Table C8). In order to conduct the pushover analysis, MXA Associates calculated scaled horizontal load vectors (Column 5, Table C8) that were incrementally increased for static nonlinear pushover analysis. The vertical distribution of seismic load (Section 3.2.1 and Figure C91; MXA Associates, 2013) was conservatively developed to combine with the pushover analysis results due to horizontal load vectors (Section 3.2.2; MXA Associates, 2013).

A comparison of the pushover analysis results of 8 load combinations shows that the load combination consisting of 100% south plus 40% east and 40% vertical seismic loads (Appendix G; MXA Associates, 2013) provides the limiting median seismic capacity of the FMB. This median seismic capacity of FMB is 2.51 times the EBE.

The FMB median seismic capacity of 2.51 times the EBE is equivalent to the demand of an earthquake with a 1 Hz spectral acceleration of 0.679g. Based on the USGS seismic hazard curve (Table 3 and Figure 13; MXA Associates, 2013), this earthquake has a $0.59\text{x}10^{-3}$ annual frequency of exceedance, which is equivalent to a 1,700-year return period earthquake with a PGA of 0.834g.

In Appendices N through Q of the Seismic Margins Assessment for the Feed Materials Building, MXA Associates provided an evaluation of the bracing connections, diaphragms, collector beams, columns, and column anchorage (Section 4.2, MXA Associates, 2013). This evaluation is based on the pushover analyses demands for load steps up to the values given in Table 11 (MXA Associates, 2013). The design of the identified members that need strengthening to support the conclusions of the seismic margin assessment is provided in Section 4.2 (MXA Associates, 2013) and referenced Appendices, such as Appendix D for the design of brace members and their connections. The median material properties and the codes, standards, and procedures that MXA Associates used for the design and strengthening of the FMB structural members for a seismic event beyond the EBE are consistent with those used for the design and strengthening of FMB structural members for the EBE (MXA Associates, 2013).

8.2.4.3 Staff Evaluation

The NRC staff performed a review of the seismic margin assessment and proposed modifications to the MTW facility. The staff performed in-office reviews of the pushover analysis to verify the adequacy of: (i) elastic model conversion from the ETABS model to the ABAQUS model; (ii) conceptualizations, assumptions, and approximations used in the ABAQUS nonlinear model to conduct static analysis of a dynamic analysis system; and (iii) interpretation of analysis results to predict the seismic margin of the structure. The staff reviewed the evaluation and design of the members that needed strengthening as a result of the conclusions of the seismic margin assessment. The staff reviewed the construction drawings for the modifications recommended to improve the performance of the structure for seismic loads equivalent to a 1700-year return period earthquake. The staff performed walk-downs of a sample of modified members to verify that the “as built” conditions are consistent with the drawings. The staff finds that the seismic margin assessment, including nonlinear pushover analysis, the structural design, and modifications are based on industry accepted codes, standards, and procedures. Based on this review, the NRC staff concludes, with reasonable assurance, that the requirements of Section IV.1 of NRC Confirmatory Order EA-12-157 have been met because the best estimate of the medium seismic capacity of the facility is 2.51 times the loads associated with the EBE. The analysis demonstrates that the seismic modifications proposed for the MTW facility significantly increase the safety basis supporting the performance requirements associated with the structure.

8.3 Internal Components

8.3.1 Equipment Restraints and Piping Supports Reassessment

Section III.C.2.c of the SBCAP (Honeywell, 2013a) describes the two approaches that were used to evaluate the seismic adequacy and proposed modifications of equipment restraints and piping supports containing hazardous material. The first approach was a detailed engineering analysis of equipment components where sufficient definitive design and construction documentation existed to support quantitative analysis. This approach was used to evaluate major process equipment such as vessels containing large inventories of hazardous materials. The second approach was detailed walk-down evaluations by a team of seismic engineers to qualitatively identify vulnerabilities of internal components that can affect their performance under seismic loading. This approach was used to evaluate the piping supports of systems containing hazardous materials.

8.3.2 Equipment Restraints Methodology for Seismic Reassessments

Enercon Services Inc., hired as a contractor by Honeywell, performed calculations to evaluate the structural adequacy of various components and equipment at the MTW facility. Enercon used the first approach described above—a detailed engineering analysis of components—for this evaluation (Enercon, 2013a). Enercon evaluated vessels and other equipment where large inventories of liquid UF_6 are stored or processed. In order to fully assess the as-built condition of the equipment, Enercon performed detailed walk-downs of the equipment to supplement information from existing drawings and previous seismic assessment reports. Enercon used the seismic accelerations obtained from ABS Consulting's linear dynamic seismic model of the FMB for a 475-year return period earthquake, as input for its evaluations of the equipment restraints. The seismic accelerations were obtained for each floor elevation and were used by Enercon as the basis for its evaluation of the equipment by floor. In Revision 2 of MTW-CALC-GEN-0018, Enercon increased the accelerations obtained from the linear dynamic seismic model by a factor of 1.5 to design and evaluate the equipment restraints for loads equivalent to a 1300-year return period earthquake event as part of the seismic margin evaluation by MXA Associates of the FMB (Enercon, 2013a).

Enercon used existing drawings and supplemental walk-down information to evaluate the equipment using structural calculations and load combinations from accepted codes and standards such as the International Building Code [IBC 2006] (ICC, 2006), American Society of Civil Engineers "Minimum Design Loads for Buildings and Other Structures" [ASCE 7-05] (ASCE, 2006) and the American Institute of Steel Construction [AISC 9th edition] (AISC, 1989). If the existing "as-built" state of the equipment did not meet the criteria specified by the codes, Enercon designed modifications to retrofit the restraint for that particular piece of equipment. The evaluations considered failure modes on the load path for gravity and seismic loads from the equipment to the structure of the FMB. Enercon used the commercially available structural software, GT STRUDL, for detailed design and evaluation of some of the equipment restraint systems.

8.3.3 Piping Supports Methodology for Seismic Reassessments

Enercon Services Inc. also performed seismic reassessments of liquid UF_6 piping systems within the FMB (Enercon, 2013b). Enercon used the second approach described above which involves walk-down inspections, to assess liquid UF_6 piping systems and provide recommendations on the adequacy of the existing piping supports. Due to the limited amount of design information for the existing piping systems and their supports, the walk-downs were used to identify vulnerabilities on the as-built condition of piping systems supports that could affect their performance under seismic loads. The walk-downs were performed using the guidelines provided by the EPRI report “Experience-Based Seismic Verification Guidelines for Piping Systems." This report provides guidelines that can be used to perform an experience-based seismic capability verification of existing piping systems and evaluate whether they will perform as required during a seismic event.

The evaluation of adequacy for supports of existing piping systems was performed by Enercon using the information gathered from facility walk-downs and guidance from EPRI and ASME B31.1 to determine the recommended spacing for a given piping system. Different types of existing or proposed supports were evaluated by Enercon to determine whether the support can withstand the loads from a seismic event. The capacities and span locations of piping supports were evaluated against the imposed load from the dead weight of the piping and the seismic loads. Enercon used the seismic accelerations obtained from the linear dynamic seismic model of the FMB, as performed by ABS Consulting for a 475-year return period earthquake, as input for the evaluations. The seismic accelerations were obtained for each floor elevation and were used by Enercon as the basis for its evaluation of the piping systems supports by floor. Enercon increased the accelerations obtained from the linear dynamic seismic model by a factor of 1.5. Enercon designed and evaluated the piping supports for loads equivalent to a 1300-year return period earthquake as part of the seismic margin evaluation by MXA Associates of the FMB. Enercon used the commercially available structural software, GT STRUDL, for design evaluations of some of the piping supports systems. In addition to evaluating the piping supports, Enercon performed a conservative evaluation of induced stress to the piping from building horizontal displacement and concluded the existing piping is adequate to withstand the stress induced from a 1% story displacement.

8.3.4 Staff Evaluation

The NRC staff reviewed the seismic reassessments of equipment restraints and piping supports within the FMB. The staff performed independent calculations to verify that the assumptions used by Enercon in their evaluations were adequate and based on sound engineering judgment. The staff performed in-office reviews and walk-downs at the MTW facility to verify that the as-built condition of equipment restraints and piping supports was adequately characterized in the seismic reassessment. The staff concludes that the methodologies used by Honeywell are consistent with codes and standards and industry accepted guidelines. The use of walk-downs to inform seismic reassessments of equipment restraints and piping supports is widely accepted for the seismic rehabilitation of structures. The staff concludes that Honeywell provided adequate information regarding the design of equipment restraints and piping supports for accelerations equivalent to a 1300-year return period earthquake and has reasonable assurance that the restraints and supports would not sustain major damage leading to significant releases of UF_6 for an earthquake of this magnitude.

8.4 Overall Staff Evaluation of Seismic Modifications to Structure and Internal Components

Based on staff's review of Honeywell's overall analysis:

- Honeywell has provided adequate information regarding the design basis associated with the proposed seismic modifications to the MTW facility.
- The FMB, if the proposed modifications are adequately installed, will withstand the design basis earthquake (475-year return period). In addition, the seismic margin analysis reflects that the FMB structure will not sustain excessive damage that could lead to inadequate performance for seismic loads equivalent to a 1,700-year return period earthquake. Thus, the staff has reasonable assurance that the FMB structure, which supports UF_6 containing equipment and piping, would not sustain damage leading to significant releases of UF_6 equipment or piping for up to a 1,700-year return period earthquake. As the seismic forces on the FMB approach or exceed levels equivalent to 1700-year recurrence interval earthquake the structural members of the FMB may experience moderate permanent deformation.
- The restraints for the UF_6 process equipment and piping are appropriately designed to withstand seismic loads equivalent to an earthquake with a 1300-year recurrence interval. Thus, staff has reasonable assurance that the restraints would not sustain major damage leading to significant releases of UF_6 for an earthquake of this intensity.
- NRC staff concludes, with reasonable assurance, that the requirements of Section IV.1 of NRC Confirmatory Order EA-12-157 have been met because the safety bases, design criteria, and methods Honeywell proposes for seismic protection of the FMB and component supports are based on industry accepted codes, standards, and procedures.

The structural performance of the proposed design modifications to the FMB and equipment provide reasonable assurance that releases of material at risk will be adequately prevented.

8.5 Tornado Modifications

8.5.1 Tornado Design Basis

In Section IV.A of the SBCAP (Honeywell, 2013e), Honeywell described the existing high wind and tornado design basis for the MTW facility, as established prior to the issuance of the Confirmatory Order. Section 11.2 of Honeywell's ISA Summary concluded that the frequency of a direct tornado strike at the MTW facility was less than $1x10^{-6}$/year and was excluded as a design basis event due to the frequency of impact to the facility and expected impacts to the facility and equipment (Enercon Services, Inc., 2006). This was based on evaluations in the ISA Summary showing that the likelihood of a tornado missile hitting the FMB was $1x10^{-6}$/year and that the wall thickness of vessels and tanks at the facility [redacted] to prevent penetration from a strike of a design missile. The design missile was a [redacted] 4-inch x 12-inch x 10-foot wooden board at a tornado wind velocity of 157 mph (Enercon Services, Inc., 2006).

In Section IV.C.2 of the SBCAP (Honeywell, 2013e), Honeywell re-evaluated the tornado design bases for the MTW facility using an NRC-endorsed methodology. The methodology used to evaluate the tornado risk of the Honeywell facility is documented in Honeywell's calculation "MTW Tornado Strike Likelihood," (Honeywell, 2011a). The frequency of tornado interactions with the MTW site was calculated using the guidance in NUREG/CR-4461, "Tornado Climatology of the Contiguous United States," (NRC, 2007b) and was determined to be a credible event that can impact the MTW facility with a likelihood of 4.4×10^{-4}/year (an increased likelihood compared to Honeywell's previous analysis). Using the guidance from NUREG/CR-4461 and the tornado intensity information provided in Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," (NRC, 2007a) the licensee calculated a maximum wind speed of 152 mph associated with an event with frequency of occurrence of 10^{-5}/year. The event frequency of 10^{-5}/year is in accordance with the likelihood definitions provided in Table 14 of Section IV.C.1.c of the SBCAP (Honeywell, 2013e).

8.5.2 Design Methodology for Tornado Protection

Honeywell evaluated the effects of a tornado generated missile impacting the facility (Honeywell, 2013a). To evaluate the consequence severity from a tornado missile striking the facility, Honeywell assumed that any missile impact from a tornado will result in a "high consequence" event. The tornado missiles used for the evaluation were obtained from Table 2 of Regulatory Guide 1.76, Revision 1, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," (NRC, 2007a). The missile spectrum includes a schedule 40 pipe, an automobile and a solid steel sphere. The maximum velocities in Table 2 of Regulatory Guide 1.76 were decreased by the proportion of the velocities from an event with frequency of occurrence of 10^{-5}/year and 10^{-7}/year. The frequency of occurrence of 10^{-7}/year is recommended by Regulatory Guide 1.76 for the design of nuclear power plants. The results of the licensee evaluation concluded that the shell thickness of certain vessels is vulnerable to penetrations from missile impacts and that the impact forces from a missile strike can lead to failure of the supports for piping and other components. In order to mitigate the consequences of tornado missile strikes, Honeywell proposes the installation of tornado missile sacrificial barriers to reduce/eliminate the energy of tornado missiles that might impact areas with large inventories of liquid UF_6 (Honeywell, 2013f).

Honeywell also proposes design changes that include the installation of tornado missile sacrificial barriers at certain locations of the FMB (Honeywell, 2013e). The proposed protective tornado barrier consists of Monel alloy plates supported by steel tube frames (AISC, 2005) attached to the exterior of the FMB steel building structure (Rhutasel, 2013). The methodology to design the Monel alloy plates is based on the method specified in Section 2.2 of a Bechtel topical report (Lindeman, 1974). The thickness of the plates corresponds to the maximum penetrating distance of a pipe impacting the plates (Honeywell, 2013f).

8.5.3 Staff Evaluation

The NRC staff reviewed the design bases and proposed modifications to the MTW facility for high winds. The staff performed independent calculations to verify that the tornado strike likelihood calculated by Honeywell as the design basis for the facility is consistent with the guidance from NUREG/CR-4461. The staff verified that the missile spectrum used for the evaluation of strike impacts at the facility is consistent with Regulatory Guide 1.76. The staff concludes that the proposed locations for the installation of missile barriers will protect vulnerable areas of the plant where large inventories of UF_6 are present. As stated in Regulatory Guide 1.76, damage to structures and components by tornado generated missiles implies the occurrence of a sequence of random events. Honeywell's proposed use of missile barrier to protect areas with large inventories of hazardous materials from a spectrum of missiles is consistent with defense in depth considerations and provides assurance that the consequences of tornado missile strikes will be mitigated. Based on this review, the NRC staff concludes, with reasonable assurance, that the requirements of Section IV.1 of NRC Confirmatory Order EA-12-157 have been met because the safety bases, design criteria, and methods Honeywell proposes for tornado protection of the FMB are based on industry accepted codes, standards, and procedures.

9.0 <u>Chemical Consequences</u>

9.1 Review and analysis of consequences from UF6 releases following seismic events

This section documents the staff's review of Honeywell's analysis of chemical toxicity consequences following seismically induced releases of UF_6 with specific emphasis on the effects to offsite receptors. The analysis is limited to the effects of releases of liquid UF_6 and UF_6 hydrolysis products because UF_6 is the only licensed material on site that can produce significant offsite concentrations of hazardous chemicals.

9.2 Potential for seismic-induced release

The NRC staff reviewed Honeywell's design basis structural analysis of the FMB, as well as the seismic margin assessment. The staff conclusions concerning the structure are presented in detail in Section 8.0 of this TER, Design of Structures, Systems, and Components. In Section 8.0, the staff concludes that it has reasonable assurance that seismic loads equivalent to earthquakes with return periods of 1300 and 1700 years would not result in damage that would lead to significant releases of UF_6. It is also recognized that at some point, a seismic load equivalent to an earthquake with a return period in excess of 1700 years could result in enough structural and UF_6 equipment/piping damage that most of the liquid UF_6 inventory would be released.

9.3 Liquid UF_6 inventory

Honeywell estimated the liquid UF_6 "mass at-risk" inventory in the FMB piping and process equipment by floor level (Table 3 of SBCAP, Revision 3) (Honeywell, 2013d). The following table shows the estimated liquid inventory in the [redacted] and the estimated inventory in the portion of the building [redacted].

Table 9.1. Summary of Liquid UF_6 Inventory in Piping and Equipment Within and Above the FMB Distillation Confinement Area

Floor	Piping inventory (lbs UF_6)	Equipment inventory (lbs UF_6)	Equipment description
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Honeywell proposes to upgrade the FMB distillation zone to create a confinement area intended to reduce the potential for and rate of release of any UF_6/HF from the lower floors of the FMB. This confinement area extends from the basement of the FMB through the top of the third floor. Honeywell estimates the UF_6 inventory in the piping within the confinement area as [redacted] The three floors above the confinement area [redacted] Honeywell estimates UF_6 inventory in the piping above the confinement area to be [redacted]

9.4 Physical Processes Important in Determining the Human Health Consequences following a UF_6 Release

A sequence of physical-chemical processes occurs following the failure of piping or equipment containing liquid UF_6. The nature and location of equipment or piping failure and the nature of the resulting physical-chemical process play important roles in the determination of consequences to offsite receptors. The following sections discuss the sequence of physical-chemical processes that occur following a release of UF_6.

- Liquid flashing following initial failure of piping or equipment

  UF_6 does not exist as a liquid at atmospheric pressure. The liquid phase can only exist above the triple point (22 psia, 147.3°F). Any liquid that is released or exposed to atmospheric pressure will "flash" into a solid fraction and a vapor fraction. The size of the fraction becoming a vapor depends on the initial temperature of the liquid and the nature of the flashing process (isentropic expansion or adiabatic isenthalpic expansion).

  The vapor fraction is typically on the order of 50%.[6] Much of the solid phase generated by the flashing process will be as fine particles which remain airborne (i.e., an aerosol).

[6] The document "Computer Programs for Developing Source Terms for a UF6 Dispersion Model to Simulate Postulated UF6 Releases from Buildings," K/D-5695 (Williams, 1995) presents a figure (Figure 6) that includes the vapor faction for adiabatic isenthalpic expansion and isentropic expansion. At 180°F,

It is estimated that about half of the solids will remain in the aerosol so that about 75% of the total uranium released will be in the vapor-aerosol mixture. The total amount of HF in the vapor-aerosol mixture could approach 100% of the HF that could be generated by the UF_6 hydrolysis reaction assuming there is no depletion by condensation or HF reaction with building and equipment surfaces.

The initial release rate will depend on the location and size of piping or equipment failure. If the line break or equipment failure is above the free liquid surface, the flashing will occur within the tank and vapor will be released. If the line break or equipment failure is below the free liquid surface, liquid UF_6 will be released and the flashing will occur after the material has been released to the room atmosphere. The rate of liquid release will be a function of the vapor pressure of the UF_6, the static head, and the orifice characteristics that restrict the release flow. Seismically induced UF_6 releases that occur for earthquakes with return periods of 1300 years or 1700 years are expected to be through relatively small openings (e.g., cracks) rather than clean pipe breaks. The vapor fraction will react rapidly with any water source (e.g., humidity, steam) to produce UO_2F_2 and HF. UO_2F_2 is a particulate that produces the white smoke observed following a UF_6 release. The reaction is exothermic and the heat generated will increase the temperature of the aerosol/gas phase.

- Vapor cloud depletion within the building

  The uranium that remains airborne (both UO_2F_2 and UF_6) as well as any HF formed by UF_6 hydrolysis will react with and/or deposit on surfaces within the room where the initial release occurs. The extent of depletion will depend on the surfaces in the release area.

- Release of uranium and HF from the FMB

  The UF_6/UO_2F_2/HF vapor-aerosol produced by the reaction of UF_6 with atmospheric and other moisture sources will exit the building by two basic processes. The first is the pressure increase that will occur from UF_6-moisture reaction. The pressure increase is the result of two effects: (1) the reaction results in an increase in the number of gas-phase molecules (or moles) (three gas-phase molecules are consumed, four gas-phase molecules are produced) and (2) the heat released from the reaction results in an expansion of the gas.

  The second physical process that will move the UF_6/UO_2F_2/HF vapor-aerosol from inside the FMB to outside the building is the wind forces on the FMB itself. Wind impacting the FMB will produce a slight positive (higher) pressure on the side of the FMB where the wind impacts the building and a slight negative (lower) pressure on the opposite side of the building. This, in conjunction with small openings in the building walls (leaks around doors, any windows, piping runs through the wall, etc.) will result in a net air flow through the building.

  One method for quantifying this second physical process for removing the UF_6/UO_2F_2/HF vapor-aerosol mixture from the FMB is to use reported air changes per hour (ACH) information, which provides some measure of leakage from buildings. A report by Chan, et al. presents some quantitative information on ACH from various types of construction (Chan, 2004). The report shows ACH ranging from 0.07 to 1.6 building volume changes

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the vapor mass fraction is 0.48 for isentropic expansion and 0.49 for adiabatic isenthalpic expansion. At 200^{o}F, these vapor mass fractions are 0.52 and 0.54.

per hour depending on the tightness of the construction and the weather conditions. Other reports provide information on infiltration measurements for industrial buildings and large aircraft hangers (Waters, 1986 and Ashley, 1986). To develop estimates of ACH for various portions of the confinement area, the staff used information provided by Honeywell that describes the actions taken to seal up the confinement.

Increased seismic forces are expected to produce higher levels of damage to the confinement structure. As the building structure experiences more damage reduced confinements (larger air changes per hour) are expected.

- Building Wake Effect

  Releases of UF_6/UO_2F_2/HF vapor-aerosol from the building will be mixed and diluted in the building wake. The building wake is a volume on the downwind side of the building (i.e., a wind shadow) where flow air patterns are determined by the interaction between the wind and the structure. Building wake will act to mix releases from various levels of the building uniformly throughout the cavity of the building wake. The release will subsequently “leak” from the far end of the cavity and be further diluted as it travels downwind.

- Dispersion processes

  After the UF_6/UO_2F_2/HF vapor-aerosol is released from the FMB wake, it will be dispersed with the concentration decreasing as the plume moves down wind. The downwind concentration at or near ground level (the location of a potential receptor) is a function of meteorological conditions (stability class and wind speed) and surface roughness. In this case, the surface roughness is low corresponding to the conservative assumption that this is a rural site.

  The meteorology is variable and the NRC staff considered two cases in this analysis: D stability class with a wind speed of 11 mph which is reflective of normal or average conditions and F stability class with a wind speed of 4.5 mph which is reflective of more conservative meteorology and generally results in greater impacts at a given distance. These two meteorology conditions are identified in the Accident Analysis Handbook (NUREG/CR-6410). The joint frequency data on distribution of atmospheric stability, wind direction and wind speed for the Paducah Gaseous Diffusion Plant, which is across the Ohio River from the MTW facility, is considered representative for the Honeywell site (Paducah, 2006). This data shows that stability class D with winds of about 11 mph has the greatest likelihood for the MTW site and occurs about [redacted]% of the time. The more stable (i.e., less dispersive) stability class F occurs about [redacted]% of the time. The most likely wind speed for F class stability is 4.5 mph. Predictions that utilize stability class F generally result in higher concentrations at a given downwind distance than other stability classes.

9.5 Criteria for Assessing Consequences

Both Honeywell and the staff used the comparison of predicted concentrations at 1850 ft with the published Acute Exposure Guideline Levels (AEGLs) concentrations as a basis for estimating whether a specific release could result in an offsite fatality. This distance was used because Honeywell identified the nearest resident as being 1850 ft to the NNW. Honeywell primarily used the 10 minute exposure AEGL-3 for HF (139 mg/m^3, 170 ppm). The NRC staff used the same 10 minute exposure AEGL-3 for HF as well as the 10 minute exposure AEGL-3 for UF_6 (216 mg/m^3, 15 ppm).

AEGL-2 is defined as the airborne concentration above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long lasting adverse health effects or an impaired ability to escape.

AEGL-3 is defined as the airborne concentration above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death.

The analysis focused on the prediction of HF and uranium concentrations that might be experienced by offsite receptors. The analysis did not estimate concentrations that would be experienced by onsite workers. The limited releases within the FMB that might occur as a result of earthquakes with a recurrence interval of less than 1700 years are not expected to result in significant worker exposure because of the limited worker occupancy of the FMB and the availability of emergency respirators. The potential risk to workers from larger releases is discussed in Section 5.2.6.

9.6 UF_6 Release Cases Analyzed

An evaluation of estimated releases for progressively more severe earthquakes was provided by Honeywell and evaluated by the NRC staff.

9.6.1 Release Consequences for Earthquakes with a Return Period less than 1300 years

For the FMB design basis earthquake (475-year earthquake) no release of any significance is expected by Honeywell or the NRC staff and so no consequence assessment was performed. While Honeywell's analysis of the FMB structure indicates that major piping or equipment failures are not expected for earthquakes with a recurrence interval of less than 1300 years, Honeywell conducted a dispersion analysis using what it considered to be a conservative estimate of liquid UF_6 release for earthquakes with a recurrence interval of less than 1300 years. This involves the release of [redacted] of UF_6 into the FMB followed by its release from the [redacted] floor which is above the confinement area. The Honeywell analysis considered the one release rate, one leak rate from the [redacted] floor (1.5 air changes per hour) and four meteorological conditions. The analysis did not consider the effect of building wake. This analysis did not result in any predicted ground-level or near-ground-level HF concentrations that were above the 10 minute AEGL-2 value for HF.

The staff conducted an independent analysis of the consequences of a comparable release quantity. The staff developed independent estimates of potential liquid release rates from the UF_6 piping into the FMB, independent estimates of uranium and HF releases from the FMB, and independent estimates of uranium and HF concentrations downwind of the FMB. The release rate from the FMB was estimated using a mixing cell calculation that considered UF_6 being released from UF_6 equipment and air entering and exiting the FMB because of wind pressures on the FMB (see air changes per hour discussed previously). The release rate of $UF_6/UO_2F_2/HF$ vapor-aerosol from the building is dynamic (not steady state) as the concentration of HF and uranium increase and then decrease in the mixing cell. An average steady state release rate was developed from the mixing cell calculations and used input from the building wake calculation. The building wake model is based on one published by Hanna et al. (Hanna, 1982). The output from the building wake calculation was used with a Gaussian dispersion model.

The staff considered Honeywell's estimate of [redacted] of UF_6 to be conservative for seismic loads up to those equivalent to a 1300-year return period earthquake and a 1700-year return period earthquake. The equipment and piping are designed to accommodate such loads and failure in the lower portion of multiple pipe runs appears to be highly unlikely for such design basis earthquakes. The staff conducted an independent analysis of the HF and UF_6 concentrations downstream of the building. From this analysis, the staff concluded that any actual UF_6 and HF releases that might occur for seismic loads less than or equivalent to a 1300-year return period and a 1700-year return period earthquakes are not expected to result in the public being exposed to HF or UF_6 concentrations that are greater than the 10-minute AEGL-2 values for these chemicals.

9.6.2 Consequences for Releases of FMB Inventory

Earthquakes that are sufficiently severe (at some point greater than the analyzed 1700-year return period earthquake) might result in substantial UF_6 releases from the FMB. To obtain some insight into the consequences of such a severe failure, Honeywell presented a single analysis using RASCAL 4.1 to estimate the consequences for the release of [redacted] of UF_6 at a release rate of [redacted]. The analysis considered D class atmospheric stability and 4 mph winds. The details of the Honeywell analysis (Reference 8 in the SBCAP) show HF concentrations at offsite locations of 44 ppm which is less than the 10-minute AEGL-2 concentration (95 ppm) and the 10 minute AEGL-3 concentration (170 ppm). This single analysis did not predict offsite concentrations that could result in fatalities.

The NRC staff conducted an independent analysis of the Honeywell-identified release quantity using RASCAL 4.2, but the staff considered a broader spectrum of release rates and meteorological conditions. The staff's analysis identified multiple combinations of release rates and meteorological conditions that would result in predictions of offsite concentrations that exceed 10-minute AEGL-3 values for HF and UF_6.

The RASCAL analysis predicts a plume buoyancy effect that might not develop following seismically induced releases. RASCAL does not have a building wake effect which results in increases in the predicted ground level concentration from elevated releases of HF and uranium near the release point. To analyze this potential situation, the staff used the previously discussed combination of models (Section 9.6.1 of this TER) that considered the effects of UF_6 reaction within the FMB followed by release from the FMB and mixing in the building wake and then dispersion. The staff's analysis identified UF_6 release rates that would result in offsite concentrations that exceed the 10-minute AEGL-3 values for both HF and UF_6. A summary of the major parameters used in the analysis as well as a summary of the results is presented in Table 9.2 of this TER. The table shows the spectrum of parameters such as ACH, release elevation and meteorology that were used in the specific analyses. The table also discusses the various parameters in terms of the degree of conservatism employed (reasonable, conservative).

9.7 Conclusions from Consequence Evaluation

The staff agrees with Honeywell's assessment that while significant releases of UF_6 are not expected for seismic events of a magnitude below the design basis for the UF_6 process equipment and piping (earthquakes with return periods of 1300 years and 1700 years), conservative analysis indicates that offsite HF concentrations, in the event of a release, would not exceed the 10-minute AEGL-2 levels. The staff's independent analysis is based on a consideration of the physical processes (e.g., mixing, leaking from building, building wake effects, ground level dispersion) that are expected to play an important role in offsite concentrations. The staff analysis also considered the toxicity of uranium which is reflected in the 10-minute AEGLs for UF_6.

Seismic events with greater than a 1700 year return period could produce offsite concentrations greater than AEGL-3. The risks associated with such concentrations are acceptable because they have been demonstrated to be highly unlikely as discussed in Section 5.0 of this TER.

Table 9.2. Comparison of Cases for Earthquake-Induced Releases

		Release rate	ACH	Release Elevation	Building Wake Effect	Dispersion	Meteorology	Result
Seismic Event less than 1300-year Return Period								
Honeywell Analysis	Release from piping above confinement area	[redacted] of UF_6 over 10 minutes,	1.5	[redacted] floor	no	Gaussian with feature for plume buoyancy	B 2.3 m/s D 3.3 m/s D 7.2 m/s F 1.9 m/s	No ground level concentrations at or above AEGL-2 or AEGL-3 for HF
NRC Staff Analysis	Release from piping above confinement area	[redacted] of UF_6 released from damaged piping ([redacted])	0.5 – 4.5 is considered to be a conservative range for the upper floors of FMB	Release into building wake	yes	Gaussian dispersion after release from the building wake. No allowances for plume buoyancy	D 5 m/s F 2 m/s	No offsite ground level concentrations above 10-minute AEGL-2 or AEGL-3 for either HF or UF6
Seismic Event Greater than 1700-year Return Period								
Honeywell Analysis	Release of UF_6 at ground level without any moderating effects of the FMB structure (RASCAL 4)	[redacted] of UF_6 released at the rate of [redacted]	Not relevant	Ground level	Not relevant	Gaussian dispersion with heat effect	D 4 mph (1.8 m/s)	Ground level concentrations reached AEGL-3 levels for HF
NRC Staff Analysis	Release of UF_6 at ground level without any moderating effects of the FMB structure (RASCAL 4)	[redacted] of UF_6 released at the rates of [redacted]	Not relevant	Ground level	Not relevant	Gaussian dispersion with heat effect	D 5 m/s F 2 m/s	There are combinations or release rate and meteorology that result in predicted offsite HF concentrations above AEGL-3 levels
NRC Staff Analysis	Release of UF_6 within the FMB	Rates estimated to be associated with substantial piping and equipment damage [redacted]	0.5-4.5	Release into building wake	yes	Gaussian dispersion after release from the building wake. No allowances for plume buoyancy	D 5 m/s F 2 m/s	There are combinations or release rate and meteorology that result in predicted offsite HF and uranium concentrations above AEGL-3 levels

10.0 Other Considerations

As part of the staff's evaluation, the staff also evaluated the seismic monitoring and shutdown system and considered issues related to the tank farm, fire safety, and loss of power.

10.1 Seismic Safety Shutdown System

10.1.1 Description of the Seismic Safety Shutdown System

In Section III.C.2.b.1) of the SBCAP, Honeywell proposes the installation of a Seismic Safety Shutdown System. The purpose of this system is to initiate the automatic closure of isolation valves installed on certain process vessels during a seismic event that approaches or exceeds a 475-year return period earthquake. The system is intended to isolate hazardous material within various system components and thereby limit the release of the materials during an earthquake. For the major components with large quantities of liquid UF_6, this system provides an additional layer of protection against large releases.

The seismically actuated shutoff valves for the Seismic Safety Shutdown System will be located on the [redacted]

The Seismic Monitoring and Shutdown System will consist of three main subsystems. The first subsystem is the seismic stations. Three seismic stations will be installed in different locations around the plant. Each seismic station will be mounted over a concrete pad and will consist of a motion sensor (accelerometer) and a motion recorder. The purpose of the seismic stations is to monitor and record ground motion at the MTW facility. Upon detection of a seismic event that approaches or exceeds a 475-year earthquake the seismic station will send a trip signal to the second subsystem, the Relay Panels. This subsystem is the logic solver of the system and consists of an arrangement of electromechanical relays that will perform the 2 out of 3 voting and trigger the shutdown of some systems and the closure of the isolation valves if 2 of the 3 seismic stations detect a 475-year earthquake. The third subsystem will be the field devices. The function of the field devices is to execute the shutdown of the systems and closure of the valves in the event of an earthquake. The field devices are remote-actuated shut off valves and relays controlling various processes.

Section III of Honeywell's SBCAP provides a general description of the Seismic Monitoring and Shutdown System, the proposed locations for the installation of the field devices, and the field devices that will be designated as PFAPs. Appendix A-7 of the licensee submittal contains the PFAP design basis document. Reference 17 of the submittal provides a more detailed description of the system, how it will be implemented at the MTW facility, and the list of the proposed equipment to be used for the system.

10.1.2 Review of the System

For the evaluation of the Seismic Monitoring and Shutdown System, NRC staff performed a review of the documents provided by the licensee in the SBCAP and Reference 17 of the submittal (Seismic Monitoring and Shutdown System). Additionally, NRC staff reviewed design documents and construction packages, during visits to the MTW facility and conducted interviews with Honeywell staff to evaluate the adequacy of the system. The NRC staff review is based on the general safety criteria of 10 CFR 40, including 10 CFR 40.32(c). The staff also used guidance from NUREG-1520 Revision 1, “Standard Review Plan for Review of the License Application for a Fuel Cycle Facility.”

10.1.3 Implementation of Seismic Safety Shutdown System

The implementation of a Seismic Safety Shutdown System will allow Honeywell to isolate hazardous materials and automatically shut down the facility in the event of a 475-year or greater earthquake. Installing [redacted] shutoff valves on equipment [redacted] reduces the likelihood of a release of hazardous material in the event of pipe failure during an earthquake. The system is designed to “fail-safe” upon loss of power and/or loss of air flow. Honeywell designated some of the shutoff valves connected to the system as PFAPs and others as asset protection safe-guards. The shutoff valves to be designated as PFAPs are those on the [redacted] The shutoff valves on the [redacted] will be designated as asset protection safe-guards.

The staff reviewed and evaluated the chemical hazards events that could impact systems containing UF_6. The staff identified that in the event of an earthquake or tornado there is a potential [redacted] By installing shutoff valves at [redacted], Honeywell reduces [redacted] impact systems or components containing UF_6. The Seismic Safety Shutdown System provides additional layers of protection by isolating the UF_6 inventory contained in the equipment within the FMB, by limiting the release of UF_6 in the unlikely event of a pipe failure and by protecting against release of hazardous materials not regulated by the NRC.

10.1.4 Evaluation of the Equipment

Honeywell states that all the equipment to be used in the Seismic Safety Shutdown System will be seismically certified by IEEE-344 (or equivalent) by the vendor and/or by a walk-down analysis by a seismic capable engineer to ensure all the equipment will withstand a design basis earthquake. Appendix B provides preliminary vendor information for the equipment proposed to be used in the system. The staff reviewed the proposed equipment and associated vendor information and found it acceptable for use for the system.

10.1.5 Staff Evaluation

The NRC staff performed a review of the design and specifications of the Seismic Safety Shutdown System. The staff verified that all electrical equipment and components of the Seismic Safety Shutdown System were seismically certified either under IEEE-344 or by walk-downs performed by a seismic engineer. The staff evaluated the functions and logic of the system to verify independence and that the system operates in a fail-safe mode, by doing in office reviews of plant drawings and observing testing of the entire system. The staff evaluated the portion of the system designated as PFAPs using NUREG 1520 to ensure that chemical hazards events that could impact license materials are highly unlikely. Based on this review, the NRC staff concludes, with reasonable assurance, that the requirements of Section IV.1 of NRC Confirmatory Order EA-12-157 have been met because the design and procedures for the installation of the Seismic Safety Shutdown System are based on industry accepted codes, standards, and procedures. In addition, the NRC staff has concluded that the asset protection portion of the system provides additional layers of protection, by reducing the amount of licensed hazardous material that might be released in the highly unlikely event of a pipe failure.

10.2 Tank Farm

Section III.B of the SBCAP describes Honeywell's corrective actions for the storage of anhydrous HF and anhydrous NH_3 in the tank farm. NRC's regulatory authority covers these chemicals only to the extent that their release or handling may affect the safety of NRC-licensed materials and thus adversely affect workers or the public. The staff determined that the corrective actions that Honeywell is implementing for seismic and tornado hazards are passive (e.g., modifications to structure) or automated (e.g., isolation valves) and would not require workers to intervene or take action to limit releases of UF_6 from the FMB during a seismically-initiated event. Thus, the staff did not evaluate the risk mitigation for the storage of HF and NH_3 in the tank farm. As described above, the staff did review the Seismic Monitoring and Shutdown System.

10.3 Fire Safety and Loss of Power

On February 20, 2013, the staff issued RAIs to Honeywell (NRC, 2013b) to clarify accident sequences associated with a seismically induced release of natural gas and the potential for an explosion or fire. Honeywell's response to the RAIs (NRC, 2013b) states that in order to protect the FMB from a substantial release of natural gas [redacted] In addition to preventing the natural gas supply [redacted]

The staff also requested information (NRC, 2013b) to clarify the potential impacts of loss of power at the plant. In response to the RAI (NRC, 2013b), Honeywell provided a loss of power hazard assessment that shows that the process facilities handling UF_6 are configured to shut-down in a safe manner.

10.3.1 Staff Evaluation

The NRC staff reviewed the information provided by Honeywell regarding seismically induced fires or explosions [redacted] and thereby reduces the potential for fire hazards within the FMB building. The staff also reviewed the loss of power hazard assessment provided by Honeywell and concludes that Honeywell adequately evaluated the potential impacts to the facility in the event of loss of power. The use of fail-safe control valves provides assurance that facility will achieve a safe condition upon loss of power.

11.0 Emergency Plan

The provisions of the Honeywell's ERP and its supporting procedures were developed to provide an appropriate means of detection and response for multiple industrial incidents and natural disasters. This plan is intended to be fully consistent with the multiple regulatory requirements that apply to activities at the MTW facility, including 10 CFR 40.31(j) and 20 CFR 191.120(q).

11.1 Regulatory Requirements

The licensee is required by 10 CFR 40.31(j)(1)(ii) to have an emergency plan for responding to the radiological hazards of an accidental release of source material and to any associated chemical hazards directly incident thereto.

11.2 Regulatory Acceptance Criteria

Regulatory Guide 3.67, "Standard Format and Content for Emergency Plans for Fuel Cycle Facilities," contains the guidance to be used to judge the level of detail required to comply with the applicable requirements for an emergency plan in 10 CFR 40.31(j)(3) (NRC, 1992). In the Confirmatory Order dated October 15, 2012, the NRC required Honeywell to submit a revised ERP that, consistent with the evaluation of external events at the MTW facility, defines all planning bases and articulates all necessary modifications to the MTW facility (NRC, 2012b).

11.3 Staff Review and Analysis

To address the possibility of a plant emergency, the MTW facility maintains appropriate agreements and working relationships with State and local government agencies and support organizations. Honeywell has both an ERP and a program to support local responders, as required by 10 CFR 40.31(j)(3), including an emergency response team to mitigate the potential impact of a process chemical release or incipient fire. Plant personnel are trained and equipped to provide the initial response to such events. The response would be initially supplemented by the Massac County Emergency Services, with support from three area hospitals: Massac Memorial, Lourdes, and Western Baptist. If the situation warrants it, further support is available from the Illinois Emergency Management Agency (IEMA) which provides a point of contact and coordinates efforts for State support.

In the event of an emergency requiring offsite support, the facility Crisis Manager will coordinate off-site emergency response through a dedicated phone line or the Massac County 911 emergency System. The Crisis Manager will coordinate reports of an Alert or Site Area Emergency to the Massac County Emergency Services, IEMA, and NRC. The notification to the Massac County Emergency Services will be made within 15 minutes of the emergency declaration. Notifications to IEMA and NRC will be made within 1 hour of the emergency declaration. The Crisis Manager is also responsible during a Site Area Emergency for ordering the sounding of the two near-site sirens, which are located on the licensee-owned property across from the facility site.

Because the most reliable indication of a UF_6 release from the plant is observation of the condensing UF_6 cloud, it is unlikely that sufficient time will exist in an emergency situation involving a UF_6 release to allow for evacuation of the downwind population. Efforts to evacuate downwind members of the populace are likely to worsen the exposure potential by drawing the population outside as the cloud is passing. Therefore, the only preplanned protective action recommendation provided from the licensee to the local authorities is for the sheltering in-place of the public within a radius of 1.3 miles of the facility upon the declaration of a Site Area Emergency.

Descriptions of the types of accidents, including the maximum credible UF_6 release, are discussed in Section 2 of the ERP. The assumptions and modeling parameters are listed. This information fulfills the requirements of 10 CFR 40.31(j)(3)(ii).

11.4 Description of Accidents and Releases

A number of potential accident situations, ranging from minor to very serious consequences, have been analyzed by Honeywell for events that could occur in the plant. Honeywell has determined that a large UF_6 release is the only event with the potential to cause health hazards to the nearby population. The previous revision to the ERP, prior to the MTW facility upgrade, provided a description of two possible releases of UF_6. There was a maximum credible release which would be at a magnitude that might be visible at the nearest plant boundary, although it would not be expected to produce measurable changes in the off-site environment. Additionally, there was a hypothetical significant release of UF_6 [redacted] The current revision to the ERP contains the following descriptions of postulated accidents which could result in the release of UF_6.

11.4.1 Most Credible Release

The ERP provides that the most credible UF_6 release that could occur in the plant is believed to result [redacted]. This is the most credible event since [redacted] is used on a routine basis by the licensee and therefore has a higher potential for equipment failure and/or human error. Honeywell has installed engineered safeguards [redacted] If a member of the public were present at the fence for the entire duration of the 30-minute release modeled, the intake of soluble uranium would be 1.1 milligrams. This intake is below the intake threshold of 8 mg of uranium that might produce some transient changes in urine indicating some effect, and significantly below the 45 mg intake level which may result in permanent kidney damage.

11.4.2 Releases Related to External Events

The ERP states that in 2013, Honeywell retrofitted the process building structural supports, equipment and piping restraints, and reduced significant chemical source terms. Honeywell further installed seismic recognition instrumentation, engineered a confinement system, and protected critical assets from severe wind and tornado debris by installing armor to improve response to natural disasters.

The ERP provides that the improvements to the FMB structure were engineered to withstand a 475-year return period earthquake. Process vessels and process piping were also strengthened using the same earthquake engineering recommendations. Additionally, footings were added around the vessels which contain liquid UF_6 in order to keep the vessels from being dislodged. Honeywell concluded that these engineering restraints reduce the likelihood of mechanical damage to the vessels thereby greatly improving survivability during a seismic event. As described in Section 8.0 of this TER, Design of Structures, Systems and Components, the staff reviewed Honeywell's structural modifications and concluded that the performance of the building structure will adequately prevent or mitigate consequences to the public from the release of hazardous chemicals associated with licensed material.

Based on accident modeling, the ERP states that if UF_6 was released in the FMB at a height [redacted] the HF would not reach the ground in a concentration greater than the AEGL-2 level. Using this information, Honeywell engineered a confinement system that would confine the UF_6 [redacted] in the event of a release of UF_6 into the building. The ventilation system has a vent stack at 90 ft above the grade evaluation that allows the HF to be sufficiently dispersed due the release height that it does not present a significant hazard to employees and the public. As described in Section 9.0 of this TER, Chemical Consequences, the staff reviewed the effects of offsite releases of UF_6 following a seismic event and concluded that offsite consequences will be below AEGL-2 for up to the 1300-year return period earthquake.

The ERP further necessitated that Honeywell perform an analysis for vulnerabilities to wind events. Based on this analysis, armor-plate shielding was installed [redacted] protect critical plant equipment from debris produced from severe winds. The ERP provides that due to the improvements discussed previously in this section, the MTW liquid UF_6 process is judged to be fully capable of withstanding a design basis earthquake ground forces without a UF_6 release and that compliance with the wind/tornado risk performance requirements is demonstrated.

11.4.3 Hypothetical UF_6 Release

The regulatory analysis provided in NUREG-1140, "A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees," discusses that of all the accidents considered, the rupture of a heated 14-ton cylinder of UF_6 was clearly and by far the most hazardous to the public offsite (NRC, 1988). While the currently installed engineered safeguards in the UF_6 cylinder filling and handling area are believed by Honeywell to be adequate to preclude a large uncontrolled release of UF_6, such an incident was modeled to determine the hypothetical public health impact. [redacted]

It is NRC policy to plan to avoid acute fatalities and serious injuries for the worst case accidents. With this in mind, NUREG-1140 recommends that the protective action distance assuming the rupture of a 14-ton cylinder would be 1 mile. The protective actions could be movement out of the plume, sheltering in buildings, or ad hoc respiratory protection, depending on practicality and feasibility in the actual situation. As discussed in Section 11.3 of this TER, the ERP provides that when a Site Area Emergency is declared, Honeywell will automatically issue a Protective Action Recommendation (PAR) to shelter in place all members of the public within a 1.3-mile radius of the plant.

11.5 Evaluation Findings

The staff reviewed the ERP using the guidance in Regulatory Guide 3.67 which contains guidance on the level of detail required to comply with the applicable requirements of 10 CFR 40.31(j)(3)(I) through (xiii). The staff agrees that, considering the extensive facility modifications, a pigtail failure is the most credible source of UF_6 release. The staff also notes that the PAR selected and incorporated into the ERP is consistent with the cylinder rupture described in NUREG-1140. After reviewing Honeywell's ERP dated January 25, 2011, and the changes to the ERP dated September 4, 2012 and May 14, 2013 using Regulatory Guide 3.67, the staff concludes that the ERP is acceptable. Accordingly the staff concludes that the revised ERP allows the MTW facility to conform to the requirements of the Confirmatory Order.

12.0 Conclusions

Under Section IV of the Confirmatory Order, Honeywell was required to provide an evaluation of external events at the MTW facility that clearly defines and provides the safety bases for: seismic and wind design; the structures, systems, or components relied upon to protect workers and the public during both intermediate and high consequence events; the definitions of "intermediate-consequence event" and "high consequence event" for non-radiological releases; and the definitions of "unlikely" and "highly unlikely" for seismic and wind events. To support this evaluation, Honeywell was required to document the design bases for the proposed modifications to MTW facility (e.g., design criteria, engineering methodology, and application of codes and standards). Honeywell also was required to submit a revised ERP consistent with this evaluation of external events.

The staff reviewed the information provided by Honeywell and has determined that the safety basis, the risk to public and workers, and the ERP for the upgraded MTW facility provide reasonable assurance of adequate protection of worker and public health and safety. The following is a summary of the staff's findings based on its evaluation of whether the SBCAP provided an adequate safety basis for the seismic and tornado modifications:

12.1 Honeywell's Safety Basis for Seismic and Wind Events

Honeywell provided the safety basis for the seismic and wind events using a risk-informed methodology that used an ISA analysis. In support of the analysis, Honeywell provided a revised risk matrix, consistent with the revised definitions of likelihood and consequence severity categories for seismic and tornado events. As described in Section 5.0 of this TER, the staff confirmed Honeywell's application of the risk matrix and demonstration of highly unlikely for the facility modifications for a range of seismically initiated scenarios up to and beyond the design basis of the modifications. The staff also confirmed Honeywell's application of the risk matrix and its demonstration of highly unlikely for the facility modifications associated with tornado-generated missiles are adequate. In addition, staff verified that, if implemented, the facility modifications meet the 10 CFR Part 40 requirements that equipment, facilities, and procedures be adequate to protect worker and public health and safety. Through this evaluation, the staff finds that there is reasonable assurance that risk to health and safety is adequately limited for workers and the public. Thus, staff finds that Honeywell meets the requirements of Section IV.1 of the Confirmatory Order.

12.2 Honeywell's Evaluation of Structures, Systems, and Components

Honeywell provided information on the structures, systems, and components relied upon to protect workers and the public during both intermediate and high consequence events. These modifications include strengthening the FMB structure, piping supports, and vessel restraints to prevent possible releases of UF_6/HF; increasing the protection of the liquid UF_6 inventory through implementation of seismic actuated shutoff valves and tornado missile shielding; and providing additional measures to confine the distillation area to reduce the release rate of any UF_6/HF releases. The staff reviewed the studies that Honeywell conducted and the resulting designs for these facility modifications. The staff also considered whether Honeywell has provided sufficient information to determine that these modifications adequately limited the risk to any individual. Based on the staff's review of Honeywell's design and implementation of the modifications to the FMB structure and the restraints and supports for the process equipment and piping, the staff has reasonable assurance that structural performance of the modified building and equipment will adequately prevent the release of material during a seismic event. The upgraded FMB would not sustain damage leading to a high consequence release of UF_6/HF unless it experiences an earthquake with a magnitude of at least a 1300-year return period. Additionally, the building is not expected to sustain significant damage from seismic loads equivalent to the 1700-year return period earthquake. Also, based on the staff's review of the design and installation of the shielding for tornado missiles, the staff has reasonable assurance that the shielding will adequately prevent the release of material from a tornado missile event. Thus, the staff finds that Honeywell had met the requirements of Section IV.1 of the Confirmatory Order.

12.3 Honeywell's Definitions of Intermediate and High Consequence Events and Likelihood for Seismic and Wind events

Honeywell provided definitions for consequence severity categories in Tables 5 of its SBCAP. As described in Section 5.0 of this TER, the staff finds these definitions to be consistent with definitions in Honeywell's ISA methodology. Honeywell also provided revised definitions for the risk performance categorization of likelihoods in Tables 4 and 13 of its SBCAP. As described in Section 5.0 of this TER, the staff finds the definitions for consequence severity and likelihood for risk performance to be reasonable and consistent with definitions used by other fuel cycle facilities. For its ISA analysis, Honeywell provided a risk matrix (Table 6 of its SBCAP) consistent with these definitions. Thus, staff finds that Honeywell has met the requirements of Section IV.1 of the Confirmatory Order.

12.4 Honeywell's Documentation of the Design Bases

As described in detail in Section 8.0 of this TER, the staff finds that the safety bases, structural design criteria, and methodology that Honeywell used to design the modifications to the MTW facility are based on industry-accepted codes, standards, and procedures. The staff reviewed construction drawings, performed its own independent calculations, conducted in-office reviews of Honeywell's methodologies and analyses, and performed walk-downs of a sample of the modifications. Based on its review, the staff found that Honeywell meets the requirements of Section IV.1 of the Confirmatory Order.

12.5 Honeywell's ERP

Honeywell submitted a revised ERP. Based on the review described in Section 11.0 of this TER, the staff finds that given the modifications and Honeywell's ability to limit source terms, the ERP is acceptable and that it conforms to the requirements of the Confirmatory Order.

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