

OE-3: 2017-02

February 2017

## Moving HVAC Parts Pose Amputation Risk

### PURPOSE

This Operating Experience Level 3 (OE-3) document provides information about a safety concern related to maintenance operations involving equipment that utilizes fans such as air handlers, exhaust fans, and other types of heating, ventilation, and air conditioning (HVAC) equipment at Department of Energy (DOE) facilities.

### BACKGROUND

In 2016, two serious events reported to the Occurrence Reporting and Processing System (ORPS) involved personal injuries while employees were working on HVAC equipment. Similar events were reported to ORPS in previous years.

On October 14, 2016, a technician at the National Energy Technology Laboratory (NETL) was injured when performing preventative maintenance checks on a return air fan. Airflow through the duct kept the return air fan rotating after the unit had been de-energized (i.e., “windmilling”). To stop the rotation of the fan, the technician placed his gloved hand on the fan pulley, and his glove was caught between the belt and the pulley. The glove pulled the technician’s finger into a pinch point, severing his left middle finger above the first knuckle. The choice to use his hand, rather than an anti-rotation device, to stop the “windmilling” effect resulted in the technician’s injury. (ORPS Report FE--NETL-GOPE-NETLMGN-2016-0006)

On June 15, 2016, a worker at Idaho National Laboratory (INL) received an injury to his right ring finger while working on an air handler. The worker was performing preventative maintenance on the air-handling system under a simple lockout/tagout (LO/TO). The LO/TO isolated only the electrical energy for the fan and did not address the potential hazard of unexpected movement of the fan or belt caused by air flow or other energy sources. The worker placed the palm of his right hand on the belt, with his fingers wrapped around the belt. When the fan unexpectedly started to rotate, the movement pulled the worker’s hand into the pulley. The worker manually reversed the belt with his left hand, freeing his right hand. The resulting injury consisted of severe trauma and a broken bone in his right ring finger. (ORPS Report NE-ID--BEA-STC-2016-0004)

On September 18, 2012, a worker at Thomas Jefferson National Accelerator (TJNAF) was injured when his gloved right hand was pulled into a pinch point between the fan belt and fan pulley of a large roof-mounted exhaust fan. After securing electrical power and locking the local disconnect switch, the subcontractor removed the guard to inspect the fan belt and pulleys as part of a preventative maintenance work order. He reported that the belt was barely moving when he placed his hand on the twin fan belt. When his hand was pulled into the pinch point, it resulted in a hand fracture, which required surgery to repair. (ORPS Report SC--TJSO-JSA-TJNAF-2012-0013)

On November 2, 2010, an electrician sustained injuries to his fingers while preparing to replace an electric motor on an air-handling unit. When the electricians performed the required electrical lockout and removed the fan guard, they noticed

that the fan was turning counterclockwise at a low speed. They determined that since the motor was electrically de-energized, the air flow was from another fan in the system that was causing a back-draft rotation. One electrician reached his right hand in and grabbed the fan belt to attempt to stop the fan rotation. He sustained lacerations and fractures to three fingers when the rotating fan pulled his hand between the two fan belts and the fan pulley. It was determined that, although the proper Hazardous Energy Control (HEC) was used for the electrical hazards, the HEC requirements for rotating equipment were not recognized or applied to account for the mechanical energy. (ORPS Report EM-CBFO--WTS-WIPP-2010-0009)

## **ANALYSIS AND OBSERVATIONS**

These events were reviewed to determine common factors and identify lessons learned. The following observations are noted.

- A common cause of these events was the failure to recognize the hazards of the rotating belt, shaft, pulley, or fan “windmilling” (i.e., rotation of the impeller and drive components due to a draft in the system) caused by air pressure differentials in an open system.
- The hazards associated with “windmilling” and controls to reduce or eliminate those hazards were not included in the job hazard analyses, job pre-briefing process or procedure.
- Workers were inadequately trained and/or briefed which caused them to mistakenly believe that when electrical energy was turned off hazardous energy exposures were controlled. This training and briefing inadequacies caused workers not to account for any remaining mechanical energy in the units.

## **DISCUSSION**

The hazards associated with the various moving components of HVAC systems is a recognized hazard. Despite this, management inadequately addressed hazardous mechanical energy when developing, reviewing and approving LO/TO procedures before work began. Coupled with inadequate training of maintenance personnel, this resulted in workers failing to apply the proper LO/TO procedures during maintenance and repair of these systems. This hazard resulted in two serious hand injuries in 2016, alone.

In the above instances, the focus of personnel working on the equipment was to isolate electrical energy to the fan. They failed to isolate the mechanical energy associated with “windmilling” because they had not been adequately trained to recognize the hazard as well as the job hazard analysis for these tasks and job pre-briefings did not clearly identify this recognized hazard.

When preparing to work with HVAC equipment, it is critical to recognize that there are three causes of motion of equipment parts: (1) electrical energy supply; (2) inertia after electrical energy supply stops; and (3) air flow caused by pressure differentials, or “windmilling.” Management should ensure that work control documents appropriately address the hazard of parts moving during normal operation, after electrical power supply has stopped, or at any time due to “windmilling.”

To stop the rotation of parts after the electrical energy supply has ceased, workers should be trained that they are NEVER to use their hands or a hand tool. Instead, they should be trained to close HVAC dampers, install baffles, or put fan partitions in place to isolate the fan from any air flow causing the rotation. Once rotating parts have stopped, the impeller should be physically restrained to prevent additional movement. Products are commercially available that prevent “windmilling” and management should ensure that such equipment is provided for the workers’ use.

Adequate training of workers should provide them with a fundamental understanding of the physics

that operates a fan with a belt-and-pulley system. In all of the ORPS reports above, workers attempted to grab the fan belt. In fact, the mechanical energy in the movement of the belt is equal to the mechanical energy in the large diameter fan blades. Due to their size differences, therefore, the fan belts move with greater force than the fan blades. Inadequate training of the workers resulted in their underestimating this force and miscalculating the risk involved in attempting to stop the fan by grabbing the fan belt.

Additionally, adequate training of workers should inform them of stroboscopic effects, wherein a rotating shaft appears to be stopped. To prevent against these effects, it is recommended that irregularly spaced marks be placed on the moving parts.

## RECOMMENDATIONS

The following recommendations for the safe maintenance and repair of HVAC equipment are provided.

- Ensure all work planning and control documents address proper hazardous energy controls. All LO/TO procedures should address multiple energy types that may be present and that require isolation.
- Train employees on the dangers of using a hand, other body part, or hand tool as a brake for moving parts of HVAC equipment, even when it appears to be moving very slowly or not moving at all.
- Before beginning inspection or maintenance of any HVAC equipment, ensure that the fan is turned off, the electrical power is properly locked/tagged out, and the mechanical energy has been isolated by restricting airflow through the housing or opening and securing the propeller.
- Install physical blocking or restraint devices to prevent the movement of HVAC equipment parts after the equipment is electrically de-energized and before maintenance/repair work has begun.

- Any maintenance or inspection of HVAC equipment is performed by qualified and trained maintenance personnel.

The following corrective actions will be or have been performed at sites where ORPS reports were filed on these occurrences, and should be applied as appropriate.

- NETL will review all work orders for hazard identification and mitigation until LO/TO plans can be completed. They will conduct refresher training in LO/TO requirements and training on trade-specific Worker Protection Plans.
- INL revised the work order for Preventative Maintenance on the unit, distributed a Lessons Learned on the event, and conducted an Extent of Condition Review on the use of supplemental protective measures, such as blocking, across INL.
- TJNAF contractors re-trained their staff on the Hazardous Energy Control Program.

## CONCLUSION

It is important for workers to be educated on the risks posed by moving parts of HVAC systems. LO/TO processes must include requirements to isolate not only the electrical energy in the system, but also the mechanical energy of the fan, belt, pulley, or shaft. LO/TO must be strictly adhered to in order to prevent the occurrence of serious injuries, including amputations.

## REFERENCES

ORPS Report FE--NETL-GOPE-NETLMGN-2016-0006. *Employee Sustains Hand Injury Inspecting a Motor Side Belt on an HVAC Fan*

ORPS Report NE-ID--BEA-STC-2016-0004. *Inadequate LO/TO Determination Results in Hand Injury*

DOE Lessons Learned ID: INL-2016-0049. *Inadequate LO/TO Results in Hand Injury*

SC--TJSO-JSA-TJNAF-2012-0013. *HVAC Subcontractor's Hand Broken While Performing Preventative Maintenance on an Exhaust Fan*

EM-CBFO--WTS-WIPP-2010-0009. *Hazardous Energy Control Process Failure – Mechanical*

DOE Lessons Learned ID: WIPP-LL- 2010-03. *RED-ISM Mechanical Energy Injures Worker*

DOE Lessons Learned ID: DOE/CH-A198E. *Rotating Shaft Accident at Ames Laboratory Ames, Iowa*

### **ADDITIONAL SOURCES OF INFORMATION**

The following websites provide additional information about industrial equipment safety and regulations:

Air Movement and Control Association.

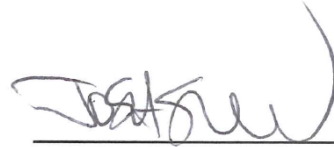
[www.amca.org](http://www.amca.org)

DOE Policy 450.4A, *Safety Management System Policy*

Occupational Safety and Health Administration.  
<https://www.osha.gov/SLTC/controlhazardousenergy/>

Questions regarding this OE-3 document can be directed to Ashley Ruocco at 301-903-7010 or [ashley.ruocco@hq.doe.gov](mailto:ashley.ruocco@hq.doe.gov).

This OE-3 document requires no follow-up report or written response.



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