Chilling Facts About Chiller Units
Tactics for Titanium Fires

by Lieutenant John Flynn, PE

A basic tenet discussed in the early stages of most hazardous-materials training classes is that hazardous-materials incidents require an entirely different thought process than other fire-related responses. Haz-mat incidents generally possess a higher degree of uncertainty and a consequential higher degree of risk than other kinds of emergencies. Haz-mat response, therefore, is predicated on a "no-rush" philosophy somewhat foreign to most firefighters. The intent is to allow a thoughtful approach with due consideration of known and potential hazards posed by the materials at hand.

The odd situation occurs wherein a bona fide hazardous-materials incident further is complicated by the presence of fire. The first responder now is faced with a dilemma: the need to satisfy the powerful firefighter instinct for rapid extinguishment versus the time-consuming process of hazard identification, analysis and mitigation.

Such a dichotomy was presented to the Fire Department on two separate occasions in recent months. Fate once again grasped the opportunity to confound the law of averages and provided the FDNY with what is likely to be the only two titanium tubing fires in the history of New York City--within six weeks (and six blocks) of each other. The circumstances surrounding each of these fires were interesting, extremely challenging and, most importantly, the basis for a unique learning opportunity.

One New York Plaza, December 1, 2001

The first fire occurred on December 1, 2001, at One New York Plaza in lower Manhattan. The first-arriving units became aware of a smoke condition emanating from a large, concrete-encased mechanical room in the basement. Within this room was a large-diameter "chiller" unit (see sidebar), which was in the process of being dismantled by a subcontractor working for the facility.

The chiller unit was situated upon a raised steel platform approximately 15 feet above the basement floor level. The dismantling process involved torch-cutting away sections of the outer steel shell of the unit from atop the tank to expose the titanium rods housed within. The massive assembly of titanium rods exposed in this manner then was severed laterally by cutting deeply with the torch, in a pattern similar to chopping stalks of celery. The work was slow and arduous.

Post-fire interviews with building maintenance personnel indicated that numerous fires had occurred within the chiller unit during the course of several days of cutting and the subcontractor had controlled these fires using portable dry-chem extinguishers. On the day of the incident, one of these fires, stubborn and deep-seated within the unit, rapidly grew to a point beyond control.

First-arriving Fire Department units quickly found themselves with their hands full. The room was large, but possessed few openings for ventilation. The smoke condition quickly became severe. Location and identification of the fire were time-consuming and access to evaluate the fire was difficult due to the height of the unit above floor level.

Battalion Chief George Belnavis (First Battalion) ordered a

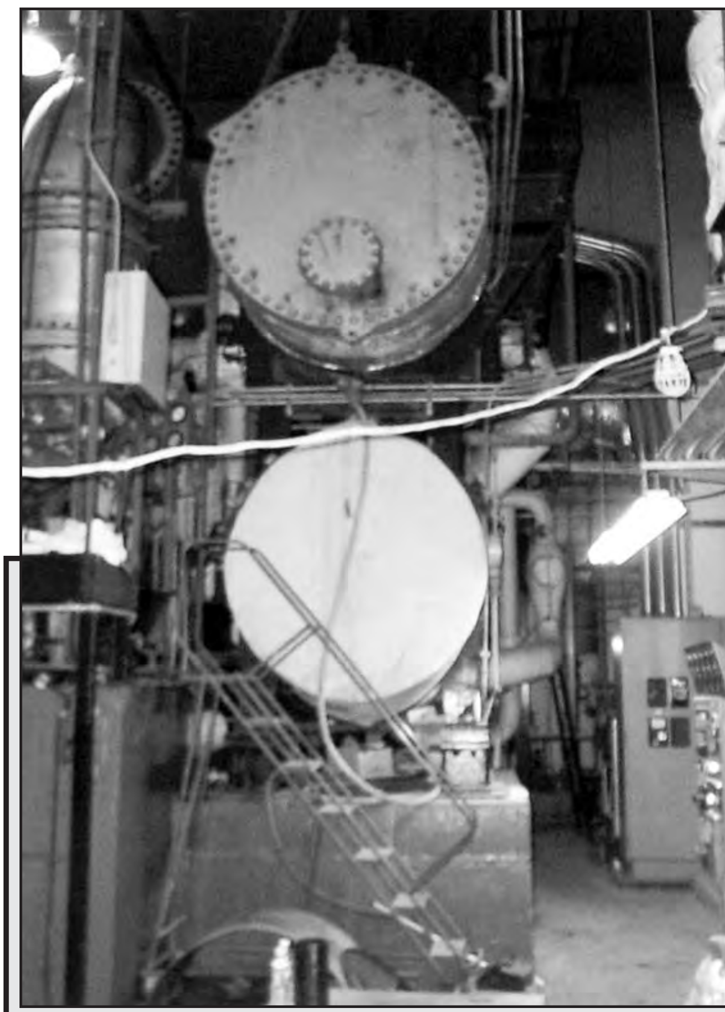

photo by Lieutenant John Flynn

The Chiller Unit

The purpose of chiller units--commonly found in buildings throughout New York City--is to allow a heat exchange to occur from a cool water source to a second medium such as coolant or refrigerant. The tubing within the elongated cylindrical chiller unit is thin-walled and possesses a large surface area. It is fashioned in a large, back-and-forth "loop" configuration, such that many tubes are parallel with each other in a tightly packed "bundle."

Titanium is used as a tubing material when brackish, salt or polluted water is employed as a cooling medium. It was used in both the World Trade Center and One New York Plaza building due to the proximity of the Hudson River and New York Harbor as water sources. Most chiller units do not possess titanium tubes. Building Inspection is a recommended time to ascertain from building engineers whether a material such as titanium exists in mechanical equipment.

search for a means of increasing ventilation of the mechanical room and instructed units to be aware of alternate routes of access to the elevated chiller unit for extinguishment. Both goals were accomplished when it was determined that the mechanical room extended beneath the exterior sidewalk and the concrete ceiling of the room was just below the sidewalk at street level.

A vent fan assembly that covered an area of approximately six by six feet served the mechanical room; removal of the assembly would result in a sizable opening into the room from the sidewalk. The opening was large enough to permit effective ventilation and was located in proximity to the chiller unit to allow for the application of extinguishing agent to the burning contents. Rescue 1 was delegated the task of removing the fan assembly to facilitate both ventilation and access.

Coincident with the ventilation activity at street level, two 2 1/2-inch hose-lines were stretched by Engines 4 and 6 from the standpipe to the basement mechanical room. Acting Deputy Chief Wayne Cartwright (First Division) and Chief Belnavis determined that application of water directly onto the burning titanium was not advisable (see sidebar, "The Trouble with Titanium"). After these lines were in place, it was determined that the intensity of the fire was growing and careful cooling of the interior surfaces of the room was in order.

The potential ramifications of applying water directly to the chiller unit were considered in this decision and attempts were made to reduce the potential for this occurrence. Water was applied to the sidewalls and ceiling using a fog stream. In the heavy smoke condition, water inadvertently was directed above the chiller unit and an unknown quantity of water entered the shell of the unit and came in contact with the titanium.

An explosion of significant magnitude occurred, resulting in numerous injuries, the toppling of a large concrete masonry unit (CMU) wall remote from the room and displacement of heavy fire pump machinery in the basement. Additionally, fire vented through the partially open vent fan assembly at sidewalk level to a height estimated at 50 feet, burning several members of Rescue 1 who were in the process of removing the fan assembly.

World Trade Center site, January 15, 2002

A second and astoundingly similar incident occurred on January 15, 2002, at the World Trade Center site. At approximately 8 p.m., Lieutenant John Flynn of Haz Mat Company 1 (HMC1) received a phone call from Deputy Chief Robert Mosier, on duty as the Fire Department Commander at the site. The Chief indicated that a large cylinder containing titanium rods was involved in fire within the debris pile and that several explosions had occurred within the cylindrical container. After a short discussion, it was determined that HMC1 should be dispatched to the scene.

Haz Mat Company 1 responded immediately. Company members found themselves in a position of unique advantage because considerable research had been done by the Officers and members of HMC1 following the incident of December 1, 2001. At the time of their arrival at the site at approximately 10:30 p.m., a preliminary plan had been formulated.

Upon arrival, a scene size-up indicated that the cylinder was, in fact, a heat exchanger virtually identical to the chiller unit encountered six weeks earlier. It was apparent that an individual intent on dismantling the cylinder had cut two holes in the top portion and, in the process, had ignited the interior titanium rods. Red hot flames and faint whitish smoke were pushing from these openings. Additionally, it could be observed through the holes that a large portion of the interior was involved in fire. First and foremost in the minds of the responders was the fact that an explosion of considerable magnitude was distinctly possible.

Further investigation yielded a number of factors that complicated mitigation. First, the cylinder was partially buried within densely packed debris and the entire length was not visible. The extent of the cylinder (and, therefore, the fire) within the pile could not be determined. Second, the cylinder rested approximately 20 feet from the exposed slurry wall at the west side of the excavation at approximately mid-height (B-3 level). This portion of the slurry wall only recently had been reinforced with "tie-backs" due to structural compromise incurred during the collapse of the Towers. This was likely the very worst location on the site for an explosion to occur because failure of the delicate slurry wall would have catastrophic results. Finally, two large tube trailers clearly marked "liquid oxygen" were resident atop the slurry wall directly above the cylinder and blocked in by large concrete median barriers. Such a complicated scenario would serve as a perfect training exercise for "worst case" incidents, but all responders were painfully aware that this was the real thing.

It was determined that as a first step, the tube trailers represented a very serious, immediate hazard and had to be removed. Surprisingly, the means to move these trailers (and the median barriers around them) readily were not present on-site. The contractor set about "making due" with raw manpower and limited machinery and estimated a completion time of one hour.

Following protracted discussion among Chief Mosier, Battalion Chief Jack Corcoran (Special Operations Command) and Lieutenant Flynn and after consultation with City-Wide Tour Commander Frank Fellini via telephone, it was determined that three options existed for control of the fire and reduction in the risk of explosion:

- Allow the cylinder to burn freely with the hope that it would "burn itself out" over time. This option was discounted because HMC1 resource Firefighters reported that titanium burns at very high temperatures, which would progressively weaken the shell of the cylinder, increasing the risk of cylinder failure. Furthermore, the extent and involvement of the fire within the pile was unknown and the fire might spread to uninvolved and deeply buried debris. This issue was complicated further by the fact that titanium reacts violently with many and diverse substances, among them chemicals such as trichloroethylene, liquid oxygen and water, all known to be present on-site.
- Inject an inert, heavier-than-air gas such as argon into the cylinder in an effort to displace the oxygen and smother the fire. Attempts at locating an adequately large supply of this gas through utilities such as Con Edison proved futile and great concern existed over the safety of a Firefighter approaching a tank to insert a hose and tube assembly. Additionally, the issue of locating a tube material with a melting point above titanium was daunting.
- Smother the fire with clean sand or soil. This option, while representing some element of risk, appeared to be the most reasonable following a risk versus reward analysis. The potential problems included the fact that sand or soil that could be guaranteed to be free of moisture and contaminants was impossible to obtain on short notice. The moisture content of the available sand and

The Trouble with Titanium

Useful in industry due to its strength, light weight and corrosion-resistant properties, titanium is not firefighter-friendly when burning. This combustible metal burns at extremely high temperatures and emits toxic fumes. It reacts violently with a large number of substances and extinguishing media, including water, CO2 and foam. Once extinguished, the fire often will re-ignite and run-off alone may create a fire or explosion hazard. Titanium dust in air can ignite or explode.

So how does one extinguish a titanium fire? The options include dry sand or dirt, dry chemical, soda ash and lime. More elaborate measures employed in industrial processes include smothering with inert gases. Ultimately, the incident may be one of those situations where the best thing to do is to do nothing--withdraw and let the fire burn itself out.

soil could not be determined and it was possible that the material might enter the tank and actually cause an explosion to occur through the introduction of moisture. A second concern was that the cylinder projected out of the base of a steeply sloping pile of debris and a stable sub-base did not exist for the approach of dump trucks and excavators.

Despite the apparent challenges, the last option was chosen. This resulted in obtaining sand remotely from the Department of Sanitation and Department of Parks (sand was chosen because it was less likely to possess moisture and contaminants than the soil/debris material available on-site). On-site personnel from the Mayor's Office of Emergency Management coordinated the delivery of the sand, which was necessarily a slow process; sand had to be located at remote locations, transferred into vehicles and delivered to the site, where it was further broken down for its final destination. Simultaneously, backfill material (debris) was placed into the voids around the cylinder to allow for close approach of delivery and placement machinery (dump trucks and excavators).

When an adequate supply of sand was on-site, it was placed gently via an excavator on top of and around the cylinder with special consideration given to covering the two existing holes. A radio-equipped member of HMC1 stood alongside the excavator operator and directed his movements; remaining members of HMC1 observed closely from the perimeter and provided guidance. As a final measure, it was determined that a portion of the exterior wall of the tank was to be left exposed to the air. This was decided for two reasons:

1. The temperature of the tank could be monitored directly using a thermal imaging camera.
2. The tank would cool off at a faster rate.

Following placement of the sand, the cylinder was monitored for several hours by the members of HMC1. Ultimately, it was determined (at approximately 2 a.m.) that the incident had been mitigated successfully.

Lessons learned

Several important lessons were made clear by each of these incidents:

1. Pyrophoric metals possess characteristics that must be clearly understood prior to the implementation of tactics. Water reacts with burning titanium to produce hydrogen gas (H2O ➔ H + O), which is a well-known explosion hazard. A first responder inadvertently may create a hydrogen bomb by allowing water to enter an enclosed burning cylinder containing titanium. Dry chemical, soda ash, lime and dry sand are the extinguishing media of choice.

photo by FM Woody McHale

(Above) Prior to the the fire in the basement involving titanium rods and a subsequent electrical explosion at One New York Plaza on December 1, 2001, several fires had occurred within this large-diameter "chiller" unit. A subcontractor was in the process of dismantling the unit.

2. Expect the unexpected. Most resource literature written for titanium indicates that this material is a fire/explosion hazard only when in powder, dust or other finely divided form. It is readily apparent that the large surface to mass ratio of tubing will allow for combustion also.
3. Mitigation of complicated incidents is very time-consuming and patience is essential. Immediate steps to reduce the hazard (such as removal of liquid oxygen stored nearby) precede more time-dependent measures, such as consideration of each and every avenue of attack.
4. Ventilation is critical for firefighting, as well as reducing the potential for structural failure in the event of an unforeseen explosion. Containers and storage rooms intended for explosive materials are designed with pressure-relief capabilities in the event of discharge. The proactive strategy of venting the involved room to the exterior in the first incident may well have saved Firefighters' lives.
5. Consideration of the "Initial Isolation Distance," per the North American Emergency Response Guidebook (ERG), is important in reducing the number of people potentially exposed at such an incident. (See "Fire and Explosion in Titanium Heat Exchanger," ***Pass It On Program***, Issue 1/2002, February 2002.)
6. The resources and experience of Hazardous Materials Company 1 are critical in incidents of this nature. Lessons learned from the earlier incident proved vital for a safe response to the later occurrence.
7. It is important to see the "big picture" during a size-up. The presence of titanium tubes within chiller units is not common unless the unit is located in proximity to a salt water source. Size-up must include a close look at all elements of "occupancy and location." The quantum leap of distinguishing a standard fire operation from a pyrophoric metals fire may be made with this knowledge in mind.

About the Author...

Lieutenant John Flynn is a 13-year veteran of the FDNY. Currently, he is assigned to Haz Mat Co. 1. He is a licensed Professional Engineer and has held the position of structural specialist on the FEMA Urban Search & Rescue Task Force since its inception in 1992.