Utility Conduits Suspended Between Ropeway Towers
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ABSTRACT:

Presentation of the design, construction and operation of aerial utility lines suspended between lift towers. The presentation is based on experience gained in the design, installation and operation of natural gas, potable water and waste water utility lines on the Iron Mountain Tramway in Glenwood Springs, Colorado.
Tourist tramways are often used to provide access to remote locations in mountainous terrain. In many cases, the upper terminal is a multiuse facility that requires basic utilities such as electrical power, water, natural gas and sewer. Fortunately, in most cases, these utilities can be economically provided by direct burial of the utility lines. However, the use of aerially supported utility lines can be considered in those rare conditions where traditional buried lines are either environmentally, economically or physically impracticable.

In 2003 aerial utilities lines were installed on the fixed grip pulse gondola manufactured and installed by Leitner Poma of America. The ropeway has a slope length of 4433 ft (1351m) and a vertical rise of 1352 ft. (412m). As installed, there are four groupings of two 6 passenger gondola cabins. Ultimate design capacity is 12 groupings of 3 carriers.

The ropeway accesses a multifunctional upper terminal at the Glenwood Caverns in Glenwood Springs, Colorado. The utility lines provide potable water, natural gas and gray water disposal for a 13,000 ft² (1,207 m²) upper station that includes a 150 seat restaurant, a 1200 ft² (111 m²) gift shop and support facilities. The tramway is operated year round. A mountain roadway provides limited year round access to the upper terminal.

During the first 18 months of operations the utility lines have proven to be an acceptable alternative to the traditional buried lines with certain limitations.
Design and Construction

Support Cable. The three utility lines (natural gas, water and gray water) are supported by a 7/16” (12 mm) IWRC EIP cable suspended directly under the tower crossarms. The selection of the cable size took into consideration live and dead loads of the utility lines, wind and the sizing of the available cable hangers. It was decided to use a standard 3 bolt guy clamp to connect the utility hanger to the support cable. A 7/16” cable was selected because it was the largest size cable that was compatible with this clamp. The factor of safety was designed for the longest span of 442 ft (135 m) with a 3% sag ratio. Local climatic conditions did not require that icing be taken into consideration. The support cable has a factor of safety of 2.5 when the utility lines are full with a 70 mph (112 km/hr) crosswind.

Clearance between the utility lines and the carriers must be taken into careful consideration. The assumed 3% sag ratio has resulted in less clearance than was anticipated. Although the ropeway haul cable was designed for a maximum 3% sag ratio, the sag of the haul rope on individual spans varies depending on the installed number of cabins within the pulse group and the loading of the cabins. In retrospect, the sag of the utility lines should have been designed to be less than the haul rope sag under the lightly loaded conditions of the initially installed capacity. Because the support cable is secured to each tower crossarm, these conditions may require that the incoming and outgoing support cable tensions differ. In these cases, the additional torque on the tower tubes and connections must be considered.

The cable was connected directly under the crossarm at a point adjacent to the tower tube for clearance issues and to reduce the amount of torque on the tower tube. Although installing the connection point on the lifting frame would have improved clearance, it was decided that the additional moment arm above the crossarm created unacceptable stress. The support cable was pulled from the upper terminal to the lower terminal across nylon rollers on each tower at the connection point. Once the cable was tensioned to provide a 3% sag ratio for the longest span, the cable was secured to each tower with strand vices.
Utility Conduits. The utility conduits are three 1-1/2" (38 mm) inside diameter fiberglass reinforced plastic tubing that is commonly used in the petroleum industry. The connections are integral threaded and coupled. The pipe which was manufactured by Star Fiberglass\(^2\) has been tested to confirm that there was no structural deterioration caused by ultraviolet radiation over the five year test period. The rated pressure for the pipe that was used on the project was 2000 psi (137 bars) for the lower section of the profile and 1500 psi (103 bars) for the upper half of the profile. The ultimate burst pressure rating for the lower section was 5000 psi (344 bars).

The pipe had been certified by a European testing agency for use in the transport of potable water. There was no similar United States certification available. The authorities having jurisdiction allowed the pipe to be use for this application in spite of no United States certification with the understanding that the pumped water would be tested monthly to confirm acceptable water quality.

The pipe was connected to the support cable at 10 ft (3 m) intervals. The connection was made with three bent plate parts that were bolted together to form a triangle. The triangle was bolted to the support cable with a 3 bolt guy clamp. The bent plates surround and lock into place a rubber gasket. The gasket was made by extrusion to match the profile of the three pipes. The goal was to ensure that the steel triangle would not contact the pipe and possibly cause abrasion. A communications line, which was electronically connected to the lift control system, was attached to the utility line to monitor the line integrity.

The pipe was installed in 30 foot (9.1 m) sections. The pipes were assembled into the support hangers before being placed into a rack that was suspended between two work carriers. The pipe laying crew started at the upper terminal and worked downhill on the light side. Each pipe assembly was attached to the support cable and then each pipe was mated with the uphill assembled pipes. The pipes were screwed together with a fabric pipe wrench to the recommended torque. Once the pipes were secured, the bolts on each hanger support were tightened to squeeze the triangular frame around extruded gasket. The entire process took about three weeks to complete.

Utility Connections. Steel utility pipes were attached directly to the first and last towers for the connection to the underground utilities. At the top of the terminus, reinforced rubber hoses were used to transition to the fiberglass pipes. This flexible connection allowed for movement between the suspended lines and the fixed steel lines attached to the towers.

A special bracket was fabricated for the crossarm on the first tower for the gray water line. The bracket was designed to act as a thrust block for the gray water as it transitioned from a high velocity flow within the fiberglass line to the steel line attached to the tower.

Vacuum breakers were attached to the lines at the upper terminus to allow for air to enter the lines during water drain back. These vacuum breakers were wrapped with heat tape for winter operations.

Operations

Waterline. The only source of potable water for the operation of the upper facility is the aerial waterline. During peak summer operations, approximately 5000 gallons (19,000 l) per day are used. This demand is reduced to about 2000 gallons (7570 l) per day during the winter.

Water is pumped from the base terminal directly to a 34,000 gallon (128,000 l) holding tank located vertically 157 ft (47 m) above the upper facility. Water gravity feeds the building with a static water pressure of 68 psi (4.6 bars). The holding tank provides for a 17 day water supply in the winter when the waterline may not be operational due to cold temperatures.

When the system was commissioned, the water was pumped by two positive displacement pumps at a rate of 30 gpm (113 lpm) with a total head of 1000 psi (69 bars). These pumps were subsequently replaced with a single 37 stage centrifugal pump with a flow rate of 42 gpm (159 lpm). Since water is drained from the line during colder temperatures, the piping system was designed to allow for drainage water to bypass the pumps to prevent pump damage.

Since the waterlines is not insulated, pumping in the winter is problematic and requires careful monitoring. If the water in the pipe was to freeze, there would be no technique that could thaw the pipe and prevent the frozen water from splitting the pipe. The upper tramway terminal is located at an elevation of 7100 ft (2164 m). An analysis of 100 years of daily temperature records for Glenwood Springs, Colorado with an elevation of 5700 ft (1737 m) shows that the average January monthly maximum temperature is 36.9 °F (2.7°C). Only the first ten days of January have an average daily maximum temperature (with a 68% confidence level) below 32 °F (0°C). Therefore, it is statistically possible to pump water during the coldest month. However, during colder winters or during extended stretches of cold temperatures, there are periods where pumping is not possible.
In order to monitor the water temperature, a waterline temperature gauge was installed at the upper terminal for the upper attendant to monitor conditions when pumping. Pumping was suspended when the incoming water temperature was 38°F (3.3°C). By suspending pumping operation at this point, there was sufficient latent heat to allow the water in the line to be drained back to the lower terminal before it reached the freezing point. With the initial incoming water temperature of 50°F (10°C) it was possible to continue to pump when the air temperature was 28°F (-2.2°C).

Even with careful monitoring of the pumping parameters, it was a challenge to keep the water level in the reservoir tanks to an acceptable level during the month of January. Although there was often a period of time during the day when pumping was possible, the total quantity of water pumped was dependant on the length of the pumping window. During the first winter of operation water levels in the tanks remained adequate for normal operation in the facilities even though there were days when pumping was not possible.

**Gray Water.** When the system was commissioned, there was no waste water disposal system at the upper facility. All waste water was conveyed to the lower terminal via the aerial pipelines for disposal by the local municipal waste water treatment facilities. Due to the small size of the aerial pipes, waste water was pretreated at the upper terminal to remove the solids. Waste water at the upper facility was pretreated with two 2500 gallon (9460 l) septic tanks installed in series. Solids were collected in these tanks and pumped from the tanks twice a year by pumper trucks.

Pretreated sewage was collected in a 5000 gallon (18,900 l) storage tank at the upper facility. A high water level sensor within the tank would start to pump the sewage to the top of the terminus tower. Pumping would continue until the low level sensor turned off the pump. The intent was to provide intermediate pumping of the sewage at higher flow velocities in order to avoid freezing of the downgoing sewage. It was assumed that water flowing at a high velocity had sufficient energy to prevent freezing even at low temperatures. This assumption proved to be incorrect. During the first winter, the automatic pumping during low temperatures resulted in a freeze up of the gray water in the utility line. Fortunately a warming trend allowed the line to thaw within a couple of days. Following the event, the sewage was only pumped when the air temperature was above freezing. In order to avoid a reoccurrence of this event, a 2000 gallon (7560 l) per day septic system was installed during the 2004 construction season to allow all sewage to be disposed of on mountain during the winter months when demand is limited.

Because the upper facility includes a 150 seat restaurant, the waste water includes a grease component. There was great concern that grease could accumulate on the walls of the aerial lines and eventually totally clog the line. In order to avoid this occurrence, all waste from the kitchen passed through a grease trap which was periodically pumped and hauled off the mountain. As an additional precaution, enzymes were added to the grease trap in an attempt to keep the grease in suspension. During the first summer of operations, there were indications that even these precautions were inadequate to prevent grease from accumulating on the walls of the utility line. Since there are limited options available to clean grease from the lines, the build up
of grease was a major concern. Ironically, the first winter of operations provided an unexpected solution to the problem. Apparently night time temperatures during the coldest months of the winter froze the accumulated grease that lined the pipe walls. It appears that the frozen flakes of grease were flushed down the lines when waste water was periodically pumped down the utility lines. A change in the type of enzymes used in the grease traps during the second summer of operations has apparently reduced the buildup of grease in the lines.

Natural Gas The transportation of natural gas on aerial lines attached to a ropeway could be perceived as a safety issue. The authority having jurisdiction had concerns that if the line ruptured and the gas was ignited, a blow torch effect may endanger the passing carriers or the haul rope.

The incoming static pressure of the natural gas was about 50 psi (3.4 bars). The factor of safety for the 1500 psi (103 bar) fiberglass pipeline therefore was about 30:1 for rupture. The total volume of natural gas in the line is 54 cubic feet (1.5 cubic meters). Because of these factors it was decided that the risk to the tramway was minimal.

As a safety feature, a valve was installed on the supply line that would shut off the flow of the natural gas if there was a sudden drop in downline pressure. In addition, on an annual basis, a pressure test is conducted on the gas line whereas the line is isolated and the pressure in the line monitored to determine if there is any loss of pressure during the test. If there was a loss observed, the line would be inspected to detect the odor that is added to the natural gas.

Conclusion. The use of aerial utilities on a ropeway has proven to be successful. The lines have been in operation for about 18 months with no major problems. Based upon the experience of the aerial utility lines at the Iron Mountain Tramway, the following observations can be made.

1. Aerial utility lines are not as reliable as the traditional buried lines. The aerial lines are subject to more operational and atmospheric variables that could affect the functionality of the utilities that are critical for the operation of the upper facilities.
2. Under most conditions, aerial water lines should only be installed in warmer climates where freezing temperatures will not become a threat to the lines.
3. If an aerial water line is used, there must be a reservoir at the upper facility large enough to supply water for a reasonable amount of time if the utility line is temporarily not available.
4. The use of aerial utilities is not practical in areas where icing is possible. The cross sectional area of the lines could result in an ice load that is not supportable by any reasonably sized support cable.
5. The use of an aerial gray water disposal line must be limited to times when the atmospheric temperatures are above freezing. High velocity flow is not adequate to prevent freezing of the gray water in extremely low temperature conditions.
6. If the upper facility includes a kitchen, extreme care must be taken to pre-treat the gray water to remove all grease that could accumulate on the walls of the line and eventually render it non-functional.

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