Weather Challenges in Ropeway Operations & Maintenance

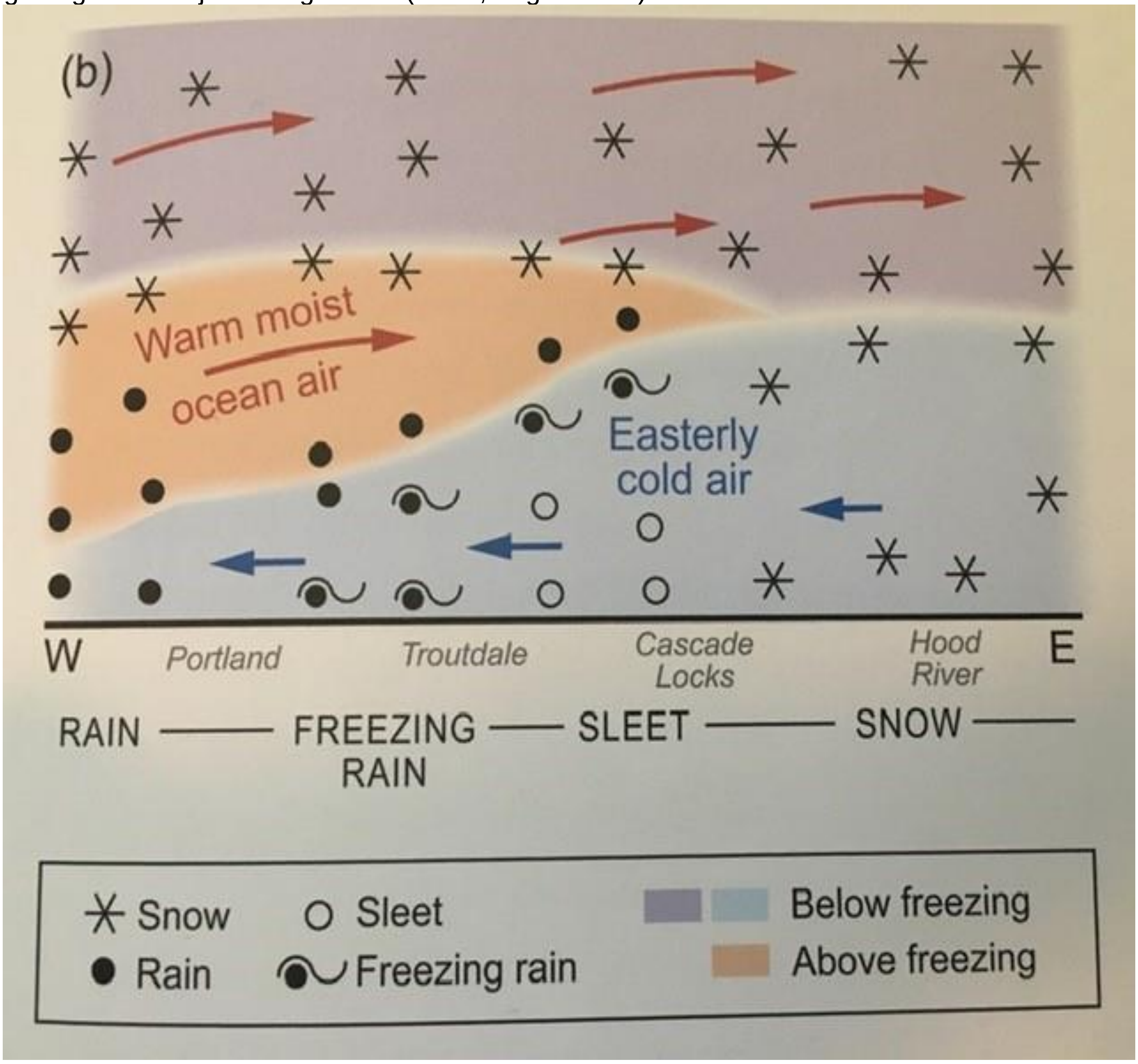
Tom Scully-USA
Risk Control Consultant-Safehold Special Risk
Tom.scully@safehold.com

The Pacific Northwest of North America has some of the most unique weather in the world. Operations and maintenance of ropeways in this region has long been challenging due to a the extensive climatic variations in temperature, humidity, extreme wind, icing, freezing rain, suspect tree health, record breaking snowpack and other outside influences. With these challenges has come many refinements and experience, which has helped to shape the advancement of detachable technology and the way lifts are operated and maintained around the world. This climate requires hard work, innovative solutions, and dedication to successfully operate ropeways. This paper will explore some of the interesting designs, discoveries and processes used throughout the ski industry during the past 50 years of building, maintaining and operating lifts on Cascade Volcanos and other Northwest ski areas.

Weather from the Pacific Ocean rolling into the north-south oriented Cascade Range plays an important role in winter storms. The low-pressure systems approaching the Pacific Northwest coastline are usually preceded by warm air brought into the region with southerly winds. These southerly winds reduce the lifting over the mountains which can be seen with westerly and northwesterly winds. This is often at odds with cold continental air and high-pressure east of the Rockies which can force cold air towards the low pressure to the west, attempting to bring the cold air through the mountain passes of the Cascades. (Mass, Cliff; The Weather of the Pacific Northwest, 2008). The typical westerly flow pushes the air up over the cascade slopes causing more convective air currents, more convective clouds which carry more moisture. With cooler temperatures, lower freezing levels, and increased moisture; increased snowfall can occur on the west slopes, mountain passes and the Cascade Crest. Overnight snowfall totals of 30-40 inches are not unheard of. (Mass, Cliff; page 48-76)

Although the prevailing winds normally come from the west, occasionally the continental easterly winds can drastically change the weather to produce another unique occurrence in parts of the Pacific Northwest, icing.

Normally the barrier of the north-south running Cascade Range and the prevailing west winds prevent continental weather and east winds from coming far enough west to influence northwest lowland weather. However, there is the Columbia River Gorge and various other mountain passes which can be a susceptible path for the continental weather breaking through. Given the proper pressure gradients between high pressure to the east and low pressure to the west, east winds are formed and the cold continental air may meet the moist Pacific air cause freezing rain. For this to happen, the warm moist air from the Pacific Ocean is pushed up and over the Cascades and the cold continental air slides under it which can cause freezing rain conditions in some locations. Because of the many variables involved, some elevations and locations may get freezing rain while others may be getting snow or just straight rain. (Mass, Page 58-70).



(Mass, Page 59. Schematic 4.8)

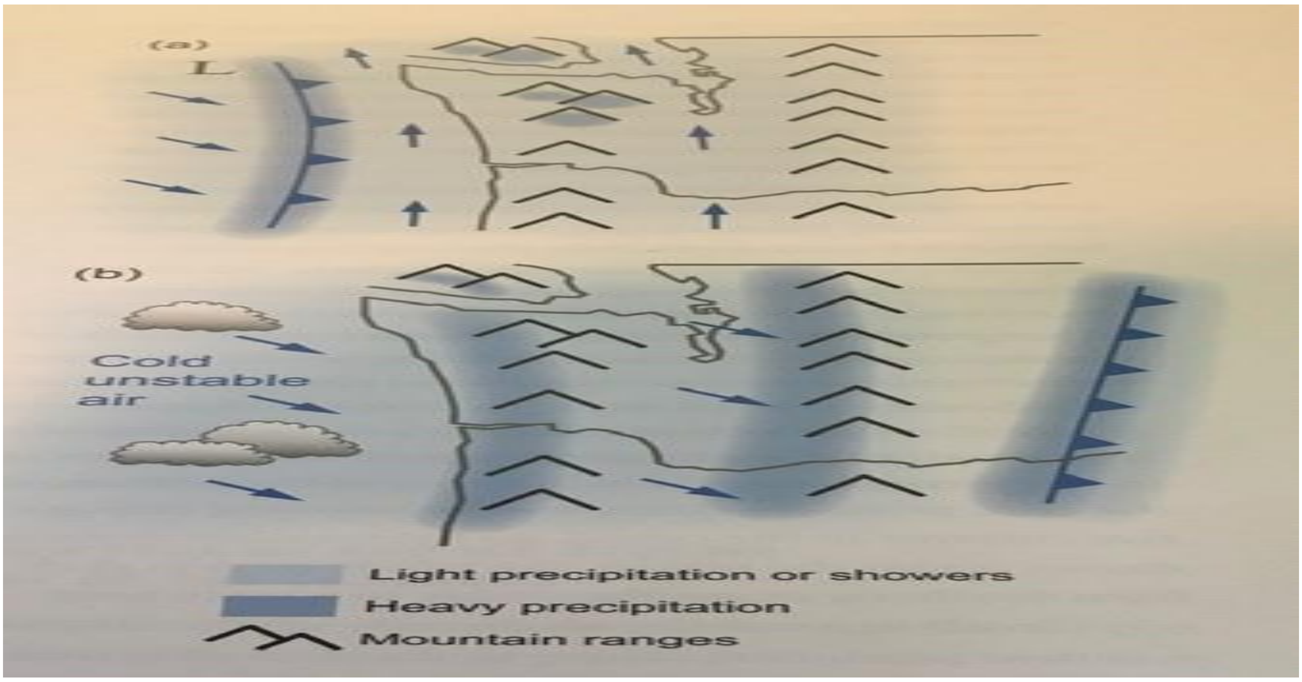
Sometimes the icing or freezing rain changes the snowpack, the skiing and additionally the ski lifts can suffer tremendously.

While the Northwest has promising topography and weather to provide good skiing, it also comes with many challenges in designing and installing ski area ropeways which can withstand the long winters of this region.

As mentioned, the mountains of the northwest are home to some of the snowiest locations in the World. Mt. Baker Ski Area, located on Mt. Shuksan in the North Cascades of northern Washington recorded the world record amount of 1,140 inches of snow at an elevation of 4,200 feet during the 98-99 winter (Mass, page 48). Many ski areas in the Cascades routinely record 400-500 inches of snowfall during a typical winter

.

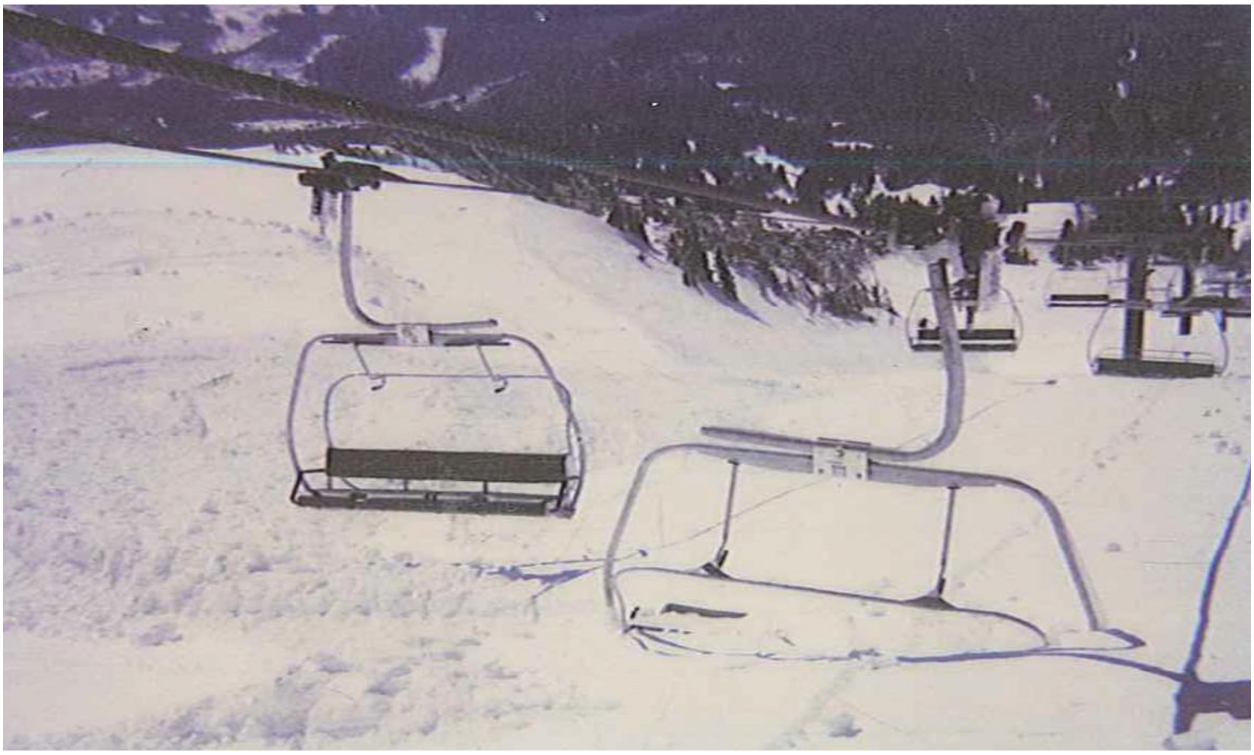
Some locations can be buried in depths of 50-100 feet of snow given the right topography, abundant moisture, winds, and freezing levels (Mass, Page 49).



(Mass, p. 65, schematic 4.13)

Lift terminals, doors and buildings are under extreme stress and load. Pictured below is the top of Palmer buried with iced up cable (Photo courtesy Rose Phillips)

Occasionally snow becomes so deep that lift lines would need to be cleared to operate the lifts.



Since many ski area operators in the Northwest observed towers becoming buried under this hefty snowpack, most lifts had some design considerations to help prevent the potential damage. This tower had a creep guard installed on the lowest 20 feet of tower as well as a stiff leg back-stay which was eventually bent under the heavy snowpack. Cables replaced the stiff legs which allowed the cable to slice through the snow better than square steel which added enough surface area and eventually buckled under the weight. Cables are used along with grooved pins which ultimately will shear about the time the cable is completely buried, thus advising the resort personnel that it's time to dig out the tower to relieve the tension of the snow creep or glide.

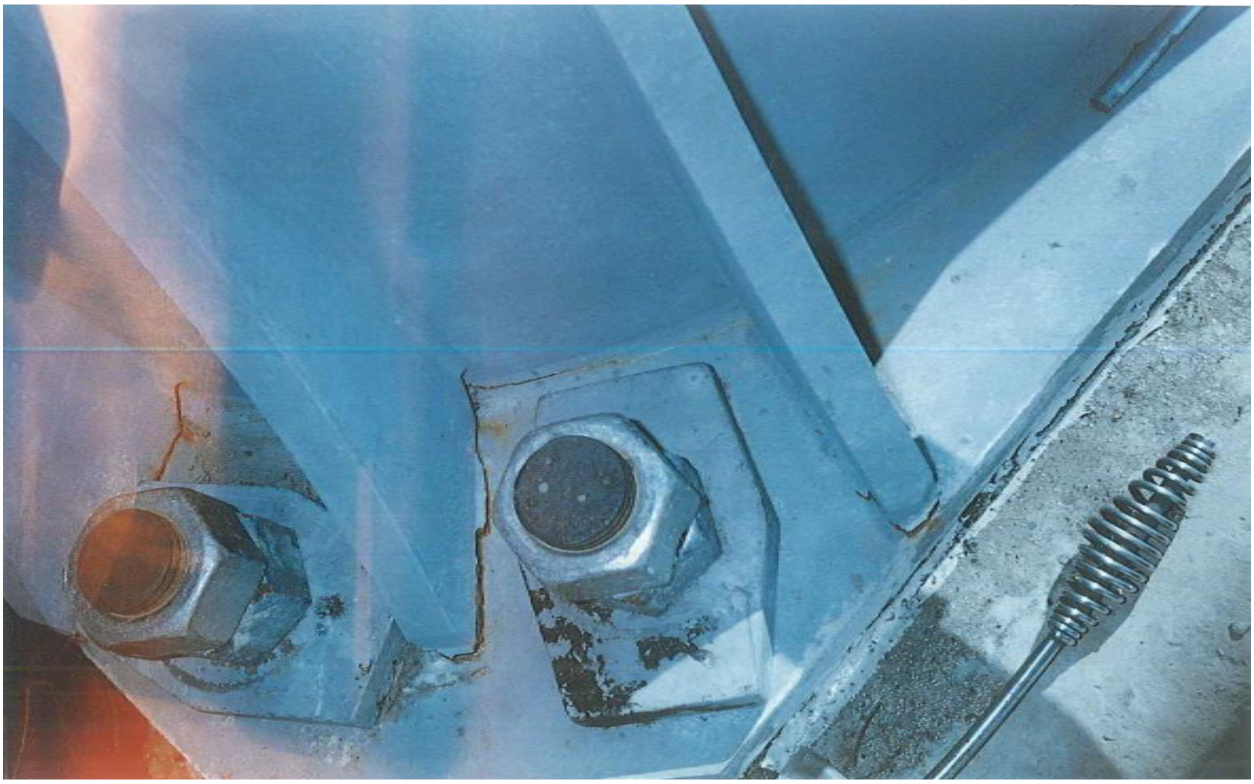
It's observations and local information such as this that has been shared with lift engineers who have the difficult job of calculating and adjusting design forces and requirements.

The Maritime snowpack becomes more isothermal in the spring which has been observed to increase the pressure with which it can exert against items, namely cylindrical masts or lift towers. Studies done around the world have measured pressure and calculated densities of various snowpacks which can vary dramatically due to many external influences. Maritime climates tend to have the highest-pressure values often shown to have densities as high as 500kg per cubic meter due to springtime temperature increases and melt-freeze snowpack metamorphosis. The density of the snow and ice in the northwest varies considerably, however under natural conditions snow density is usually between 0.10 to 0.40 g./cm.^{3} and may reach 0.55 g./cm.^{3} when compacted artificially, such as with a snow groomer. Field studies indicate that the density of snow-ice formed either naturally or artificially is usually between 0.87 and 0.91 gm./cm^3 . The observations on blue ice, formed naturally and in the cold room, suggest that density values between 0.90 and 0.92 g./cm.^{3} will probably be the most frequent ones when the ice can freeze without restriction. For the case where water is cast on bare ice in layers a few centimeters thick, both laboratory tests and field observations indicate that values between 0.87 and 0.91 g./cm.^{3} may be found **(**Ager, B. H. 1960).

Density (kg m^{-3})	Characteristics
50 - 100	Fresh falling snow.
100 - 200	New top snow. Uncompacted. Called "**powder**" by skiers.
200 - 300	Settled snow on ground. Self-compacted after several days.
300 - 500	Compacted snow by grooming machines. Some target densities (kg m^{-3}) for groomed ski slopes are: 450 for cross-country (**nordic**) tracks, 530-550 for snowboard and downhill (**alpine**) runs, and 585 - 620 for slalom. Also forms naturally in deep layers of snow, such as during glacier formation.
500 - 550	Called "**névé**". Snow that has been partially melted, refrozen, & compacted.
550 - 830	Called "**firn**". Naturally compacted and aged over 1 year. A form of ice still containing air channels, observed during glacier formation.
830 - 917	Ice with bubbles, typical in the top 1000 m of old glaciers.
917	Solid ice (no bubbles). Typical of glacier ice below 1000 m depth.

Table 7b.1 - Typical snow densities ranging from freshly fallen snow (lowest) to solid ice (Credit: Roland Stull)

Left untreated, the snow creep will certainly do real damage.



Snowpacks which may get saturated at times with large amounts of rainwater can also fail and cause local slides and can produce catastrophic results.

That maritime moisture which saturates the soil can also make some trees more susceptible to uprooting. The Western Hemlock is one such species which is known for uprooting and occasional sudden failure which can come during high wind events.

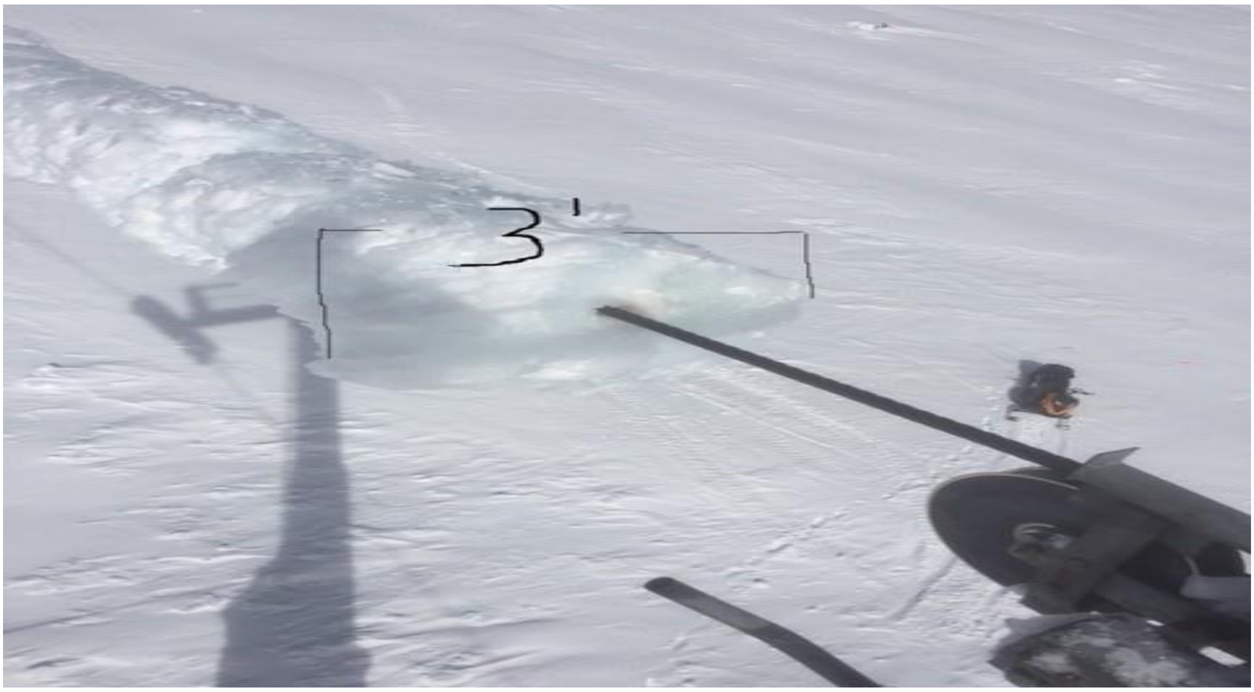
The Pacific low-pressure storms which bring deep snow can also bring damaging winds. The strongest winds present during these fall and winter Pacific low pressure periods tend to come from the west and originate in the Gulf of Alaska. These deep lows can produce strong winds known as mid-latitude cyclones or Pacific cyclones. They generally develop on the boundary between warm air from the tropics and cool air from the northern latitudes (Mass, p.30). Like tropical cyclones, these storms are associated with low pressure centers and winds that rotate counterclockwise in the Northern Hemisphere. Northwest cyclones are different than the tropical cyclones in the variation of temperature between the warm tropics and the cooler artic air. The tropical kind can develop into hurricanes with the abundance of warm air and water, but since the water temperature of the northwest rarely goes above 50 degrees, they can hold their power over land more effectively than tropical storms which weaken rapidly when cut off from the warm water. (Mass, p.78)

Sudden rouge wind gusts can do real damage to ropeways of all sizes. The tram at Alyeska was faced with this scenario during the 2013 holiday season.

Beyond the deep snow and high winds, resorts continue to refine processes and procedures to make ski lifts operational during the winter months when icing can occur.

Iced up cables on Mt. Hood have been seen up to ~50 inches in diameter of clear water ice.

Here is an example of typical ice storm remnants where humidity was high and freezing level was fluctuating and left approximately 36” of mostly hard blue ice with some frothy rime on top which is brought in with the wind towards the end of a storm.



Since Mt. Hood has experienced these icing challenges and conditions with some regularity, it has allowed some successful methods to be developed over the years. It has also put some lift designs to the absolute limit.

Due to the icing, some lifts in this region have carrier storage which allows lifts to be mothballed during winter or put into “Night Drive Mode” This operating mode was developed to allow the rope to run empty during the night with a small AC motor which has thermal limits and special bypasses to prevent nuisance stops in order to keep the cable moving, thus preventing ice from building on the rope and machinery. During this mode, cable proximity or position switches are turned off and brittle bars are employed to stop the lift in case of derailment.

Often, high winds will derail the empty rope when carriers are removed, breaking a brittle bar thus stopping the lift, which then causes large diameter ice to build on the cable. Other times, tower machinery and sheaves will freeze and stop turning while the cable continues to move which then destroys sheaves, axles and shafts by the moving cable which acts as a giant band saw. This action can saw through axles and shafts throughout the course of a couple of days before a cut brittle bar wire finally will stop the lift.

Once the lift has stopped in night drive mode then the effort required for removal of the ice gets much more involved.

Soft rime ice may often be brushed away with a broom, but it can also be a multi-day battle.to safely remove the ice. Most ice storms at a ski area require some type of manual de-icing, generally done with some type of large, soft-faced hammer. To remove the ice from the cable, many methods are used. Small amounts of ice can be knocked off the cable by running the lift and allowing the ice to go through the sheave assembly. Care must be taken to protect brittle bars and to avoid derailments. Large ice may take other methods and since wind shear forces increase exponentially with each inch of ice, entire ski lift towers can buckle under the weight if left neglected.

The effects of the ice on the machinery can vary from no impact to complete machine lockup.
The volcanic cone of Mt. Hood is susceptible to this phenomenon due to the geographical location, the topography and terrain which all affects the upslope and downslope winds and corresponding temperature fluctuations. Freezing levels which are typically at pass level during a normal winter storm may move down slope to near sea level at the gorge or may move up near the summit (11,235') and may cause there to be multiple layers of freezing conditions. These Northwest icing events have caused a wide variety of challenges, hazards, and damage to roadways, homes, power poles, powder lines, and ropeways.

With the added weight of the ice on the cable it is often too heavy for most winches or hoists to lift the rope back onto the sheaves so the ice must be stripped clean first.

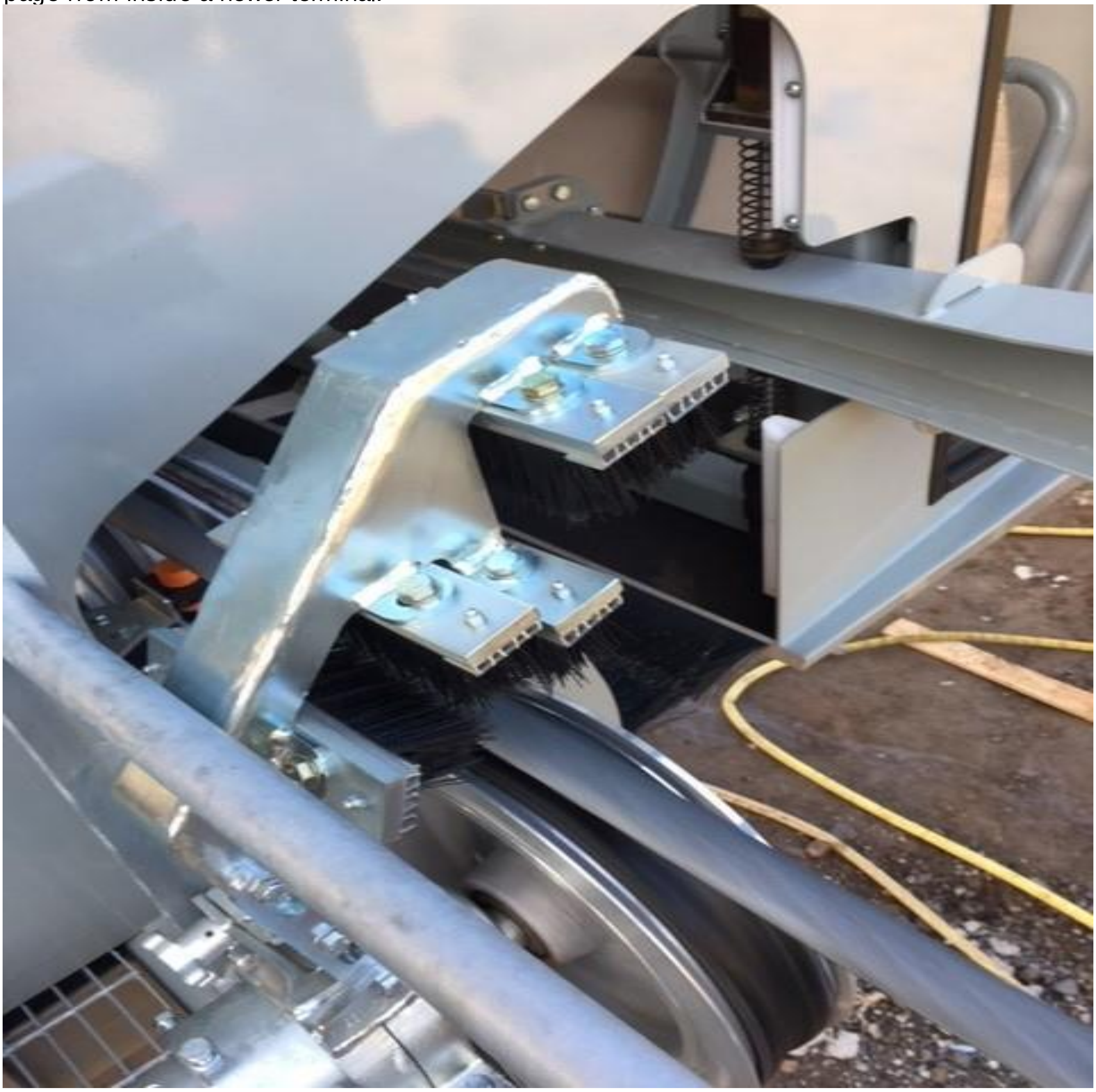
This process is time consuming but one of the most successful processes has been to install a shackle on the haul rope and pull it along the length of rope by connecting it to a snow cat via a rope sling. As the cable clears itself of ice, it can be quite dramatic. Depending on the force of the pull, many towers need to be tied down to prevent more derailments.

The effect of ice goes beyond what is often visible as well. Ice jacking inside towers has been a problem in these moist climates. The Whistler gondola once was evacuated when an upper section of tower was lifted off its lower section. Water turned to ice inside the tower and its upward expansion snapped the connection fasteners which broke the tower in two.

Additionally, ice jacking left unnoticed caused nearly 100 feet of cracks in a tower causing catastrophic failure of the tower, luckily overnight when no passengers were riding the lift.

Improvements in design and operational processes have benefited the entire ropeway industry because of lessons learned from northwest ropeway operations. Since deicing a lift and returning it to public operation can often take days or weeks, operators needed to improve the process to keep customers satisfied. This influenced the development of specialty products, parts and supplies which assist the resorts in keeping terminals free of snow, cleaning grips of snow and ice while moving, and providing additional friction for the lift carrier conveyance system. Other improvments included reverse mode, better grip/rope contact, easier opening and closing of grips, power take-off sheaves with more aggressive wrap angles to supply consistent power to the tires, belts and pullies. Lift manufacturers in the US have essentially dwindled to a hand full of suppliers which is down substantially from the 70's and 80's. Resorts have limited options so owners and operators have a continued need to collaborate with manufacturers to produce long standing, strongly built lifts which are reliable in all weather conditions.
Now as other parts of the country are seeing changes in their weather paterns, they may begin to see ice and rime effecting their lifts and operating schedules. This change in weather may necessitate more advanced lift technology and lift icing options in regions other than just then the Pacific Northwest. Some options which have been made available to all buyers are underbelly brushes and grip path brushes. Below are early versions of these tools.

Now we fast forward a couple of decades and lifts come with options or standard equipment which have been refined by the manufacturer. Adjustable terminal entrance grip brush shown below and the following page from inside a newer terminal.



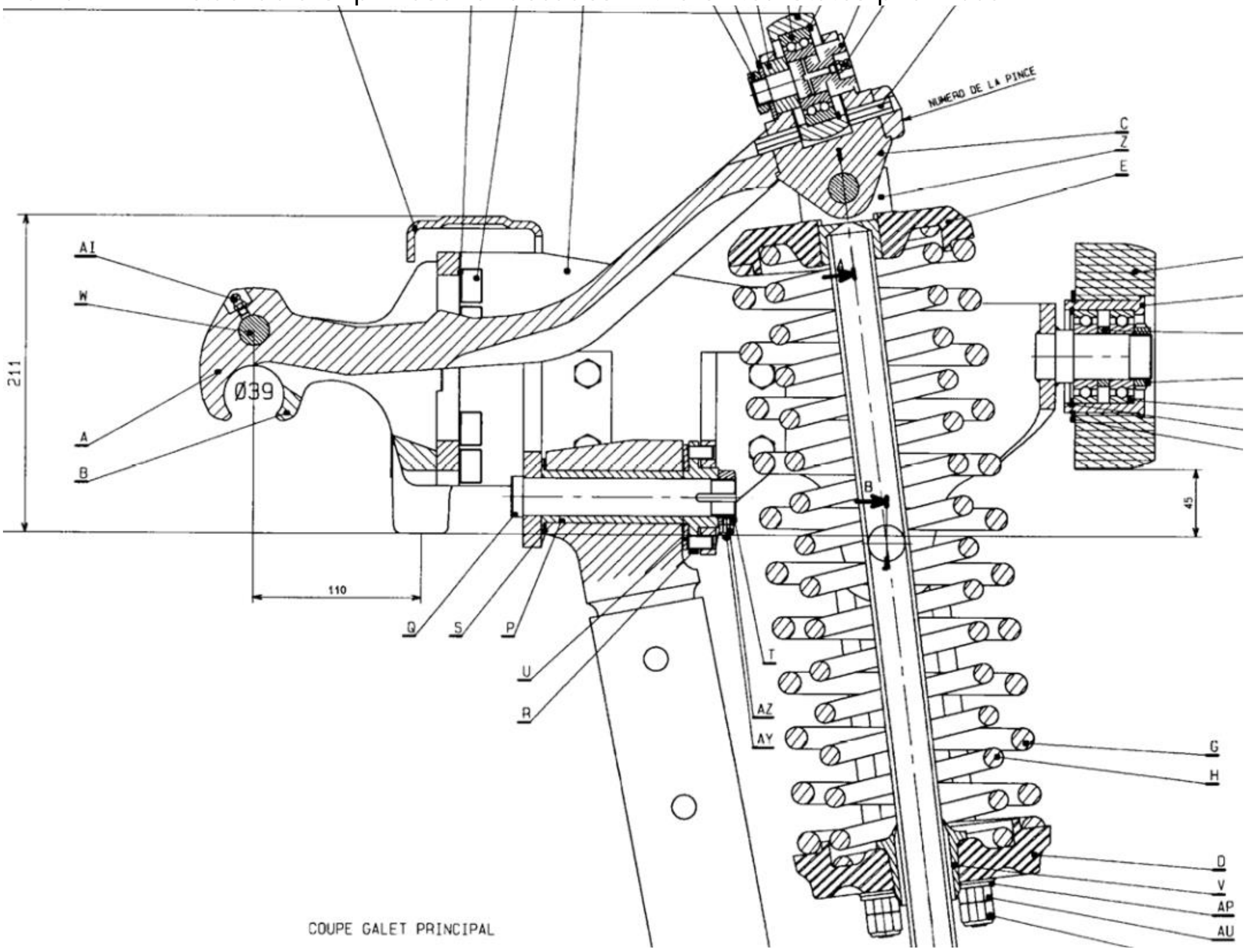
As experience was gained by customers in various environmental conditions, customers shared their thoughts with manufacturers in hopes to make improvements which could further assist resorts in running detachable lifts in all weather conditions.

One such area is the terminal conveyance of detachable grips through the detach and attach zones. This takes proper setup of the power take off sheaves providing consistent power to the tires and belts and offering the proper friction between grip traction plate and the tires. Since the grip opens and closes when forced under a rail, this robs power from that system and even small slips can thwart forward progress. Friction here is often the crux during ice storms and can prevent detachable ropeways from running. Ski areas began to see that some days may require an army of technicians and staff pushing stuck chairs, cleaning grips profusely to move through the terminals, often while customers waited for the lift to open. Small improvements were made but more needed to be done.

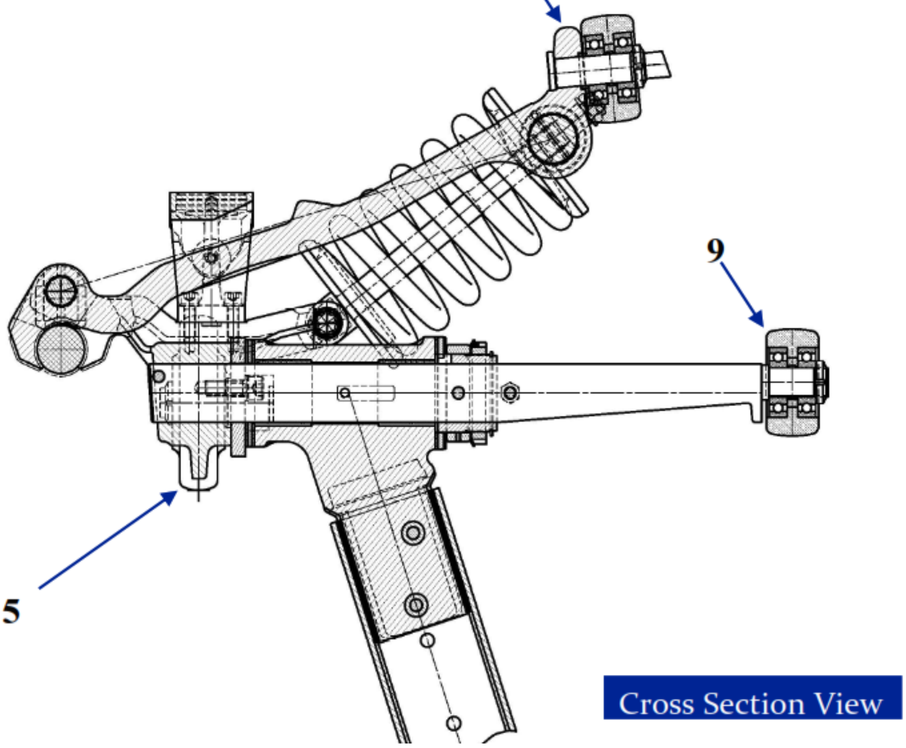
New detachable grip models were developed with various improvements over past models. Leitner Poma and Doppelmayr continued to improve grip designs for US customers over the 90's to 2000's. LPOA stated with its latest L-PA grip "because of the unique geometry the grip develops a large griping force with a relatively modest effort of the depression roller. Because of this, the grip requires less effort of the conveyor to propel the grip through the station…The long opening and closing action of the two open coil springs lowers the opening forces and allows operation of the lift in substantially icy conditions". (Leitner-

Poma of America, L-PA Grip Manual, Page 3). Wrap angels of the PTO sheaves were improved and by removing one of the sheaves was able to gain friction on the remaining two PTO sheaves in some terminals. Poma also improved other grip design features such as changing the friction plate to an open grating style treadplate, used solid tires for pushing grips and rounded principle rollers and rails which would help to push and clear contamination out of the rails.

Poma TB-41 Detachable Grip-in use for decades in the United States prior 2005



The L-PA detachable grip now in use throughout Europe and the United States with improved opening and closing forces, new open grate friction treadplate, improved grip jaw and rounded rollers.



(L-PA Grip Information Manual Page 4)

Despite improvements to grips and terminals, advancements in night drive operation and parking of carriers was still needed in many locations. Cost is a major consideration for many resorts when purchasing a new lift and often a parking garage makes the lift cost impractical for many resorts. Covered parking rails was another way to remove chairs from the cable without having to build large enclosed parking storage but this can increase the manual work required to keep the chairs and grips free of snow and ice in the parking rails.

Next was improvements to the terminal tire beam by Doppelmayr and Poma which could allow the detachable tire rails to be raised thus allowing chairs to be parked inside the terminal itself while still giving the option of running the lift cable on night drive mode even with the chairs in the terminal. This is accomplished by raising the entire tire beam and pushing chairs along the rail without any contact with the tires.

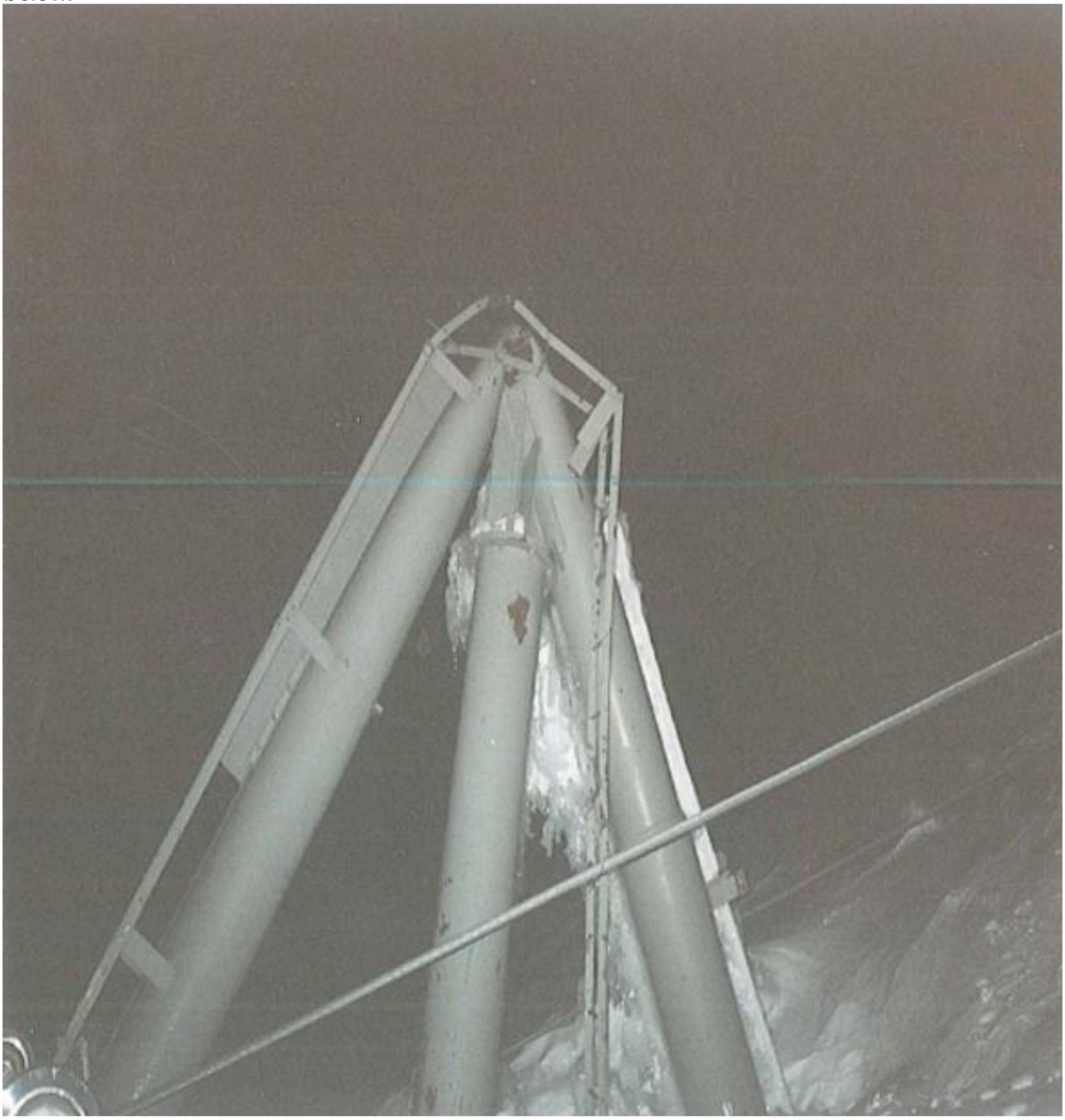
Some lifts such as the one shown here park 1/3 of the chairs in each terminal and the last 1/3 under a smallish parking rail which lowers cost considerably (Photo: Woods, Mt. Hood Meadows).

One special lift in the Northwest was built high on the flanks of Mt. Hood on a year-round glacier (Palmer) and has seen more than a few changes since its installation. The original Palmer chairlift was constructed in 1976 by Riblet Tramway Company, it was a fixed grip double. During the first winter significant damage occurred to the line towers due to snow creep, wind and ice loads. The following summer the towers were repaired, and tripod legs were added. This lift was only operated in the summer months. During winter, chairs were removed from the line and stored in the basement. Also, the haul rope was lowered and put into winter mode.
In 1996, the current Palmer was constructed by Doppelmayr. A high-speed detachable quad with a mid-station load (used in summer months). All equipment was new with the exception of the line towers, though a few new towers were added. Knowing of the historic icing events Doppelmayr designed the lift with a night drive mode to run during storms with carriers removed to prevent ice build up. Since that time, the lift went through hellish winters and mainly operated during the summer months for ski race camps.

ss| June 17 to 21, 2024| 7

Eventually during low snow winters, the owner considered operating the lift in winter which could prove to be very difficult. It only takes a few days of non-operation for the lift to be coated in heavy ice and with strong winds the lift could be susceptible to failure given the added weight and surface area for wind effects.

As most lifts in milder climates could be designed for 1”-2” ice and 100 mph winds, this standard was inadequate for this location. This discovery was made after the failure of the towers during the Christmas storm of 1998. A similar occurrence happened in 1999-2000 and again in 2019-2020. These events combine the added weight of ice, increased surface contact area and strong wind forces to cause major shedding of ice. When the haul rope begins to sway and bounce it can result in structural failure as seen below.



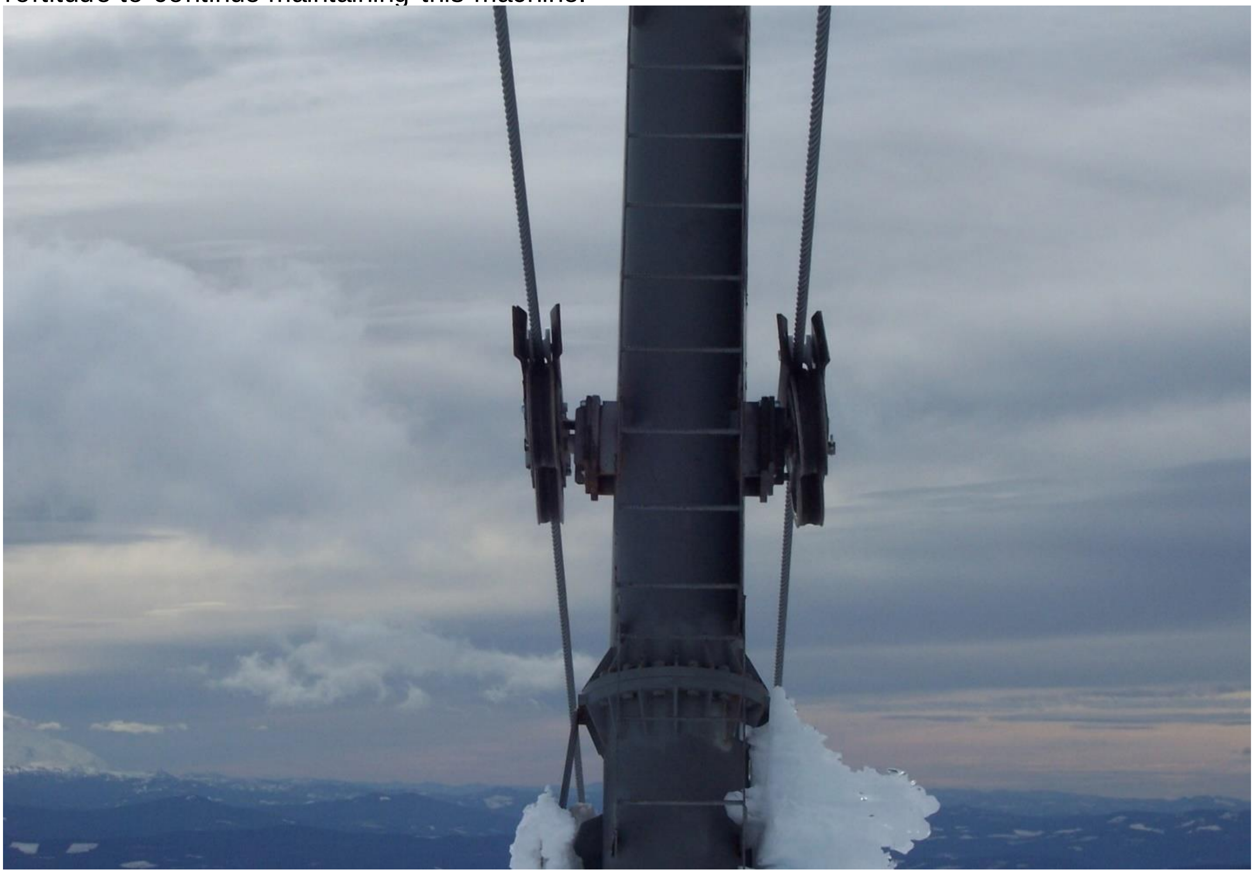
Most recently in 2019-2020, the haul rope was retired after it exited the tower machinery and pushed one assembly more than 50 feet away from the tower. Two other towers had the cable land on top of the lifting frames during the event, causing one to completely fail and fall from tower while another was bent beyond repair.

The haul rope's constant motion in the wind left its impression on the tower cross arm nearly 1/2" deep. Its destructive forces broke many wires in the haul rope as seen below. Multiple lifting frames, crossarms and tower machinery were replaced in addition to the wire rope at a huge expense to the resort.

Cross arm ripped from tower and found on ground.

This tower had the rope fall on top of the lifting frame, causing it to buckle and lock the rope into itself.

This event forced the ski area to take a look at the ROI of limited upper mountain winter operations and eventually went back to winter storage of the haul rope into specially designed two pair holding sheaves. These small assemblies cradle the cable down below the machinery which lowers the weight on the tower and captures the haul rope as seen in the photos below (Phillips). This still takes an amazing amount of time and labor and patience as the lower elevation ski lifts begin opening in the fall while the Palmer lift needs to be "winterized" and put to bed at the same time on the upper elevations of the mountain. This is no small feat and is completed annually, by the dedicated, hard-working crew at Timberline and their fortitude to continue maintaining this machine.



Now below we can see the Palmer lift as it sits in storage waiting for the spring. Then the process begins again with extensive inspections after extensive deicing, reinstallation of the haul rope on each tower and repairs of battered line machinery. An amazing amount of work so people might ski in the summer and spring months when snow has melted at lower elevations.
Its to these lift maintenance heros who work so hard to make skiing available for us that I salute those hard-working men and woman of lift maintenance in the northwest, one of the most challenging regions in the world to maintain and operate ropeways!

To be continued….

Sources:

1. Cliff Mass: The Weather of the Pacific Northwest, 2008; University of Washington Press
2. Stull: Roland Stull Table 7b.1 - Typical snow densities ranging from freshly fallen snow (lowest) to solid ice. COMET/UCAR: The source of this material is the COMET® Website at http://meted.ucar.edu/ of the University Corporation for Atmospheric Research (UCAR), sponsored in part through cooperative agreement(s) with the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce (DOC). ©1997-2016 University Corporation for Atmospheric Research.
3. Rose Phillips photos (Timberline Ski Area General Manager Outside Operations)
4. Marshall Woods photo (Mt. Hood Meadows, Lift Maintenance Manager)
5. Tom Lomax, et al photos (Former Mt. Bachelor Director of Mountain Operations)
6. Tom Scully photo collection
7. Leitner Poma of America; Maintenance Manual, L-PA Grip Information guide, conversations with Natalie Tusberg et al.