REPLACEMENT OF THE POINT MACKENZIE SUBSTATION BATTERY

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Abstract

In the early 1990's Chugach Electric (Chugach) fell prey to the allure of valve regulated lead-acid (VRLA) batteries. Widespread application of this battery technology has resulted in additional costs and lessons learned. Application of a VRLA battery at the Point MacKenzie Substation, a remote site, has resulted in high costs over the years and forced development of an effective solution. This paper presents a history of events and decisions made in selecting a replacement battery for the Point MacKenzie Substation.

Chugach Electric

Chugach is the largest electric utility in Alaska serving 69,000 wholesale and retail customers in a service area the size of the State of Delaware. Chugach's total capacity is just over 600 MW which is the largest for an Alaskan utility but small compared to Lower 48 standards. There are 37 substations and switchyards operating at voltages from 12.5kV to 230kV with standby battery systems maintained by Chugach's Substation Department.

Point MacKenzie Substation

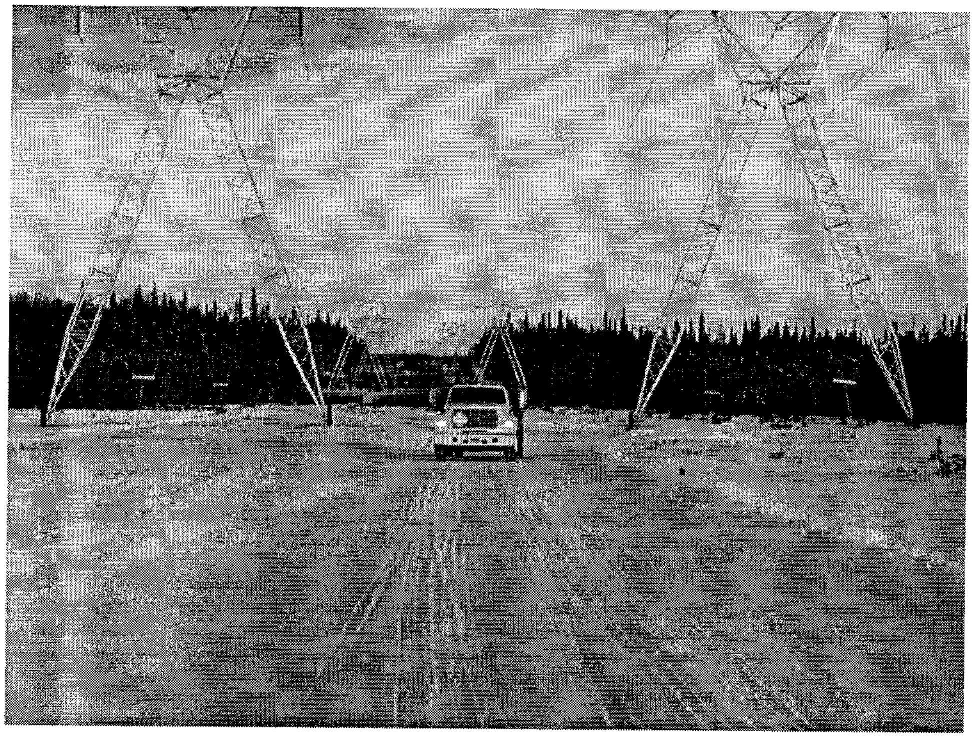
The Point MacKenzie Substation is located 5 miles across Cook Inlet from Anchorage, Alaska. This substation is the terminus for two 230 kV transmission lines and one 138 kV transmission line which are connected to Chugach's Beluga Power Plant. Two 138 kV undersea cable fields leave the station and cross under Cook Inlet to deliver power to Anchorage. Two 230 kV transmission lines route power overland from the station to Anchorage, via a 230kV undersea cable field, and to wholesale customers in the Matanuska Valley and the interior of Alaska. Approximately 70% of the power generated by Chugach passes through the Point MacKenzie Substation making this one of our most important installations.

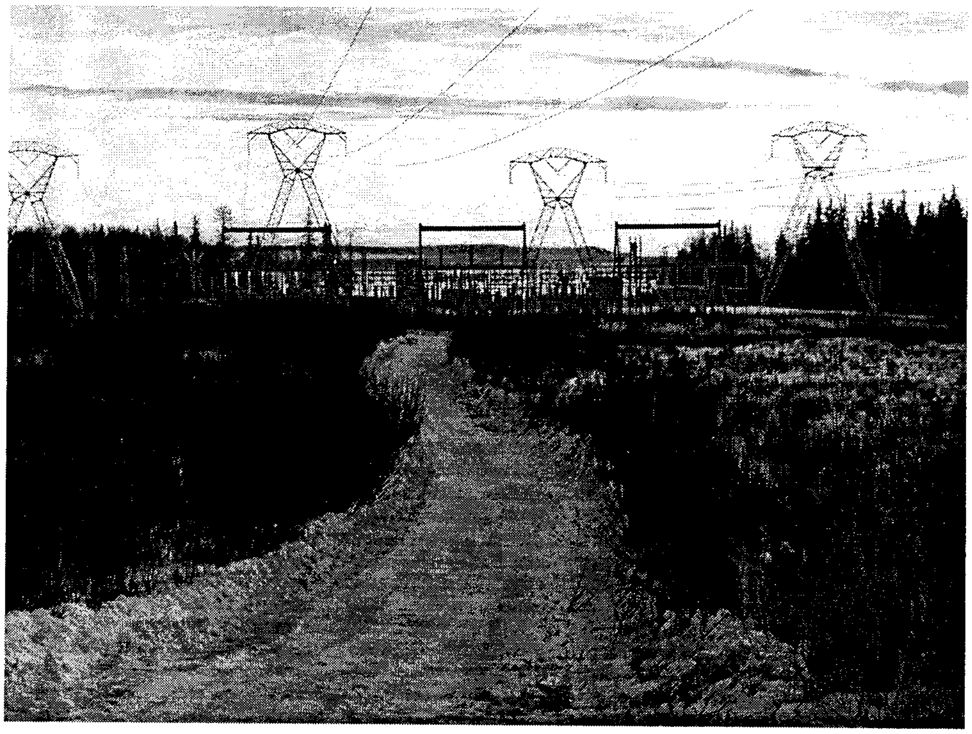
The substation is surrounded by environmentally sensitive wilderness: Susitna Flats State Game Refuge and Goose Bay State Game Refuge to the west and north and Cook Inlet and Knik Arm in the south and east.

Road access to the station is possible only in the winter when conditions allow for the construction of a snow road to cross the streams, tundra and marshes that surround the station. The snow road is 3 miles long and must be constructed along the transmission line right-of-way. Construction of the snow road begins in December and is typically ready for use by mid January.

Construction of the snow road entails using a John Deere 350 bulldozer to plow a road to the station. A plow truck follows behind to clean up the loose snow and groom the road. It is important to keep the plowed road relatively clear of snow so the ground can freeze and attain the strength necessary to support vehicle traffic. The road must be replowed after each substantial snowfall. Equipment breakdowns can complicate the construction process. Cost to construct the snow road is approximately $21,000 (3 men x 7 days x $100/mhr x 10 hrs/day).

The snow road becomes impassible when warmer weather arrives in March. The most opportune time to use the road is in January and February unless a warm winter complicates construction and use of the road. Total road miles from Anchorage to the Point MacKenzie Substation, including the 3 miles of snow road, is 97 miles. One way drive time from Anchorage is approximately 2.5 hours.





3-mile snow road crosses streams, tundra and marshes

Year-round access to the station is limited to a 10-minute helicopter flight, one way, from Chugach Headquarters in Anchorage.

The Point MacKenzie DC system consists of a 125 volt battery and charger which provide power to the station's high voltage circuit breakers, motorized disconnect switches, protective relays, communication, and auxiliary systems. Because of the importance of this facility to the operation of Chugach's system it is critical to have a reliable DC system. Secondarily the DC system must be easy to maintain. If the battery must be removed from service a mobile battery must be brought to the station to provide an alternative source of DC. Utilization of Chugach's mobile battery which is contained in a towable trailer requires the construction of a snow road. Construction of just the snow road and mobilization and demobilization of the mobile battery costs a minimum of $25,000.

Outdoor temperatures can vary between 85 °F and –34 °F throughout the year. The temperature inside the substation control building battery room is maintained at approximately 75 °F.

The First VRLA Battery

In 1989 the existing 20 year old flooded lead-acid battery was capacity tested at approximately 50%. In 1990 this battery was replaced with a new 60-cell VRLA battery. The decision to install a VRLA battery was based upon the following manufacturer claims:

- Smaller footprint than flooded lead-acid batteries
- Lighter weight
- Easy assembly and installation
- Does not require a separate battery room
- No spill risk
- Minimum maintenance required
- Twenty year life

The promise of minimum maintenance and 20 year life was especially attractive considering the remoteness and cost of performing maintenance at the Point MacKenzie Substation.

The Second VRLA Battery

In 1994 the new VRLA battery was capacity tested at 46% per IEEE Standard 450. (Four other station batteries of the same manufacturer and age were also tested with similar results.) This battery was replaced with a new VRLA battery, from a different manufacturer, which happened to be on hand waiting to be installed on another project. The installation was considered a temporary measure until a flooded lead-acid battery could be purchased and installed. By this time Chugach was recommending against installing VRLA batteries at bulk transmission substations (certain brands of VRLA batteries were still approved at that time for use in non-bulk transmission and distribution substations).

The New Flooded Lead-Acid Battery

In 1997 a new flooded lead-acid battery was ordered to replace the temporary VRLA battery. The delivery was scheduled to allow installation during the 1997/1998 winter season. A snow road was constructed and materials staged, ready to mobilize to the Point MacKenzie Substation as soon as the new battery arrived. Shipment of the new battery was delayed until spring and it finally arrived in Anchorage too late to be installed that season. The next possible opportunity to install the new battery would be during the winter of 1998/1999. The new battery was unpacked, connected to a charger and placed in temporary storage until the 1998/1999 winter construction season.

New Flooded Lead-Acid Battery Concerns

In early December 1998 while the new flooded lead-acid battery was being dismantled and repacked for the journey over the snow road to the Point MacKenzie Substation, a black discoloration was noticed on the terminals of the cells. The discoloration was evident on the positive post only and could be found on 39 of 60 cells. The discoloration covered the battery posts in differing amounts and always began at the base of the post/cell cover interface and then covered a portion or almost all of the post. Our research determined that the black discoloration was most likely lead dioxide, a product of creep corrosion that occurs when the positive post-to-cover seal fails and battery acid migrates up the cell post (Ref. 1). Lead dioxide has a high resistance and must be periodically scraped off the posts and intercell connectors. Creep corrosion is characterized as a self-sustaining phenomenon that requires continual maintenance.

Periodic cleaning of the battery represented an additional maintenance requirement not anticipated at the time of purchase. The cost to remove lead dioxide from the cells, once only, was estimated at approximately $34,000. This figure included construction of the snow road, mobilization/demobilization of the mobile battery, cleaning the cells and helicopter flights to and from the station. The original purchase price for the battery was $16,000. Clearly, this battery could not be installed at the Point MacKenzie Substation or at any other substation on Chugach's system.

Impending Death of Second VRLA Battery

By the summer of 1999 condition of the existing VRLA battery at the Point MacKenzie Substation (installed 1994) was unknown. It had been in service for 5 years and we had already experienced high rates of failure of VRLA cells from the same manufacturer after a similar time period. This VRLA battery was of a very compact design. There was ample access to the top layer of cells but not enough room to safely test the cells on the lower layer. A cellcorder test was performed on the top layer of cells only. Results indicated one cell was most likely shorted and others were not charging. Twenty out of the thirty cells on the top layer showed some sign of plate growth, i.e., the positive posts were pushed up and almost all cells had indications of past venting. The condition of the battery was severely compromised and would most likely not perform as designed. Ten heavy-duty truck batteries were flown to the station and connected to the DC system as a temporary measure until a new flooded lead-acid battery could be installed.

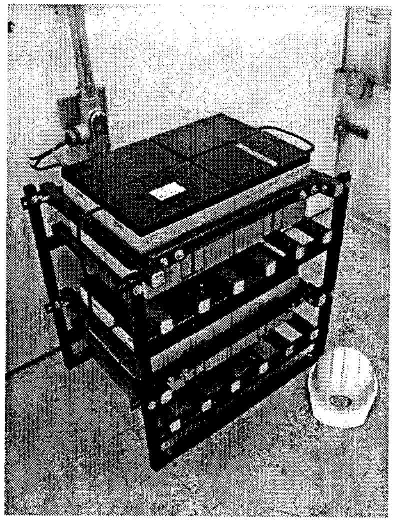
VRLA Battery History at Chugach Electric

Chugach has had experience with VRLA batteries from five different manufacturers. VRLA batteries were purchased almost exclusively during the early 1990's for use in metalclad switchgear and substation control buildings. Their small footprint enabled them to be squeezed into small areas and the promise of no or low maintenance was attractive to the system designers of that time. Since then, for Chugach's applications, VRLA batteries have not performed as advertised. Performance has been dismal at best. Average life for a VRLA on our system has been between 3 to 7 years. Because of their poor performance history, high maintenance costs, and sudden and catastrophic failures, VRLA batteries are no longer installed on Chugach's system.

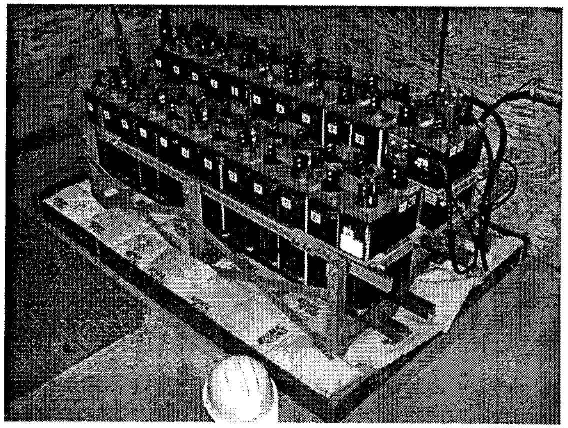
VRLA Battery Alternatives

Chugach is presently in the process of replacing all the VRLA batteries on the system. Where space permits, a flooded lead-acid battery replaces a VRLA battery. In metalclad switchgear and substation control buildings (primarily 48 volt systems) where space is at a premium, a vented nickel-cadmium (NiCd) battery is installed to replace the VRLA battery. The 48 volt NiCd has a footprint slightly larger than the 48 volt VRLA battery it replaces and is considerably smaller than an equivalent 48 volt flooded lead-acid battery.

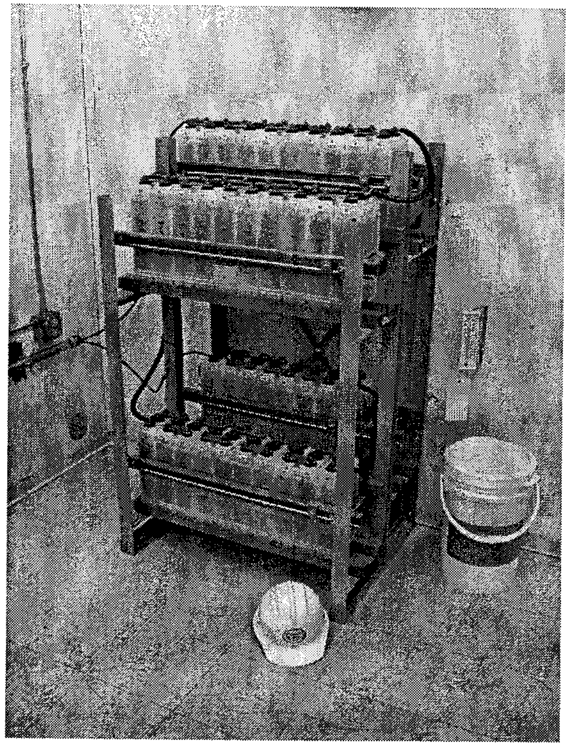
Battery Size Comparison



48V, 160Ah
VRLA



48V, 350Ah
Flooded Lead-acid



48V, 161Ah NiCd

Life Cycle Costs of Battery Alternatives

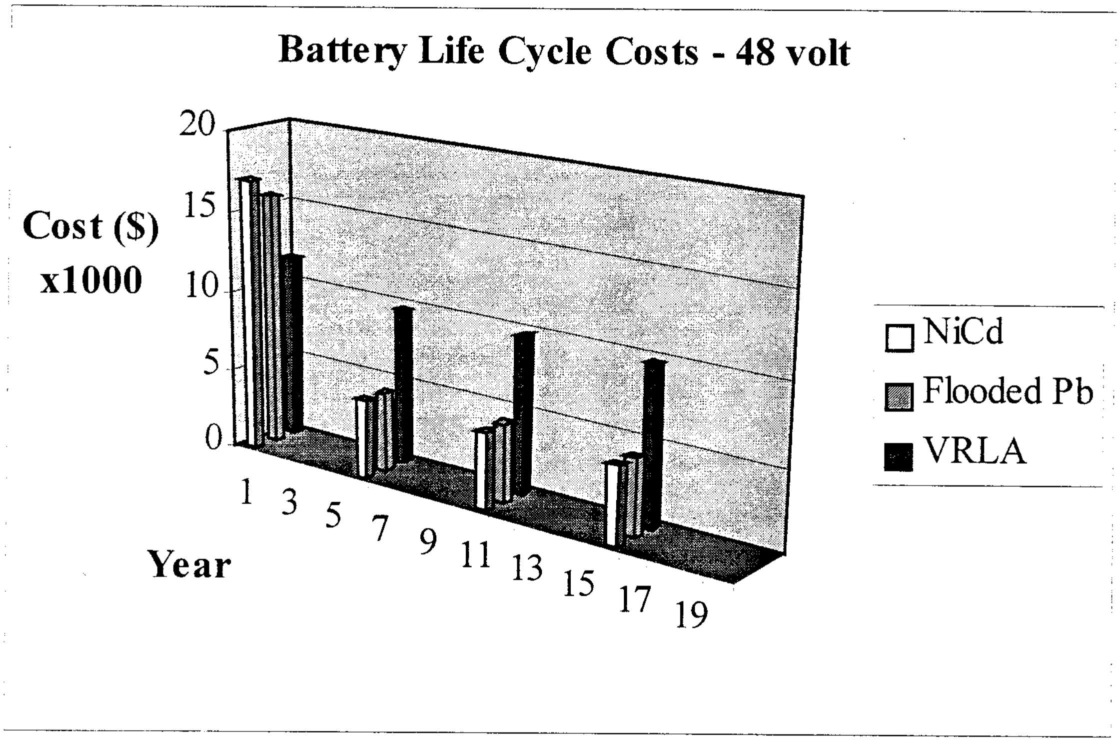
Life cycle costs for 48 volt and 125 volt VRLA, flooded lead-acid (flooded Pb) and NiCd batteries are shown below:

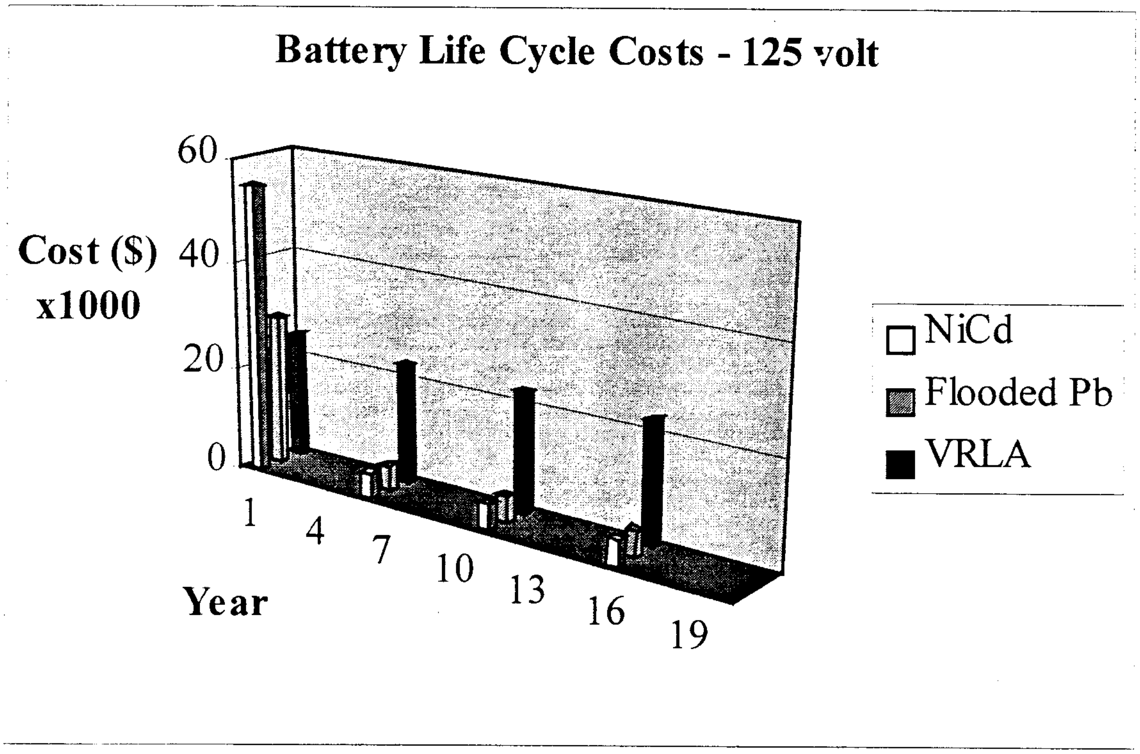
Battery type:	VRLA	Flooded Pb	NiCd	VRLA	Flooded Pb	NiCd
Voltage:	48	48	48	125	125	125
# Cells/blocks:	8	24	37	60	60	97
Amp-hour capacity:	160	350	161	320	350	346
Battery cost:	$2,550	$5,200	$6,380	$12,363	$13,556	$39,000
Rack cost:	$240	$1,400	$1,000	$1,248	$2,061	$2,500
Shipping cost:	$700	$1,200	$1,650	$1,070	$3,446	$3,900
Installation labor:	$8,000	$8,000	$8,000	$9,600	$9,600	$9,600
Total:	$11,490	$15,800	$17,030	$24,281	$28,663	$55,000
Life Cycle Costs						
Capacity test cost:	na	$4,800	$4,800	na	$4,800	$4,800
Battery life (years):	5	20	20	5	20	20
Cost of capital(%):	8	8	8	8	8	8
Year 0	$11,490	$15,800	$17,030	$24,281	$28,663	$55,000
Year 5	$9,650	$4,800	$4,800	$23,032	$4,800	$4,800
Year 10	$9,650	$4,800	$4,800	$23,032	$4,800	$4,800
Year 15	$9,650	$4,800	$4,800	$23,032	$4,800	$4,800
Net present cost:	$197,368	$108,257	$109,488	$467,922	$121,120	$147,458

Notes:

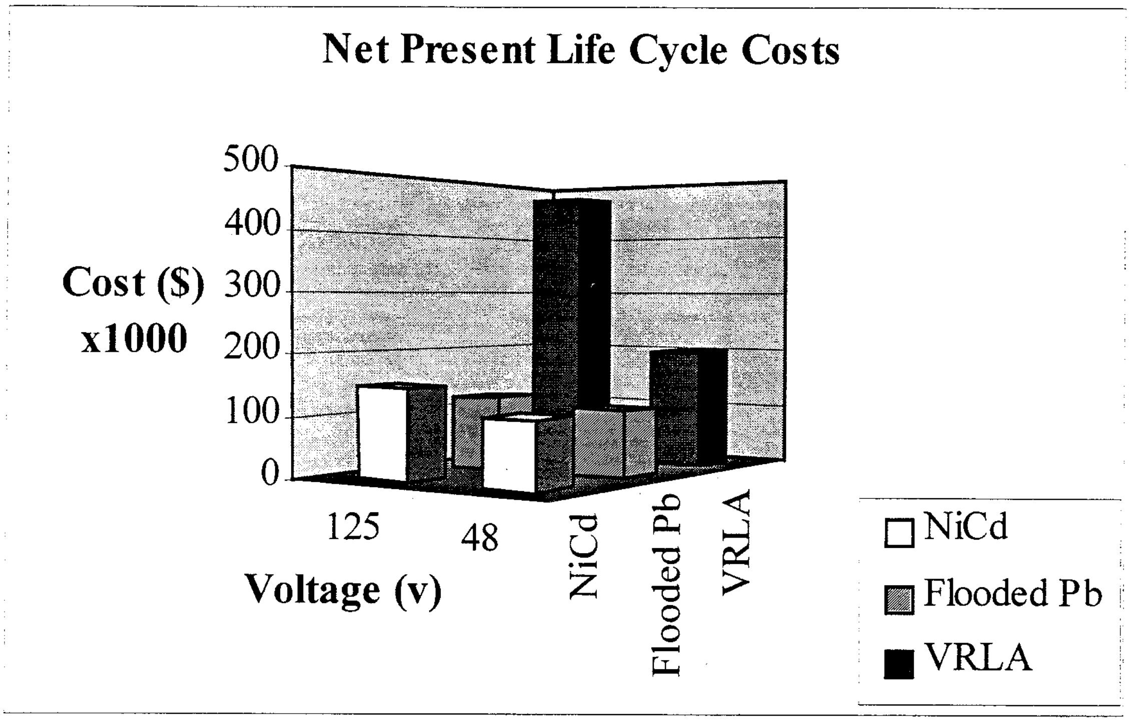
1. Material and shipping costs reflect actual prices and quotations 1998 through 2000.
2. Shipping costs are FOB Anchorage, Alaska.
3. NiCd cells are vented type.
4. Life cycle costs do not include maintenance costs such as travel, inspection, specific gravity tests, watering, etc. Life cycle costs only include capacity testing for flooded lead-acid (flooded Pb) and NiCd batteries performed at 5 year intervals per IEEE Standards.
5. VRLA costs include cell replacement every 5 years. No additional costs are included for the annual performance tests recommended by IEEE Std. 1188-1996.
6. Five year life for VRLA batteries reflect the average performance history of VRLA batteries on Chugach's system. Twenty year life expectancies for flooded lead-acid and NiCd batteries are based upon empirical data.
7. Installation labor costs are based upon: 2 men x 8 hours/day x 4(or 5 or 6) days x $100/manhour.
8. Capacity test labor costs are based upon: 2 men x 8 hours/day x 3 days x $100/manhour.
9. Battery recycling costs are not included.
10. The net present cost for a 48 volt NiCd battery could be less than the 48 volt flooded lead-acid battery if specific gravity and watering costs are considered. These variables were not considered in this comparison.
11. The 48 volt flooded lead-acid and NiCd batteries were sized to a similar duty cycle to serve a typical distribution substation load for 8 hours. Momentary loads such as operation of a breaker trip coil may only exist for a fraction of a second. IEEE Standards suggests treating such momentary loads as a full one minute load for a lead-acid battery and a full one second load for a NiCd battery. This results in a lower amp-hour rated NiCd battery for the same duty cycle. The duty cycle the 48 volt VRLA battery was designed for is not known.

Battery life cycle costs for 48 volt and 125 volt VRLA, flooded lead-acid and NiCd batteries are represented graphically below:





Results of the net present life cycle cost comparison are represented graphically below:



The relatively high first cost of a NiCd battery is offset when one considers that only one NiCd battery must be installed over a 20 year period versus four VRLA batteries that must be installed over the same time period. With Chugach's relatively high labor costs, the 48 volt NiCd becomes the cheaper alternative after only 6 or 7 years.

The flooded lead-acid battery is still the least cost battery alternative. However, the difference in cost between a 48 volt flooded lead-acid and 48 volt NiCd battery are relatively small. A more detailed analysis which considers the longer watering interval and not having to perform specific gravity tests may make the 48 volt NiCd battery the least cost alternative. Where low or high temperature variations or vibration is of primary concern the NiCd battery could be the obvious choice regardless of cost. In Chugach's situation the only workable alternative due to space constraints is to replace the 48 volt VRLA battery with a 48 volt NiCd battery.

A NiCd Battery for the Point MacKenzie Substation

After some negotiation with the manufacturer of the flooded lead-acid battery exhibiting the post discoloration an agreement was reached where Chugach would receive credit for the return of the battery and with additional funds, could purchase an equivalent NiCd battery at an attractive price. Although not the battery technology Chugach would have initially pursued for this installation, it did provide an enticing alternative to a flooded lead-acid battery at this remote location. In theory the maintenance costs of the NiCd battery should be less than a flooded lead-acid battery because the absence of specific gravity tests and the longer watering interval.

The flooded lead-acid battery was returned to the manufacturer, the additional funds agreed to, and the 125 volt NiCd battery purchased.

Installation of the NiCd Battery

The 125 volt NiCd battery was received in time to be installed during the 1999/2000 winter construction season. The snow road was constructed, and the mobile battery, new NiCd battery and miscellaneous equipment and materials hauled to the site as planned. Installation of the NiCd battery was completed in February 2000.

At last the Point MacKenzie Substation has a reliable battery. In Chugach's opinion, a flooded NiCd battery represents the optimum battery technology for this installation. The criticality of the DC system and the remoteness of the site (plus the attractive price offer) made the installation of a NiCd battery the most attractive solution.

Conclusion

VRLA batteries are not a cost-effective technology for use as DC standby power on Chugach's system. As a replacement for VRLA batteries Chugach has been installing flooded lead-acid batteries and, where space is a concern, vented NiCd batteries. An investigation of life cycle costs for Chugach Electric demonstrated the cost advantage of flooded lead-acid and NiCd batteries over VRLA batteries. The investigation also demonstrates the cost compatibility of 48 volt flooded lead-acid and 48 volt NiCd batteries. The 125 volt flooded lead-acid battery still appears to have an economic advantage over a similar 125 volt NiCd battery. Further investigation of life cycle costs that include routine maintenance procedures of flooded lead-acid batteries versus NiCd batteries would most likely result in a clear economic advantage for 48 volt NiCd batteries and a reduction of the economic advantage of the 125 volt flooded lead-acid battery.

References

1. Migliaro, M, "*Stationary Batteries, A Pictorial Reference for Maintenance and Testing*," The Battery Connector, Inc., CD-ROM.