Fishing Vessel Energy Audit Project

To provide vessel owners with practical measures to save fuel, the Alaska Fisheries Development Foundation (AFDF) partnered with Alaska Longline Fishermen's Association (ALFA), Alaska SeaGrant, Nunatak Energetics, and Navis Energy Management Solutions to conduct energy audits and collect data from Alaskan fishing vessels between 2012 and 2017. The information below is provided to help vessel owners identify operational and equipment solutions to improve fuel efficiency and further tailored to their specific needs.

Improving Deep Freeze System Performance

There are many types of freezer systems used on Alaskan fishing vessels—from hydraulically driven plate freeze systems to AC powered blast freeze systems. Hold conditions also vary widely between vessels. The following are some practical operational and equipment-related strategies to improve refrigeration performance and save fuel.

Operating practices

The easiest energy conservation measures (ECMs) to implement are simple changes to operating practices that require no new equipment. Many of the vessels surveyed can reduce refrigeration fuel consumption by up to 15% and improve refrigeration capacity by opening their condenser water flow valve.

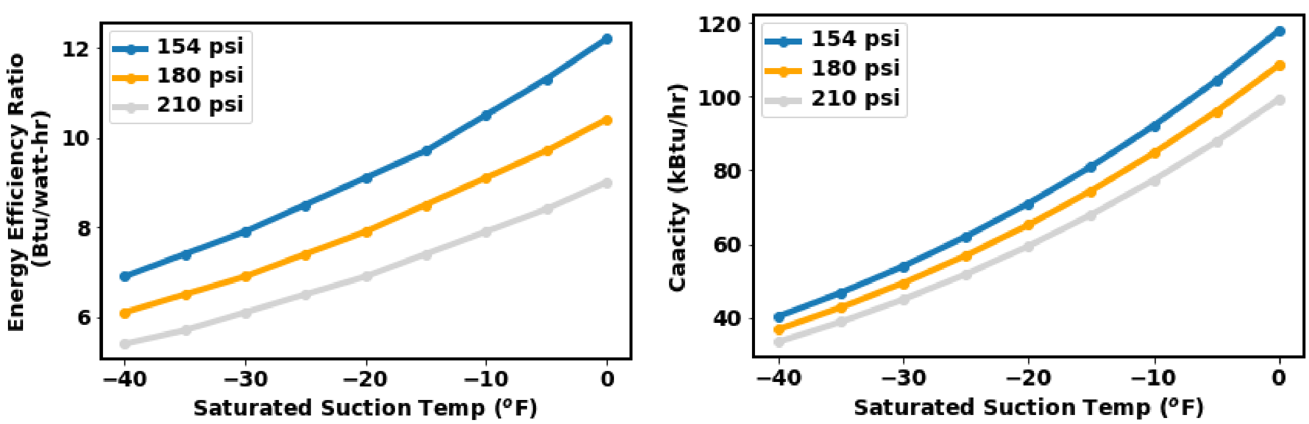

Figure 1 Compressor EER and Capacity dependence on discharge pressure

This publication is supported in part by funds from NOAA Award # NA15NMF4270275. The statements, findings, conclusions and recommendations are those of the authors and do not necessarily reflect the views of NOAA or the Dept. of Commerce.

Increasing condenser flow allows the condenser to remove more heat from the refrigerant. This has the effect of lowering the discharge pressure from the compressor and increasing the system capacity. As long as the pressure differential required by the thermal expansion valve is maintained (typically around 75 psi), lowering the discharge pressure by increasing condenser flow will have a positive effect on performance. Figure 1 shows how discharge pressure affects the performance of a Carlyle O6D compressor according to manufacturer's specifications.

Variable Frequency Drives (VFDs)

VFD adjust the frequency of AC electricity to slow down or speed up a compressor motor. In blast freeze applications, VFDs typically use a sensor in the suction line to precisely control system capacity. As suction pressure nears zero, the VFD slows the compressor down. When suction pressures increases, such as during fishing operations, the VFD speeds the compressor back up. VFDs also provide a soft-start feature that eliminates the sudden power surge normally associated with starting a large motor.

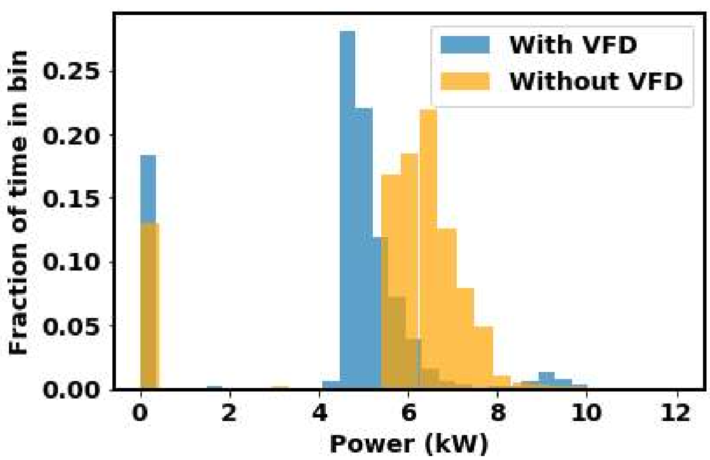

Figure 2 Compressor power distributions

VFDs often reduce short-cycling of the compressor and reduce wear on the system, particularly if the starting surge current is beyond the rated capacity of the generator. Installing a VFD will slow down the compressor so that the fishing hold temperature does not fluctuate as quickly. After the compressor cycles off, the VFD will eliminate the current surge at restart.

Figure 2 shows the effect of reducing discharge pressure and installing a VFD on compressor power. The data are from two one-month long recordings on a troll vessel with a blast freeze system. Although there are many variables that cannot be controlled between seasons (fish catch rate, for example), the data provide a first estimate of how much fuel can be saved by reducing discharge pressure and installing a VFD. The reduction in power shown in Figure 2 can be multiplied by the hours of freezer run time and marginal engine brake specific fuel consumption to calculate fuel savings. The measurements indicate a savings on this vessel of 2.7 gallons per day, or approximately $600 per year in fuel. VFDs of this size typically cost $1-$2 thousand, hence in this case, the VFD would pay for itself in less than 3 years.

Freezer system type

Three types of freezer systems were observed in the fishing fleet: AC powered blast freeze systems, hydraulic powered blast freeze systems, and hydraulic powered plate freeze systems. Figure 3 shows the power

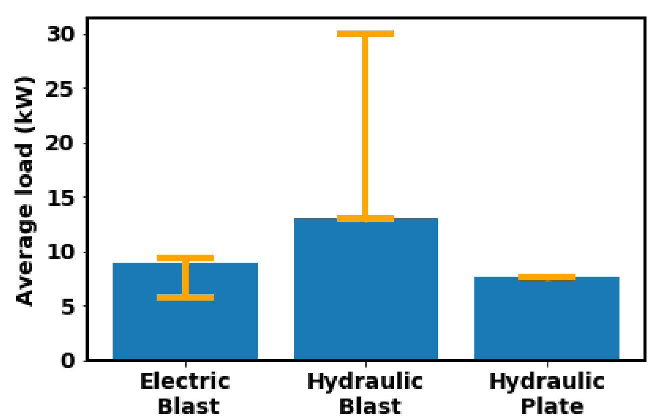

Figure 3 Freezer power by system class

This publication is supported in part by funds from NOAA Awa
conclusions and recommendations are those of the authors a
the Dept. of Commerce.

consumption measurements associated with each type. The blue bars indicate a 'typical' system in good condition, while the error bars indicate the most extreme measurements. The blast freeze system that used the least power had a small compressor operating at low discharge pressure controlled by a VFD, while the system with largest load used a hydraulic compressor driven by a worn hydraulic pump. For the purposes of estimating fuel savings, a reasonable rule of thumb is a 1 kW reduction in average load decreases fuel consumption by 1.7 gallons per day.

Hold Insulation

Insulating and sealing the fish hold reduces heat infiltration that must be removed by the freezer system. A well-run AC powered blast freeze system can achieve a coefficient of performance (COP) of about 1.4 when the hold is at -35°F. That means every 1 kWh supplied to the system removes 1.4 kWh of heat from the hold. Figure 4 shows fuel consumption per day for a range of hold insulation values. The figure assumes a COP of 1.4, typical dimensions of a fish hold with a carrying capacity of 11,000 pounds of salmon (600 square feet of surface area) and average ambient conditions. The R value represents both heat conduction through the walls and heat convection into the hold due to air leaks. The reported fuel consumption accounts for neither freezing fish nor engine idle fuel consumption because those loads are independent of the hold insulation.

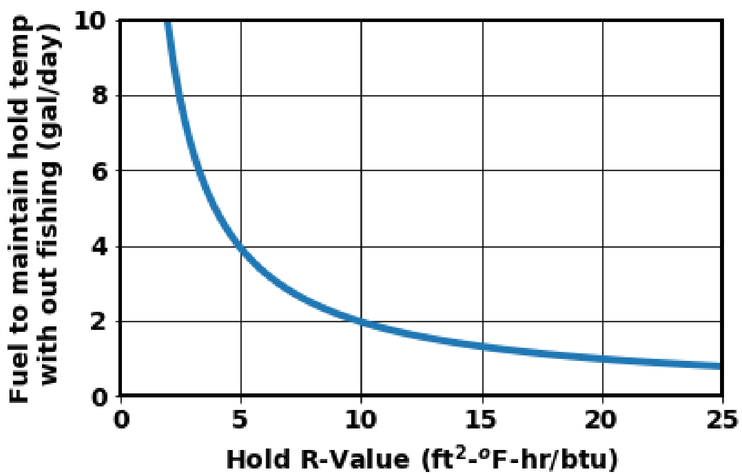

Figure 4 Value of hold insulation

Estimating the overall R-value of a fish hold can be tricky. One method is to use the freezer system to pull the hold to 32°F, then place a known volume of ice in the hold and turn the freezer system off. Record the outdoor air and water temperature, and time how long it takes for the ice to melt. The overall R-value is then given by equation 1, where A is the surface area of the hold (ft^2), *time* is time it takes the ice to melt (hours), T_{air} and T_{water} are the ambient air and water temperature in degrees Fahrenheit, and m_{ice} is the weight of ice introduced to the hold (pounds). R is the overall average R-value of the hold, in ft^2-hr-°F/Btu.

$$R = 3.15 \times A \times time \times \frac{(T_{air}+T_{water})/2-32}{m_{ice}} \quad (1)$$

This publication is supported in part by funds from NOAA Award # NA15NMF4270275. The statements, findings, conclusions and recommendations are those of the authors and do not necessarily reflect the views of NOAA or the Dept. of Commerce.

Simple steps to save fuel:

- **Reduce compressor discharge pressure—**Discharge pressure can be regulated by the amount of water moving through the condenser. Lowering the discharge pressure can significantly reduce energy consumption and increase system capacity. Check with your refrigeration technician to evaluate the minimum discharge pressure needed for your application.
- **Power source—**Refrigeration systems can be powered electrically, hydraulically, or mechanically using a direct drive. Field tests established that hydraulic powered refrigeration systems can be 50% less efficient than electrically powered systems.
- **Variable Frequency Drives (VFDs)—**VFDs speed up or slow down electric motors by regulating the frequency (hz) of the power supply. VFDs can use the suction pressure to automatically adjust compressor RPM to meet demand. Field tests indicated that installing a VFD on a blast freeze system and increasing condenser flow can reduce freezer system fuel consumption by 20%.
- **Insulate—**Check the insulation and seals on hatches to make sure heat stays out.

This publication is supported in part by funds from NOAA Award # NA15NMF4270275. The statements, findings, conclusions and recommendations are those of the authors and do not necessarily reflect the views of NOAA or the Dept. of Commerce.