Mechanical Refrigeration and Icebox Conversion

In 2004, I added mechanical refrigeration to the BRIGADOON (hull 474). The job consisted of partitioning the original reefer into two compartments, adding new insulation, and installing the refrigeration system. The new refrigerator compartment is accessible through the front loading door in the galley. The remainder of the box, let's call it the "ice chest", is accessible through the cockpit ice hatch and is intended for chilled beverages.

This article is a synopsis of the materials used and general process I followed to complete the work. It was initially submitted on the old T34 web site. I have dusted it off and added comments about system performance.

AFTER A FEW YEARS, HOW DOES IT WORK?

In a word, great! The digital thermostat is programmed to maintain a refrigerator temperature between 38° and 40° F. (This is user selectable.) The system maintains this temperature with remarkable effectiveness. The compressor is silent. The only way to know it is running is to look at the indicator LED on the control panel. In summer conditions, (ambient temperature in the high 90s and 80-degree seawater) power consumption is about 30 amp hours per 24 hours, or barely more than 1 amp per hour. Most of the time, the compressor runs at the slowest, most efficient speed. The compressor speed control module shifts to a faster speed when a large quantity of warm food placed inside the refrigerator causes a rapid increase in temperature. The evaporator bin provides a small freezer. Frozen food placed in the bin at the beginning of a cruise stays frozen.

Ten to fifteen pounds of ice in the cockpit ice chest keeps drinks cold for several days. Since the ice chest doesn't do anything except chill beverages, it isn't necessary to have a large thermal mass to keep perishable food cold. Consequently, a little ice goes a long way.

MATERIALS (THE IMPORTANT STUFF)

1) Refrigeration components: Frigoboat K50 compressor with Smart Speed Control. Model 160H evaporator. Standard keel cooler (without zincs). Carel digital thermostat. Available from Coastal Climate Control, Annapolis MD. http://www.frigoboat.com/home.html
2) Aluminized radiant heat barrier. Everfair Enterprises "Heat Shield". 48" x 96" x 1" thick. One sheet.
3) Door gaskets. 1.25" x 0.5" hollow "P" gasket. 0.75 x 0.31 twin hollow rubber gasket. One roll of each. http://www.rparts.com/
4) Dow "Tuff-R" insulation. 48" x 96" x ¾". Five sheets.
5) Construction adhesive. Several tubes to glue the Tuff-R in place.
6) White fiberglass shower enclosure panel. 48" x 96" x 1/16". One sheet.
7) Expanding foam-in-a-can. Four to five cans.
8) Muffin fan. Radio Shack 273-240. 0.13 amps.
9) Electrical supplies such as wire, splices, ring connectors for compressor and thermostat connections.
10) Marine caulk. "Life Seal". Three tubes.

REFRIGERATION SYSTEM SELECTION AND DESCRIPTION

The initial task was to select the refrigeration system for the conversion from icebox to refrigerator. There are varieties of choices on the market and the challenge was to match the system to the boat and the box. The Boatowner's Mechanical and Electrical Manual by Nigel Calder and the 12 & 24 Volt Refrigeration Manual by R. J. Kollmann were particularly helpful references. After considerable research, analysis, and evaluation of the competing alternatives for our cruising style, I selected a Frigoboat system consisting of a constant-cycling DC compressor, a horizontal bin evaporator and a passive water-cooled condenser. Made in Italy, these systems are distributed in the USA by Coastal Climate Control of Annapolis, MD.

The compressor is a Danfoss BD50 with a "smart" compressor speed control. A microprocessor in the speed control capitalizes on the variable speed capability of the BD50 and automatically selects the most efficient compressor speed for the evaporator heat load. The horizontal bin evaporator serves a dual function. It provides a chamber for freezing and refrigerates the rest of the box. The condenser consists of a series of cupronickel coils within a small (7" x 2.75" x 0.875") sintered bronze casting mounted on the

outside of the hull. The heat absorbed by the R134A refrigerant as it passes through the evaporator is transferred to the seawater through this heat exchanger. There is no water pumped into the boat and no electric power consumed to run a water pump or condenser fan. (Photo courtesy of Frigoboat.)

INSULATION

A mandatory part of this project was to improve the insulation of the box. For this, I used a combination of ¾" sheets of aluminum-faced polyisocyanurate (Dow Tuff-R), 1" aluminized radiant heat barrier (Everfair Enterprises Heat Shield), and expanding foam-in-a-can. Other sheet insulation products I considered but did not choose were extruded polystyrene (Dow Styrofoam, a.k.a. blue board) and urethane. Compared to extruded polystyrene, polyisocyanurate has a slightly higher "R", is fire resistant and not affected by solvents in the construction adhesives used to glue it in place. Urethane has a higher initial "R" than the others but a shorter life expectancy because its propensity to absorb moisture eventually reduces its insulation effectiveness. I used the expanding foam to fill up all the nooks and crannies that the sheet insulation would not fit. The Heat Shield was applied over all exterior surfaces to reduce radiant heat gain, especially from the hull and deck.

WORK AREA ACCESS

To get at the work area, I removed the pantry (the shelf unit outboard of the galley stove) and the icebox fascia (the plywood panel with the icebox door.) This was very straightforward and took about an hour. After these parts are removed, the top, outboard side and interior of the box are accessible.

PARTITIONING REFRIGERATOR COMPARTMENT FROM ICE CHEST

On the inside of the box, I glued a sheet of Tuff-R insulation to the top and covered this with a sheet of fiberglass cut from the 4' x 8' shower enclosure panel. This augments the insulation added to the exterior and does not materially affect the box capacity. I then constructed a partition to separate the refrigerator from the ice chest. There are vertical moldings in the walls of the T34C icebox on a dividing line between the sections for "food" and "ice". I glued a sheet of fiberglass panel to these moldings and caulked it all around with Life Seal. This is the new aft wall of the refrigerator. Working through the cockpit hatch to the ice compartment, I added four layers (three inches) of Tuff-R behind this fiberglass panel, fitting and gluing each in place, and filling any voids with expanding foam. A double-thick fiberglass panel completes the forward wall of the new ice chest.

I inserted expanding foam in any remaining void and into the space between the wall of the ice chest and the cockpit sidewall. This space is accessed by removing the teak trim from the sidewall.

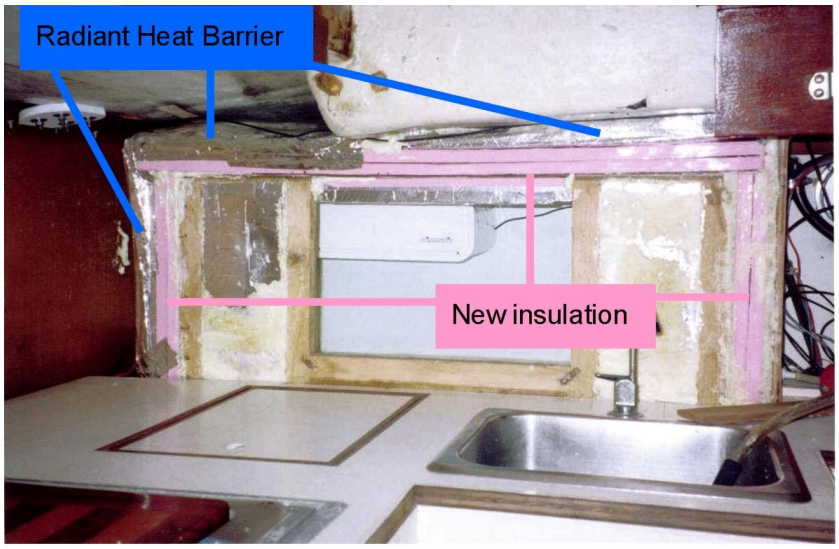
I finished the new partition with more pieces of fiberglass on the top and some redwood trim, and then thoroughly caulked all seams with Life Seal. This new locker is the cockpit "ice chest" for chilled beverages.

INSULATING THE BOX'S EXTERIOR

Inside the boat, under the cockpit seats, I tore off the thin layer of factory insulation that covered only 90% of the top of the box. After measuring and spotting the correct locations, I glued two strips of wood to the top (exterior) as back-ups for the evaporator mounting screws. I then glued pre-cut sheets of Tuff-R to the exterior top, sides and bottom of the box; two layers all around. Since neither the new insulation nor the box surfaces were completely flat, some ingenuity was required to obtain a good glue seal around all the edges. I used zip-lock bags of damp sand to weight the insulation sheets and shape them to the contours of the top. On the outboard (starboard) side of the box, I wedged floatation cushions and rags between the insulation and the hull to keep the insulation in place until the adhesive set.

On the bottom of the box, inside the galley locker below the sink and under the cockpit, I had the opportunity to perfect my skill as a human pretzel while holding the insulation in place until the construction adhesive set.

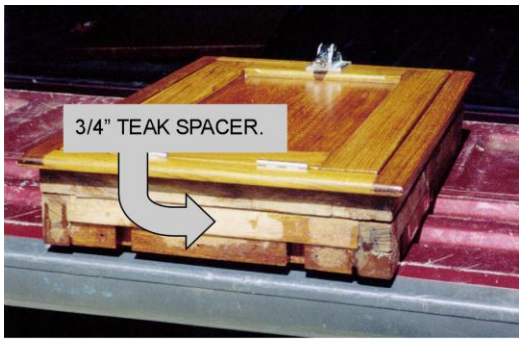
After the refrigeration components were installed and tested, I applied Heat Shield to the top, both sides and the bottom, inside the galley and under the cockpit.



This photo shows the new insulation and heat barrier in place. All seams and edges of the radiant heat envelope were sealed with adhesive aluminum tape and edges of the insulation panels were sealed with air conditioner duct tape, hence the pink color of the latter.

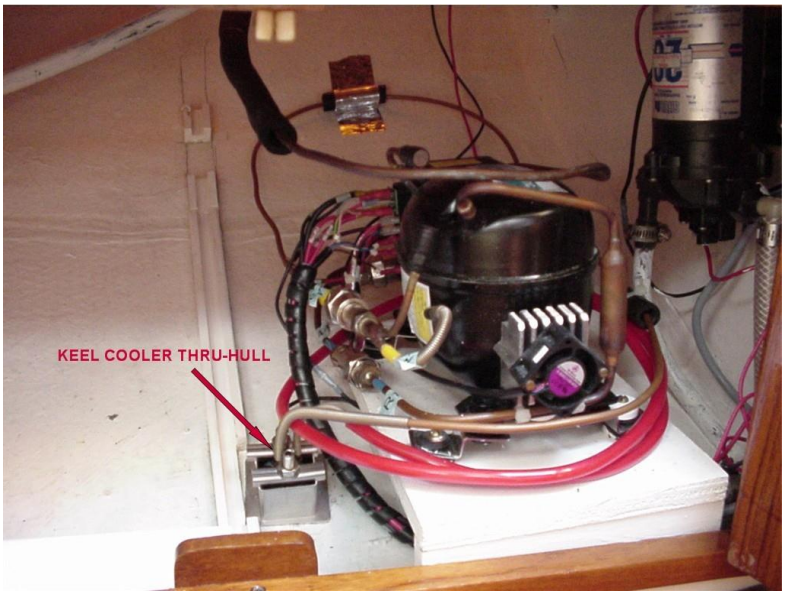
I used expanding foam to fill in every void and gap in the insulation that I could find or even imagine might exist. To get foam to the rear of the box, I stuck the spray tube of the foam can inside one end of a long piece of flexible plastic tubing and taped the other end of the tube to a stick

On the front of the box, I glued a single layer of Tuff-R (not shown in photo above) to either side of the door cut out. This of course shifted the box fascia forward by ¾" and required a modification to the refrigerator doorframe and pantry. The depth of the refrigerator doorframe was increased ¾" with a teak spacer. The length of the pantry was correspondingly reduced by trimming ¾" off the aft end of the shelf and panels. The final piece of woodwork in this area was a ¾" spacer for the gap between the fascia and the plywood around the centerboard winch compartment behind the companionway.



The increase in depth of the doorframe allowed me to add a piece of Tuff-R on the inside of the door, under the molded fiberglass insulation panel. I also replaced the door gaskets with a "P" type gasket on the frame that compresses into a twin hollow gasket on the door and makes a very airtight seal.

COMPRESSOR AND CONDENSER INSTALLATION



Installing the refrigeration components was relatively straightforward. I put the compressor and condenser in the after half of the small locker under the cutlery drawer. The space is accessible for maintenance and close enough to the refrigerator box for the length of pre-charged refrigerant tubing supplied with the evaporator. Fore 'n aft, the underwater hull here is flat which makes for an excellent seal around the hole for the external condenser "keel cooler" through-hull. This location also minimizes the possibility of damage to the condenser during haul-out. (The black / silver object in the upper right of the photo is a fresh water pressure pump, not part of the compressor.)

To finish the compressor installation, I built a plywood partition for the locker. This keeps anything stored in the forward half of the locker from tangling with the machinery in the after half. The partition can easily be removed to provide access for maintenance.

To install the external condenser, I scheduled a haul-out with a local yard and completed the job in less than two hours while the boat was hanging in the lift slings. This photo was taken during a subsequent haul-out for routine bottom maintenance. It shows the location and relative size of the condenser.

EVAPORATOR INSTALLATION

I installed the evaporator, a small muffin fan and thermostat sensor in the refrigerator box, routed the refrigerant lines and electric wires through a hole in the sidewall and then plugged the hole with expanding foam. After this was complete and all systems tested, I applied the Heat Shield, as discussed in a previous paragraph.

The muffin fan (mounted to the box's ceiling in the forward, outboard corner) is connected to the compressor power supply and turns on whenever the compressor is running. It gently tumbles the air inside the box, blowing it across the evaporator and improving the heat exchange efficiency.

This photo is post-installation. As you can see, the additional ¾" insulation on the front of the box moved the fascia forward but not so much that it blocks the cabinet hatch to the dry storage locker.

The digital thermostat and compressor speed control module are on the teak panel covering the centerboard winch compartment. Electrical connections were simple and straightforward.

To complete the galley makeover, I installed a brass piano hinge and a spring-loaded lift on the dry storage locker door and a push-button switch that turns on a convenience light when the locker door is lifted.

We replaced the venerable Kenyon pressure alcohol stove with a non-pressurized Origo alcohol stove with which we have been quite pleased, added an Alpenglow fluorescent light with both white and red bulbs, and (eventually) a mixing faucet for hot and cold pressurized water as part of the hot water heater project.