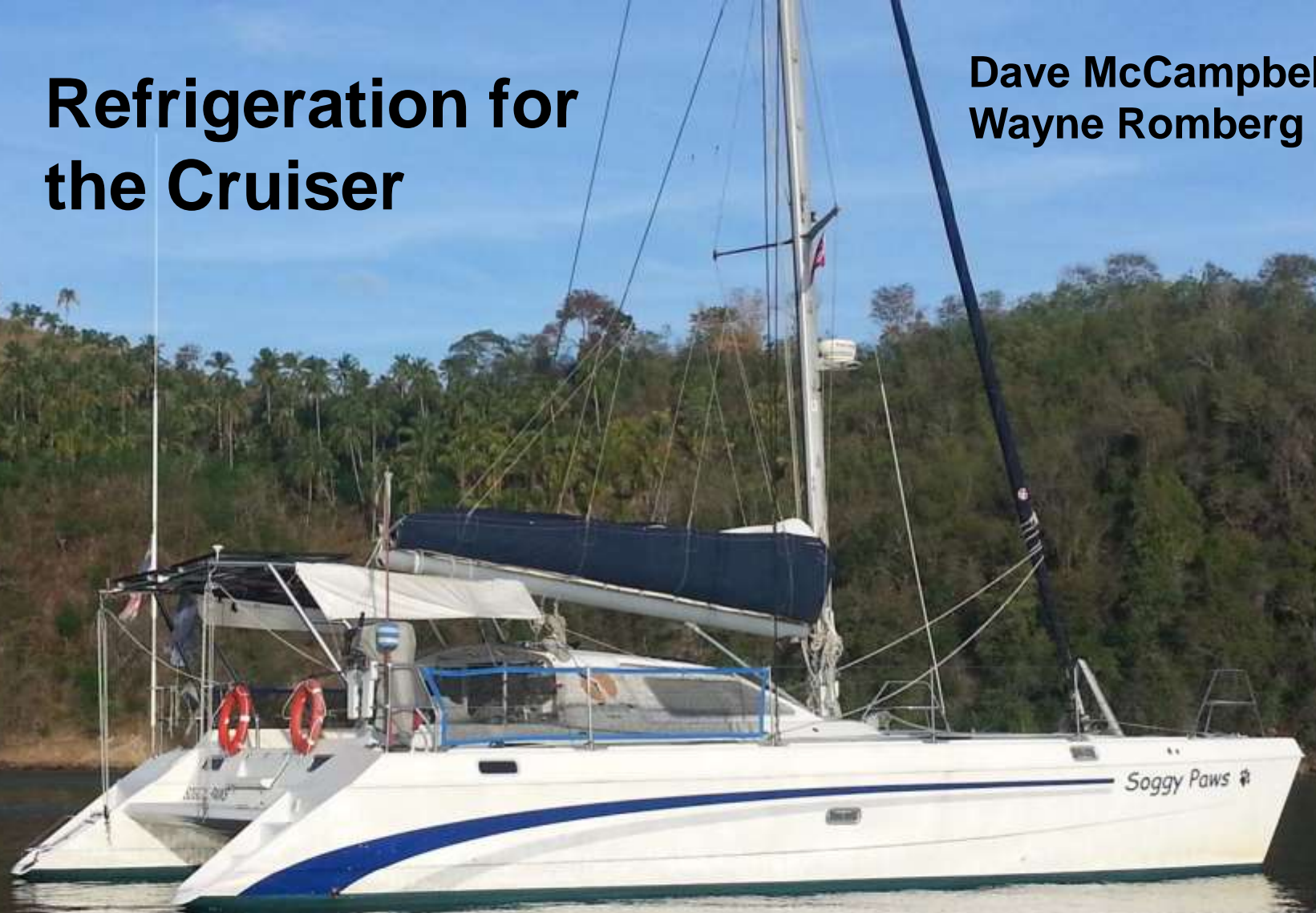


Refrigeration for the Cruiser

Dave McCampbell
Wayne Romberg

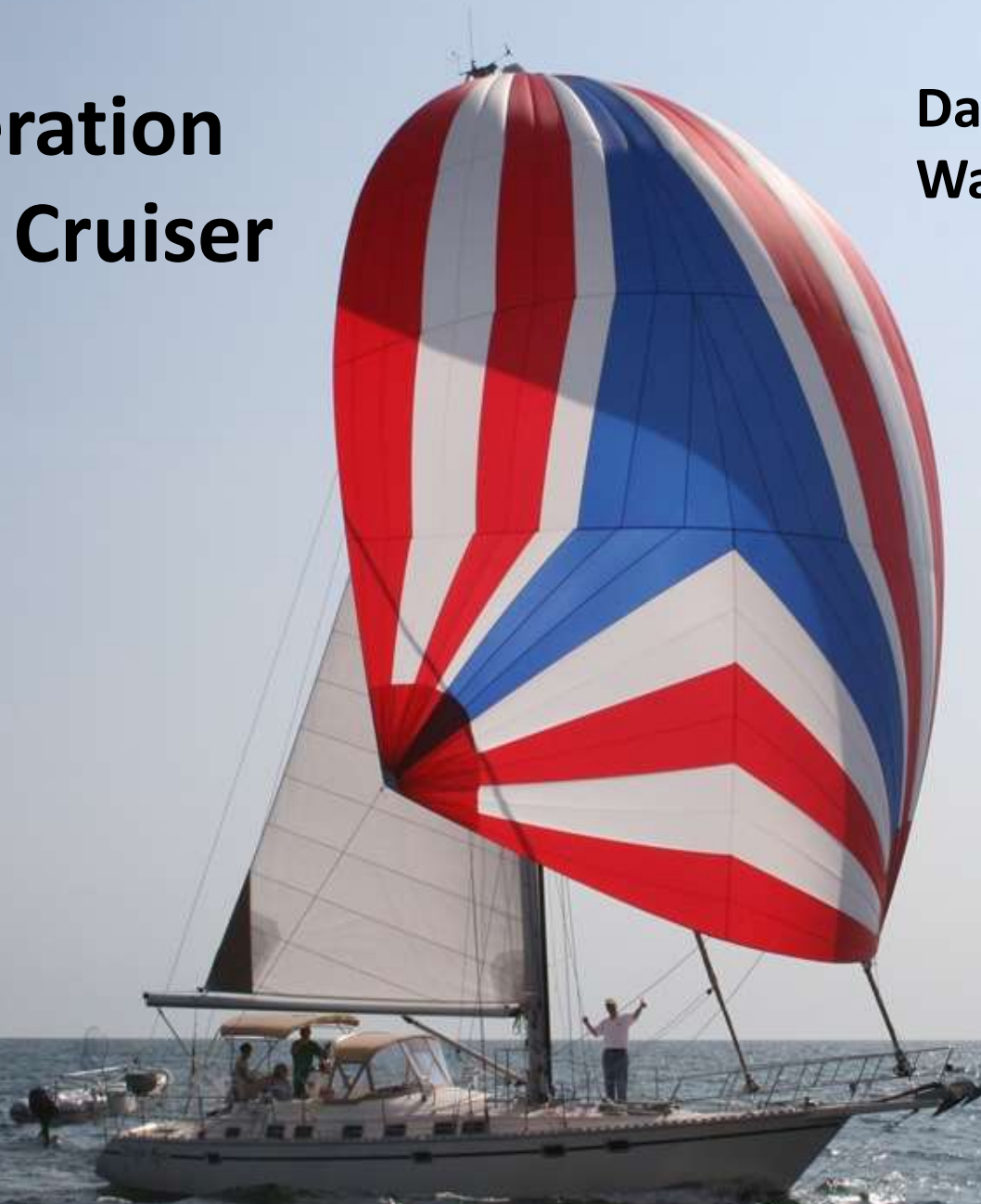


St Francis 44
Davao Gulf
2015

Refrigeration for the Cruiser

Dave McCampbell
Wayne Romberg

Bright Ayes
Underway
Offshore



Refrigeration for the Cruiser

CSY 44
Marquesas,
F Polynesia

Dave McCampbell

Wayne Romberg



Refrigeration vs Ice

Storage- Short trips ice, cruising refrigeration



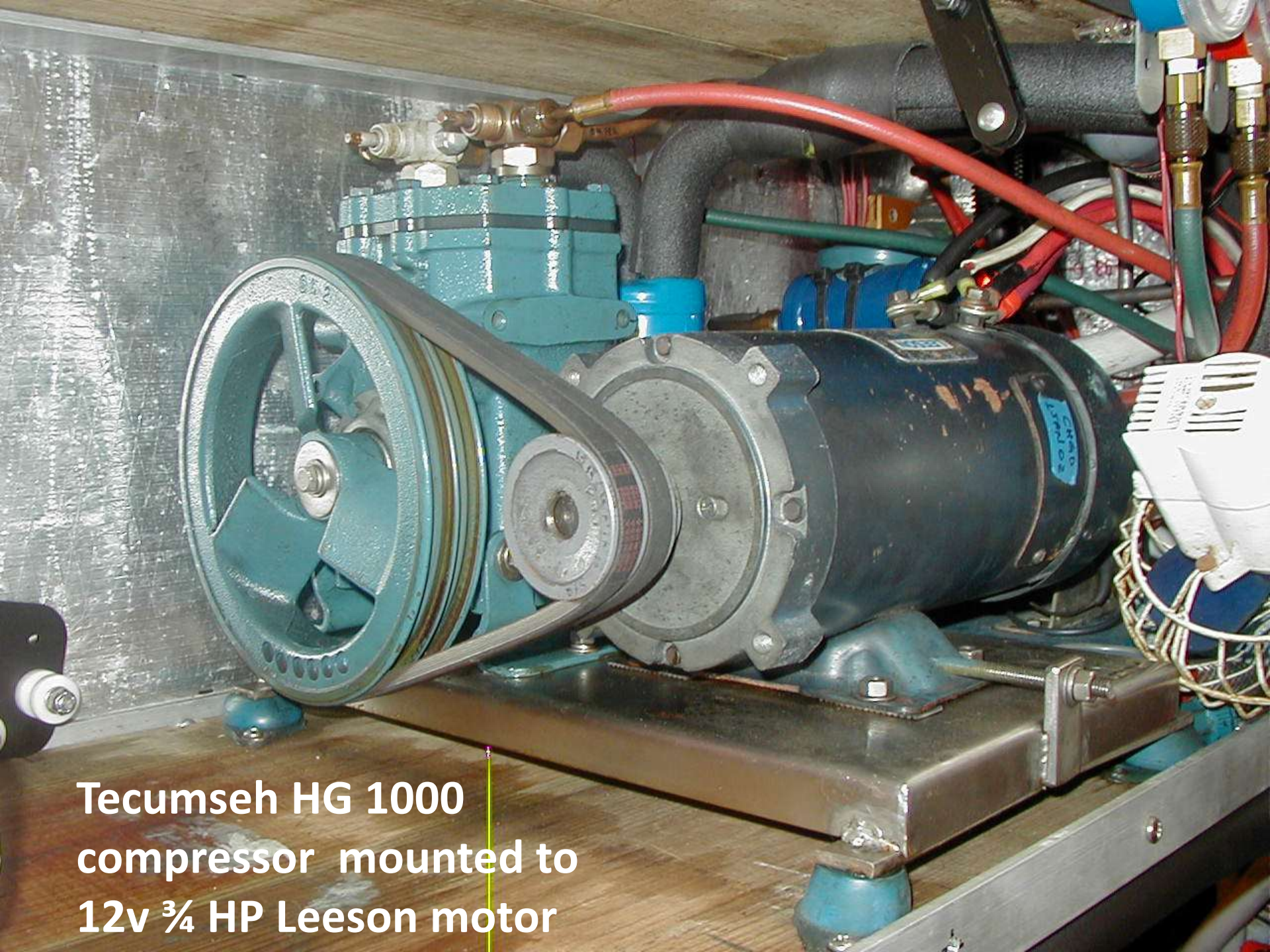
Why- keep foods & drinks longer, beer, ice



**Side Loading
Refrig Box**

My Refrig Goals:

- easy owner install
- steady box temps
- minimize heat load
- efficient heat removal
- easy box content removal



**Tecumseh HG 1000
compressor mounted to
12v $\frac{3}{4}$ HP Leeson motor**



**Nightmares: Tecumseh HG-1000
compressor partial tear down**

Glacier Bay's MARK II and Whisper Jet systems



Very efficient but
very expensive



Side loading box-
separate refrig &
freezer boxes, 3 cold
plates, R20

**Top load 3
cf freezer
box, 2 cold
plates, R22**



Danfoss Compressor Evaporator Plate Systems



Sealed connections, variable speed, bendable evap plates, almost silent, light weight, tight box temp delta

**Compressors- lots of makers, Danfoss now Secop,
3 sizes: BD 35, 50, 80 capacities, variable speed**



Speed capacities

**Danfoss BD
BD 50 compressor
w/ ECM attached**

Sealed connections



**Rear of BD50, two
heat sinks, filter
dryer**

Heat sinks



Installation- big ventilated
compressor space with
digital speed control,
thermostat, R134a can



**Electronic
Control
Module
w/electrical
connects,
note only 2
power
connections**

Control module, standard, for BD35-50 Compressors

**Evaporator
Plate- Large
vertical,
vertical ice
trays**



Evaporator Plate- Flat Bendable





Using heat gun prior to bending new freezer evap plate

**Bending new
freezer evap
plate around
1.5" PVC pipe**



Adler Barbour Cold Machine Air Cooled Condenser



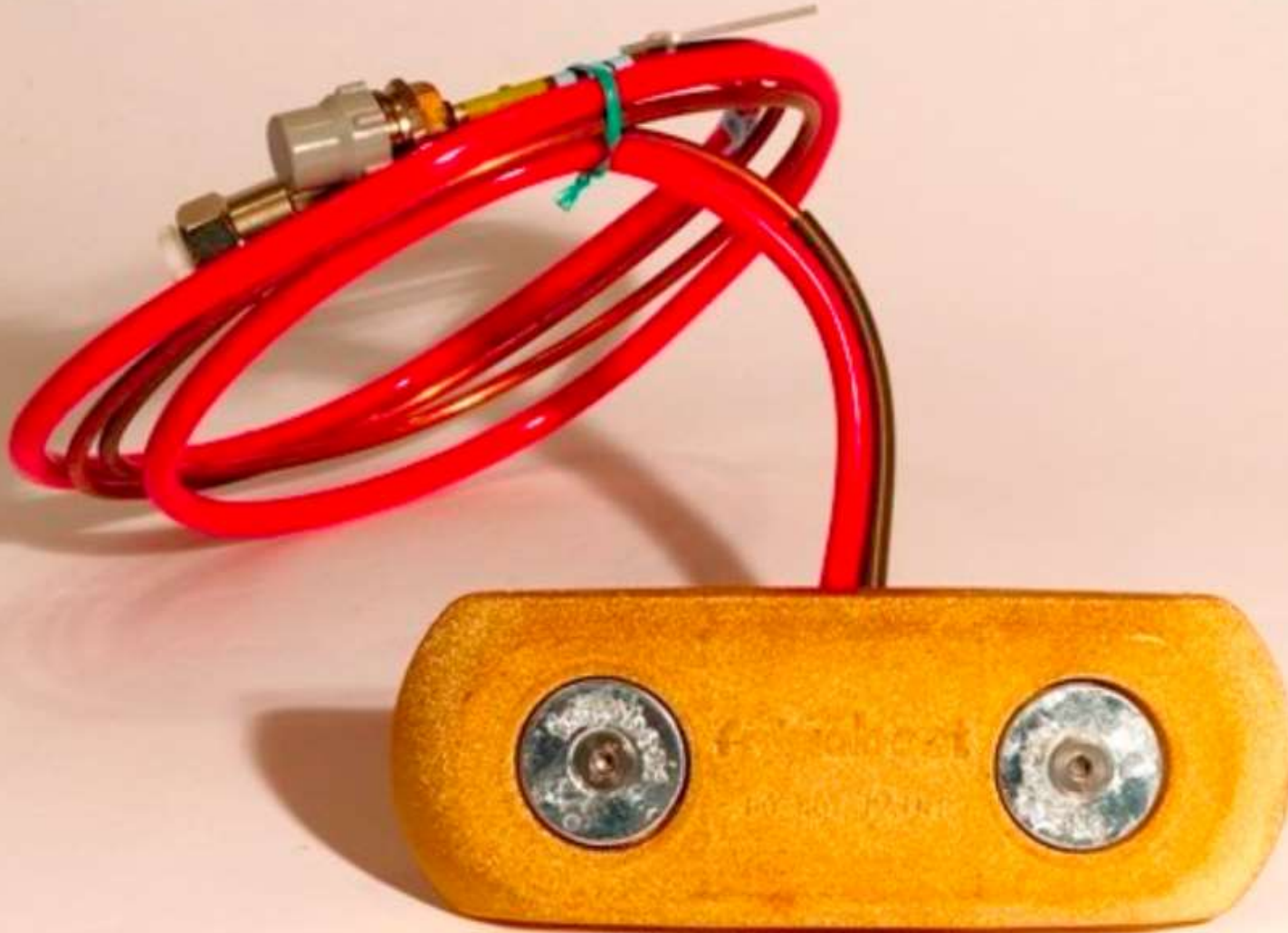
Air Cooled Condenser Unit



Frigoboat Pumped Water Cooled Condensor/Compressor



Keel Cooler with Zincs



Keel Cooler without Zincs





Frigoboat Keel Coolers

Installing a Keel Cooler

1.5" hole in hull

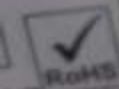


Danfoss BD 50F
12v compressor-
self sealing SS
connectors, RPM
vs amps

RPM MAX	WATERCOOLED	
	AMP 12V	AMP 24V
2000	3.8	1.9
2500	4.7	2.4
3000	5.6	2.8
3500	6.7	3.1

FRIGOBOAT ITALY
E51975VVA
FM H 50F 12/24V 90P VECOM
S/N 503297 Sait.070
www.frigoboat.it

Danfoss
BD50F
12/24V DC
THERMALLY
PROTECTED
SYSTEM



87

42

Frigoboat Digital Thermostat w/ Temp display



Expensive

Internet Digital Thermostat w/ temp display



About \$15

1 of 6

Digital Thermostat and Manual Speed Control Combination w/ Fault Light



Expensive

Separate digital
thermostat and
auto speed control
mounted

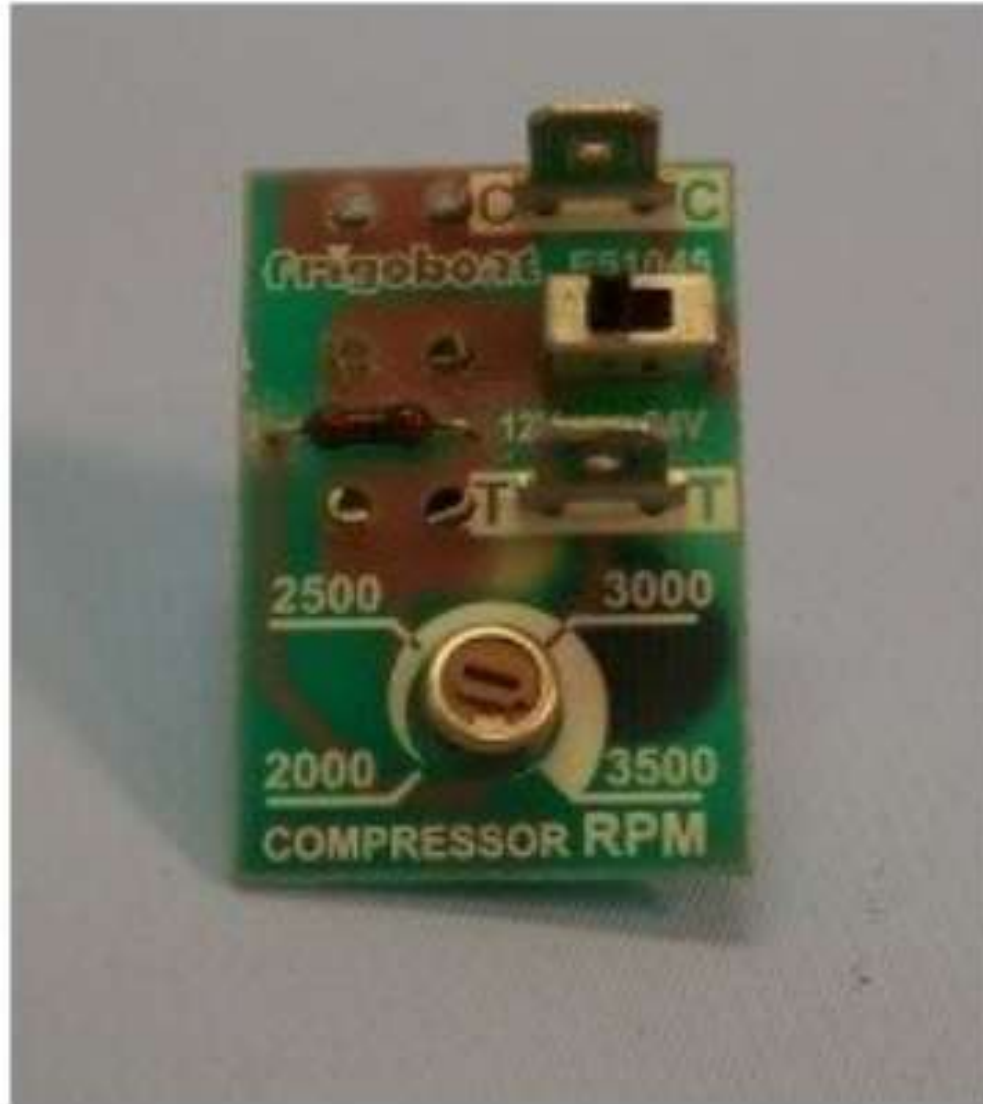


Smart Compressor Speed Control

Auto speed adjustment, soft start



Manual Compressor Speed Control



Manual speed adjustment- most efficient if left on lowest speed, inexpensive



**Mechanical
Thermostat- no
temp display,
freezer/refrig**



Old 30 lb can of R-12 w/ Schrader valve, \$1000

R134a Refrigerant Options



12 oz Can



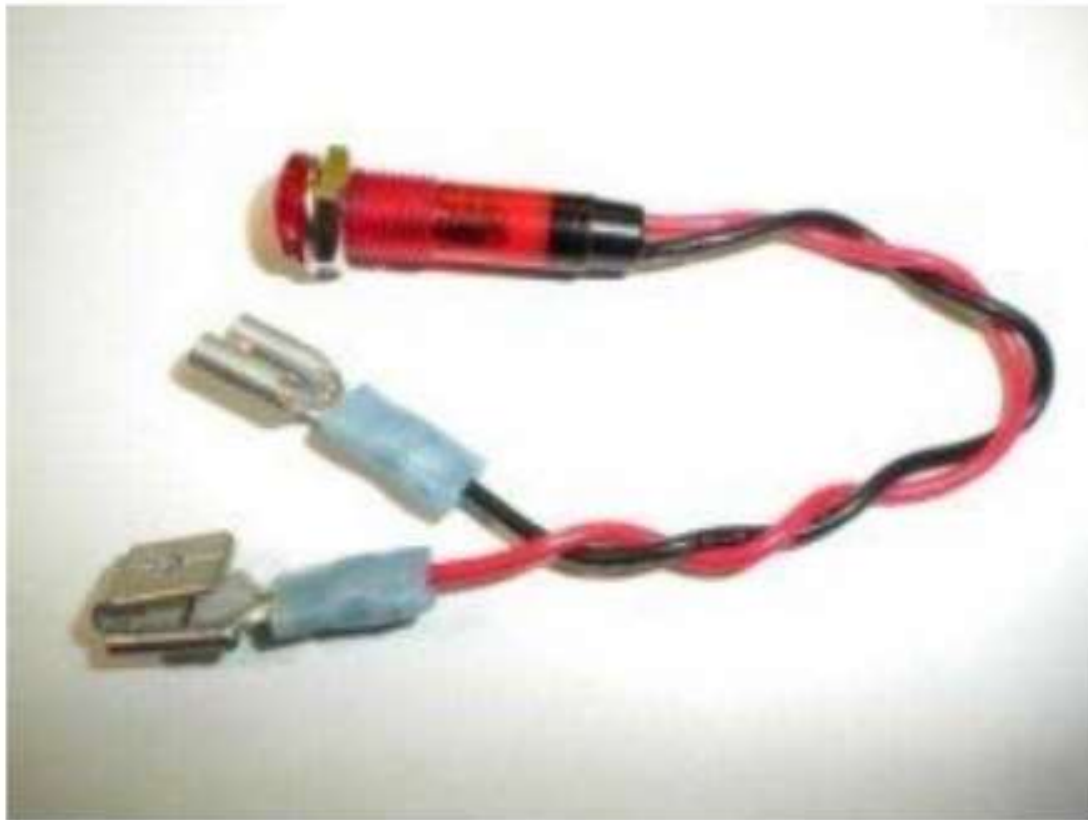
30 lb Cylinder



22 oz Kit

Diagnostic LED Fault Light Assembly

Worth having or make your own if not included on unit

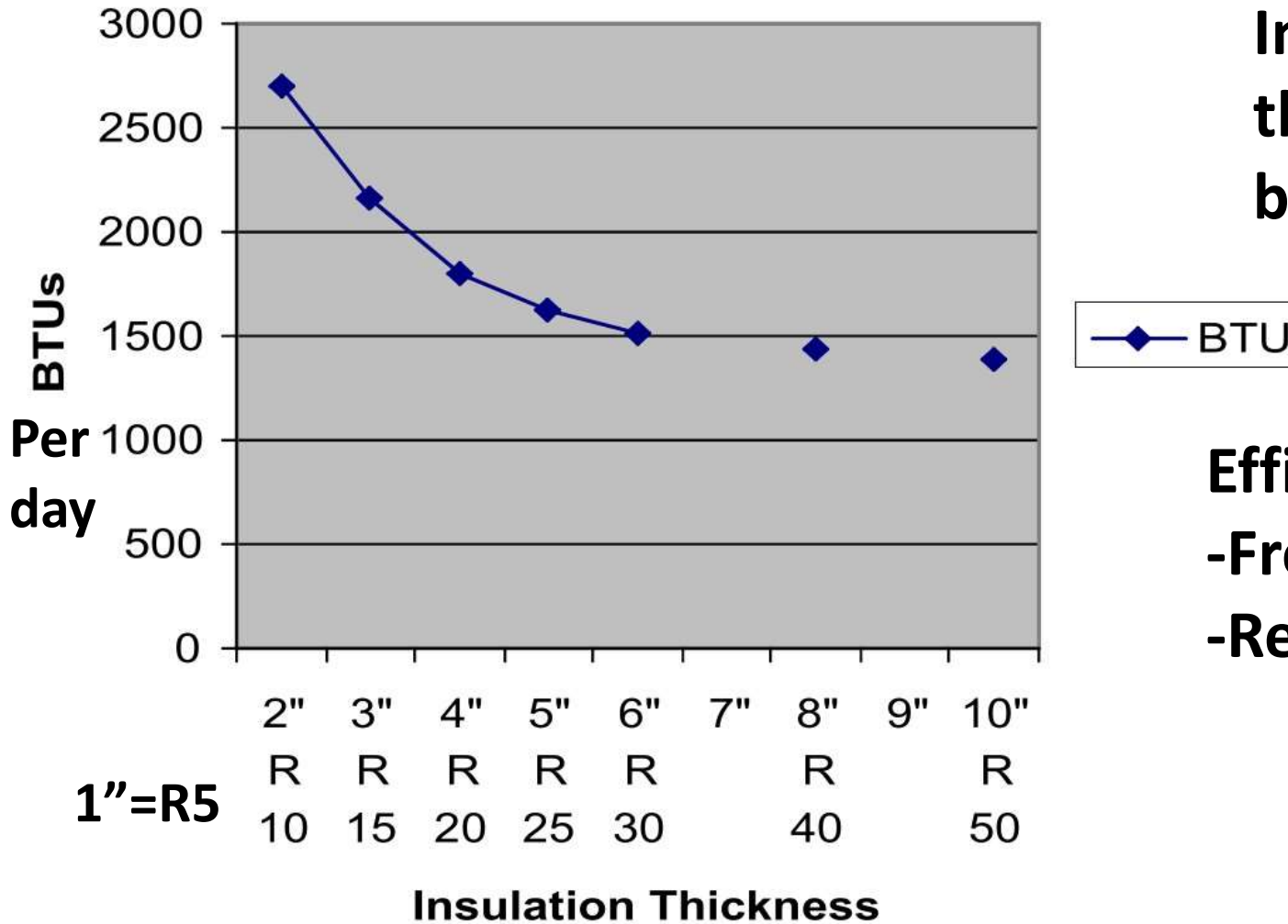


Box Construction



Freezer insulation thickness values

R value per insulation thickness

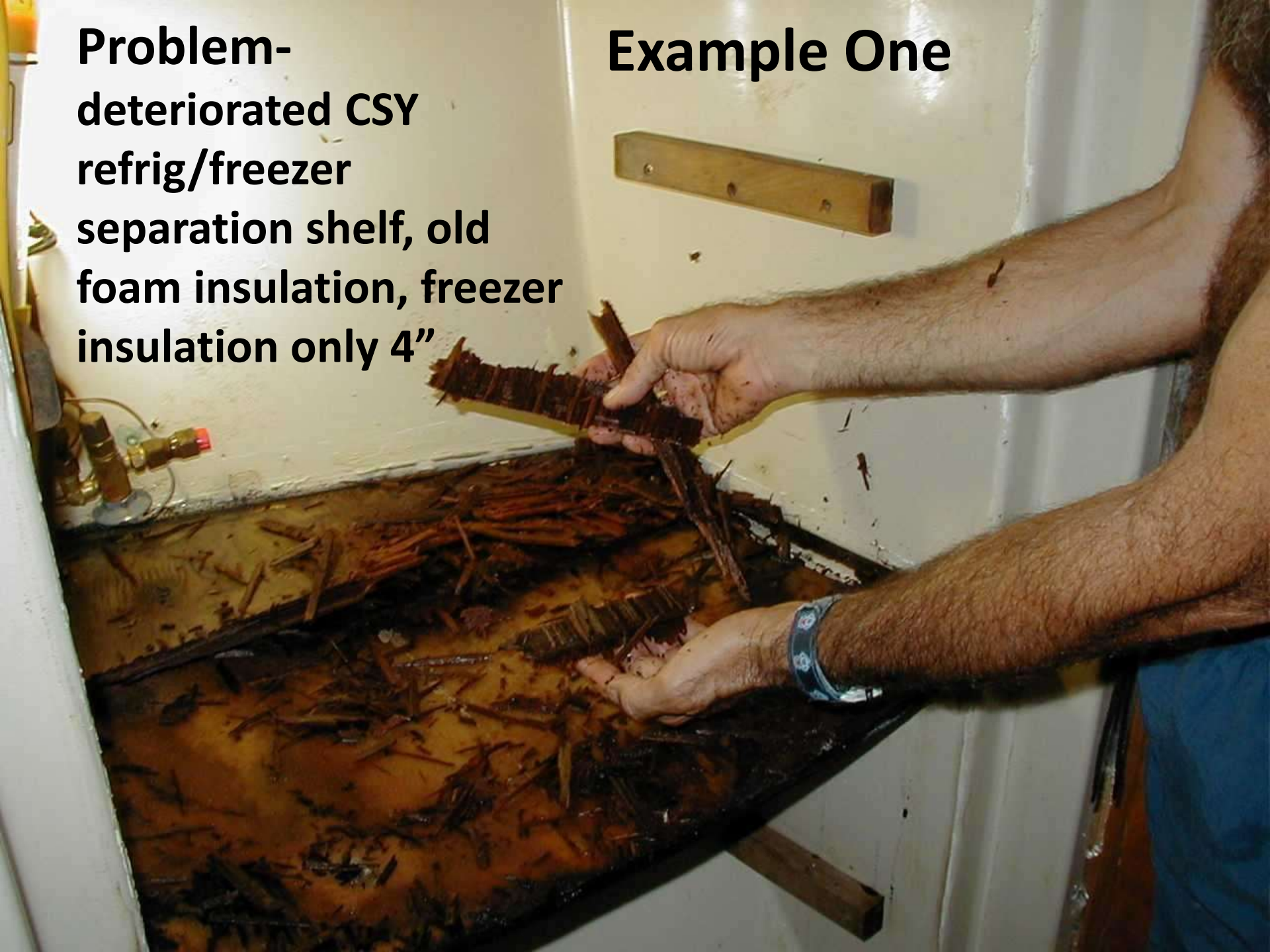


**Problem-
Insulation
thickness vs
bigger box size**

**Efficiency Goals:
-Freezer R30
-Refrig R20**

**Problem-
deteriorated CSY
refrig/freezer
separation shelf, old
foam insulation, freezer
insulation only 4"**

Example One



Rebuilt separation shelf, added one new freezer plate



--12 cans of new R5 refrigeration foam to replace original foam, 1/4" holes



**Rebuilt 8.5cf side loading refrig up, 2.5 cf freezer below,
--later changed to all refrigerator w/ holes in separation shelf,
--removed freezer holding plates**



Example Two

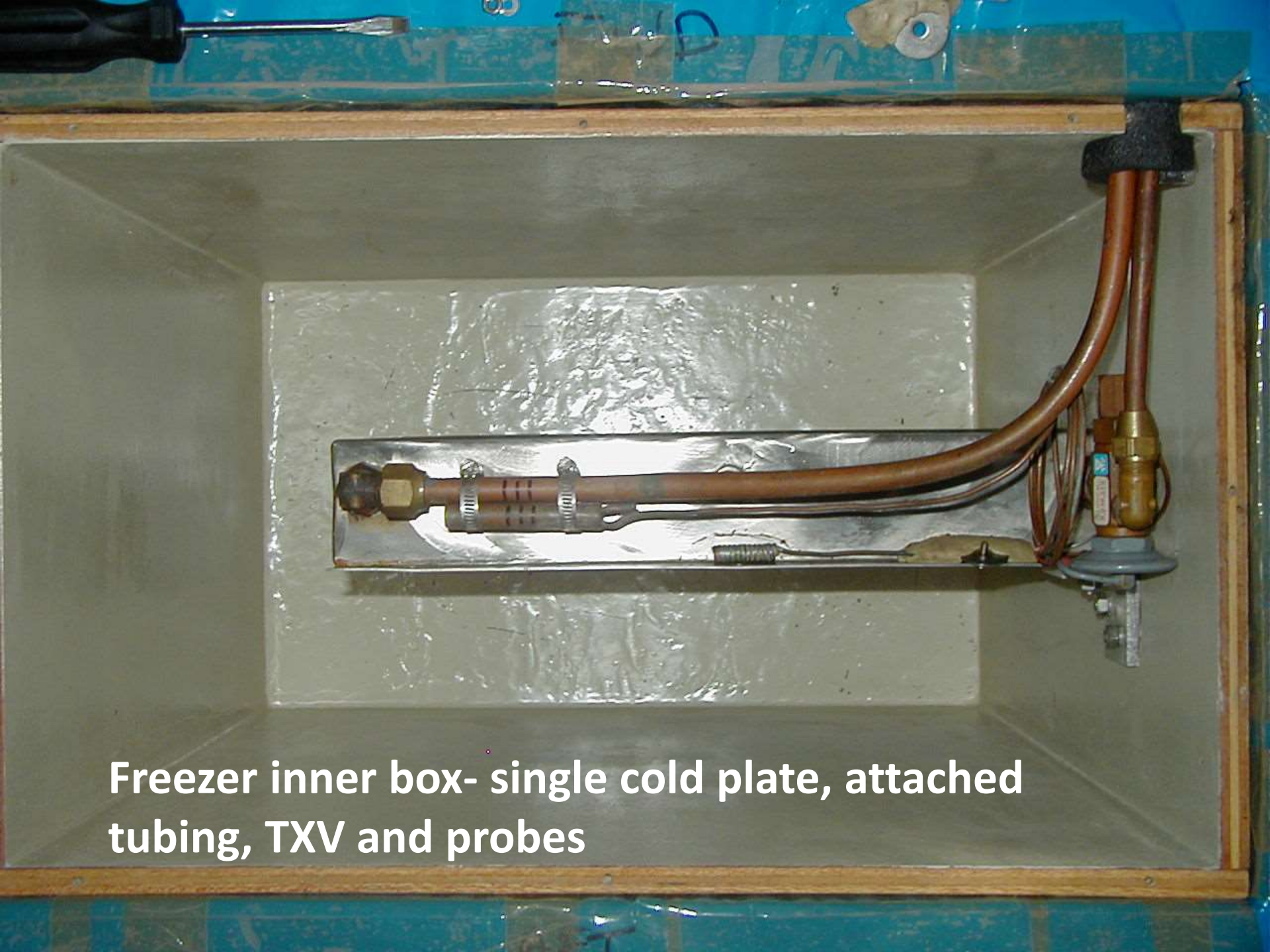
**New Freezer Box-
Inner box 3 cuft ½”
fiberglassed plywood
and outer 1” varnished
hardwood**



New freezer box components



**Original plastic sheet
covered *expanded*
polystyrene, ~R15, not
good insulation, all
available in Guatemala**




Freezer inner box- single cold plate, attached tubing, TXV and probes

3 cf freezer
box, later
2 cold
plates





**Later Freezer Box-
w/ Extruded
Polystyrene
insulation, evap
plate & compressor**

The image shows the interior of a freezer. The walls, floor, and ceiling are lined with a white, crinkled material, which is extruded polystyrene insulation sealed in mylar. The insulation is visible as a textured, slightly wrinkled surface. The freezer's metal frame is visible around the edges. The lighting is somewhat dim, with a bright spot on the left side of the ceiling.

**Freezer *Extruded*
Polystyrene
insulation sealed
in mylar**

FRONT ↑ F

F
↑
PORT

F
↑
STBD

AFT ↑ F

reezeFr w/ Extruded
Polystyrene and evap plate



Ship's carpenter
sanding solid oak
table top in P Harbor





**Final CSY freezer box-
mounted in main
cabin table, top
loading, R22 w/
*Extruded Polystyrene***

Example Three

Refrig project in cat-replace small, 2.5 cu ft, air cooled RV refrig/freezer

Thin insulation



New 8 cuft side loading refrig in fwd half of bunk, big box pantry storage in aft half of bunk



Outer ½" fiberglass/epoxied
ply & inner ½" expanded PVC
boxes in yard workshop





Inner expanded PVC box w/ evap plate mounted



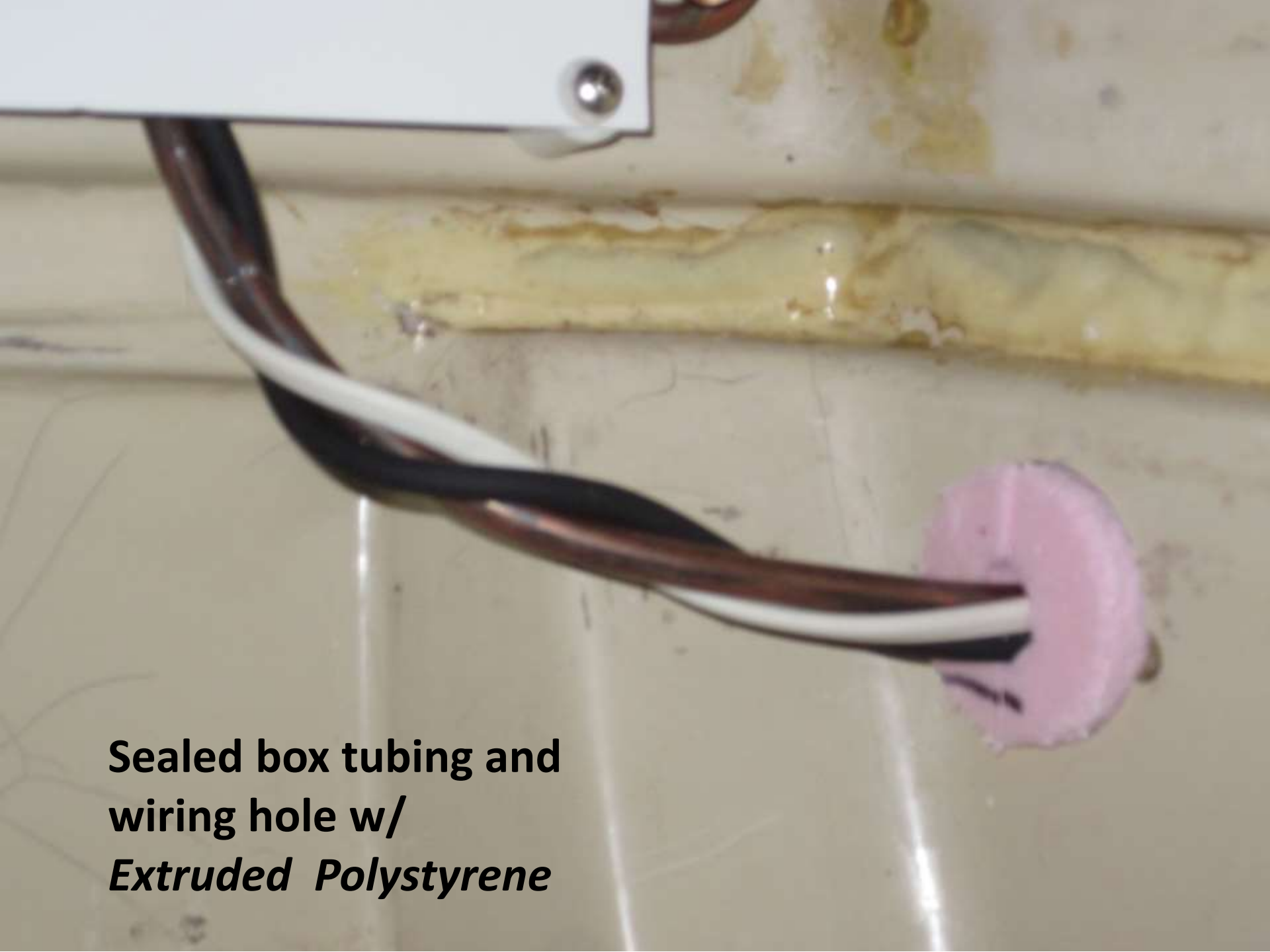
**Fitting door trim
& box front in
workshop**



**Refrig box painted & temp
assembled with screws**



Completely disassembled box pieces, before assembly onbd



**Sealed box tubing and
wiring hole w/
*Extruded Polystyrene***

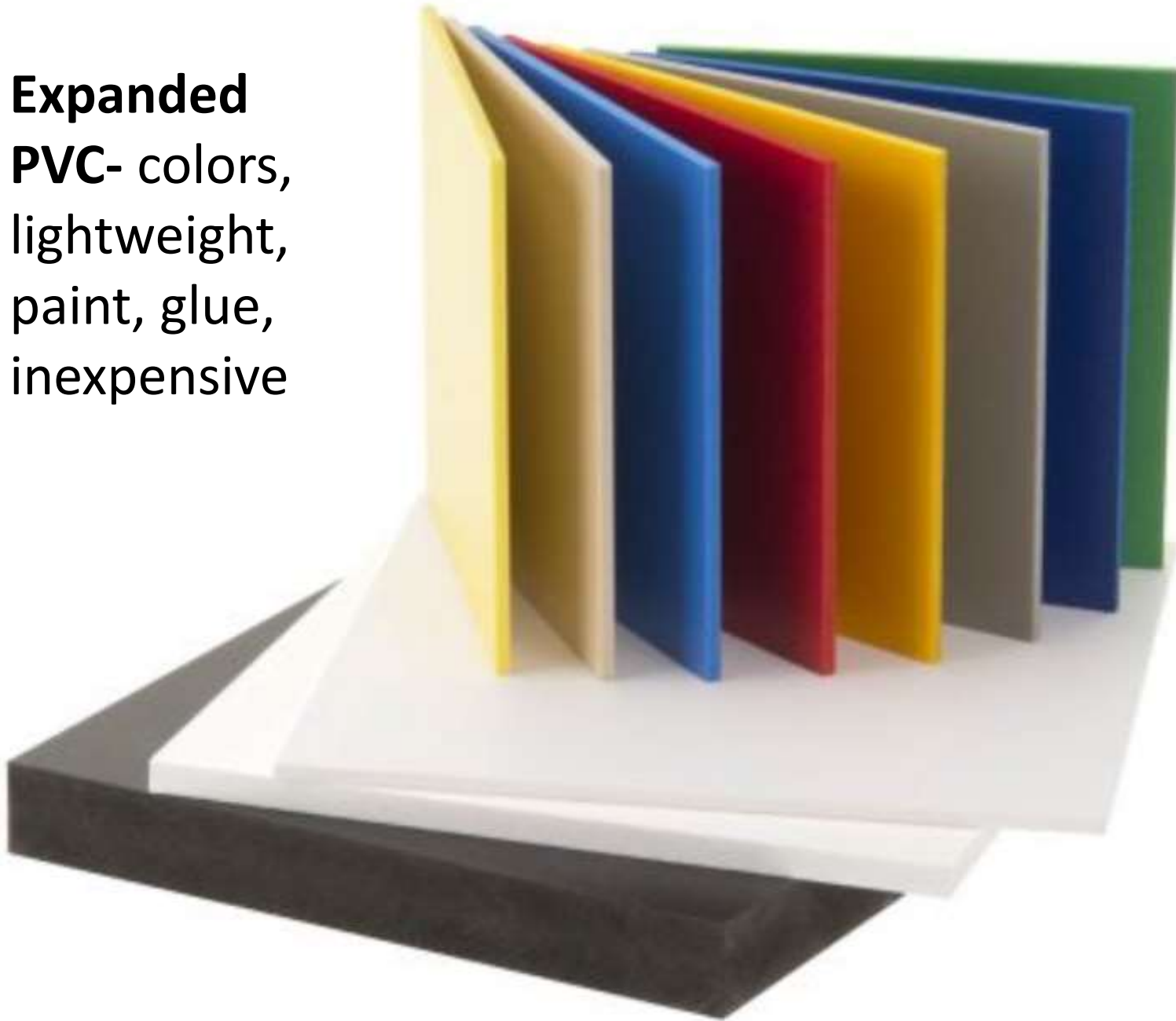


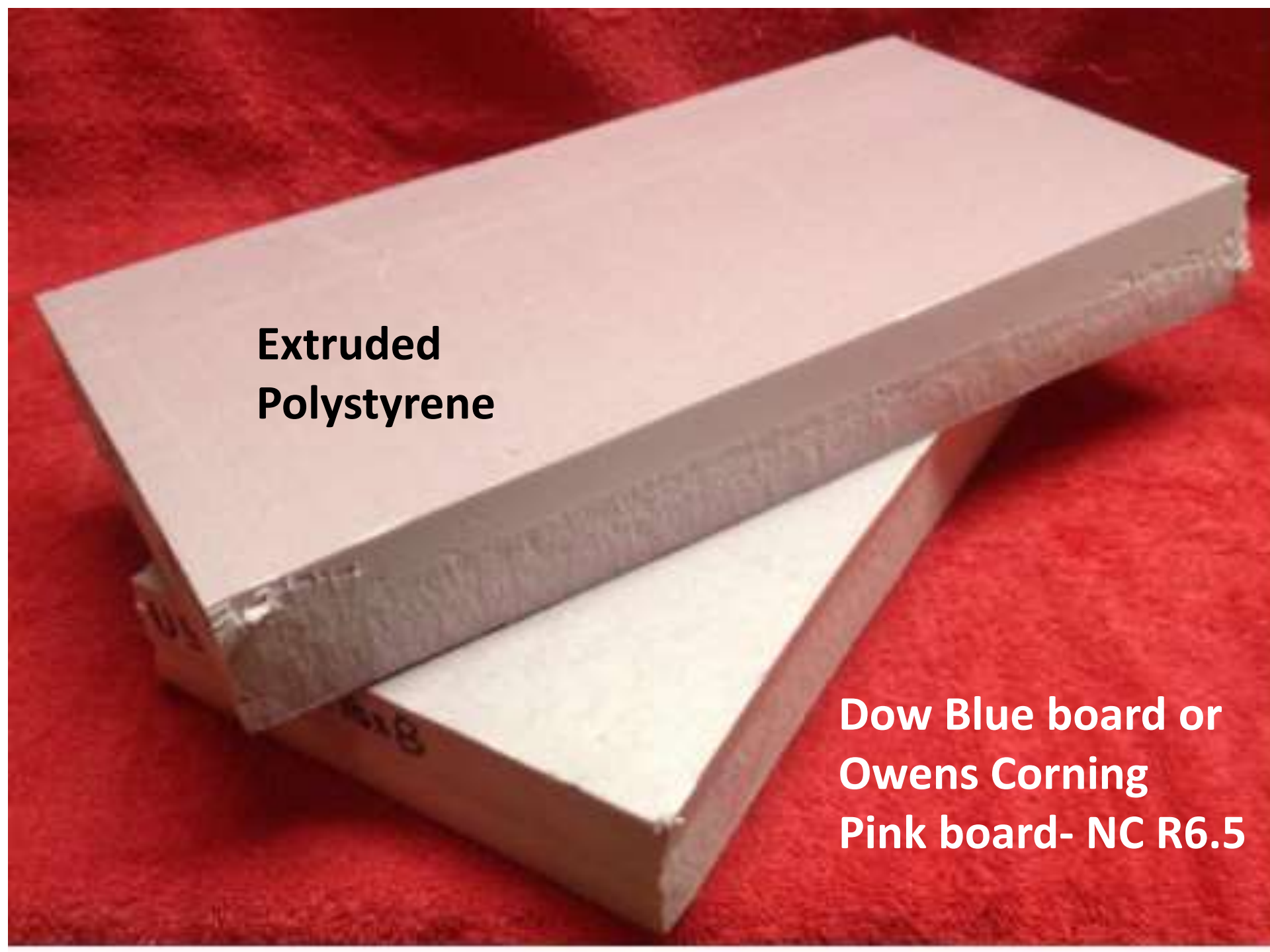
**Refrig box w/ one door
and no gasketing yet**



**Carpenters Gilbert
and Alfredo w/
finished side
loading 8 cuft refrigerig
box onboard**

**Expanded
PVC-** colors,
lightweight,
paint, glue,
inexpensive





**Extruded
Polystyrene**

**Dow Blue board or
Owens Corning
Pink board- NC R6.5**



EPDM rubber
ribbed door
gasketing
weather strip-
best for refrig
doors, double
gaskets for
freezers



Final Project

**Minus 40 4 cf freezer box:
air cooled BD 35, only 3"
R5 insulation, foam gasket**

MINUS 40

MODEL	115	SER. NO	510875
VOLTS	12	CAPACITY	115R
AMPS	4.5	GAS 134a	2237

MINUS 40 P.O. BOX 254
EPPINDUST 7475 R.S.A.

510875

**220v or 12v, auto shift to 12v if
220v shuts down, 50%= 54 ahr!**

Refrigeration for the Cruiser (Wayne)

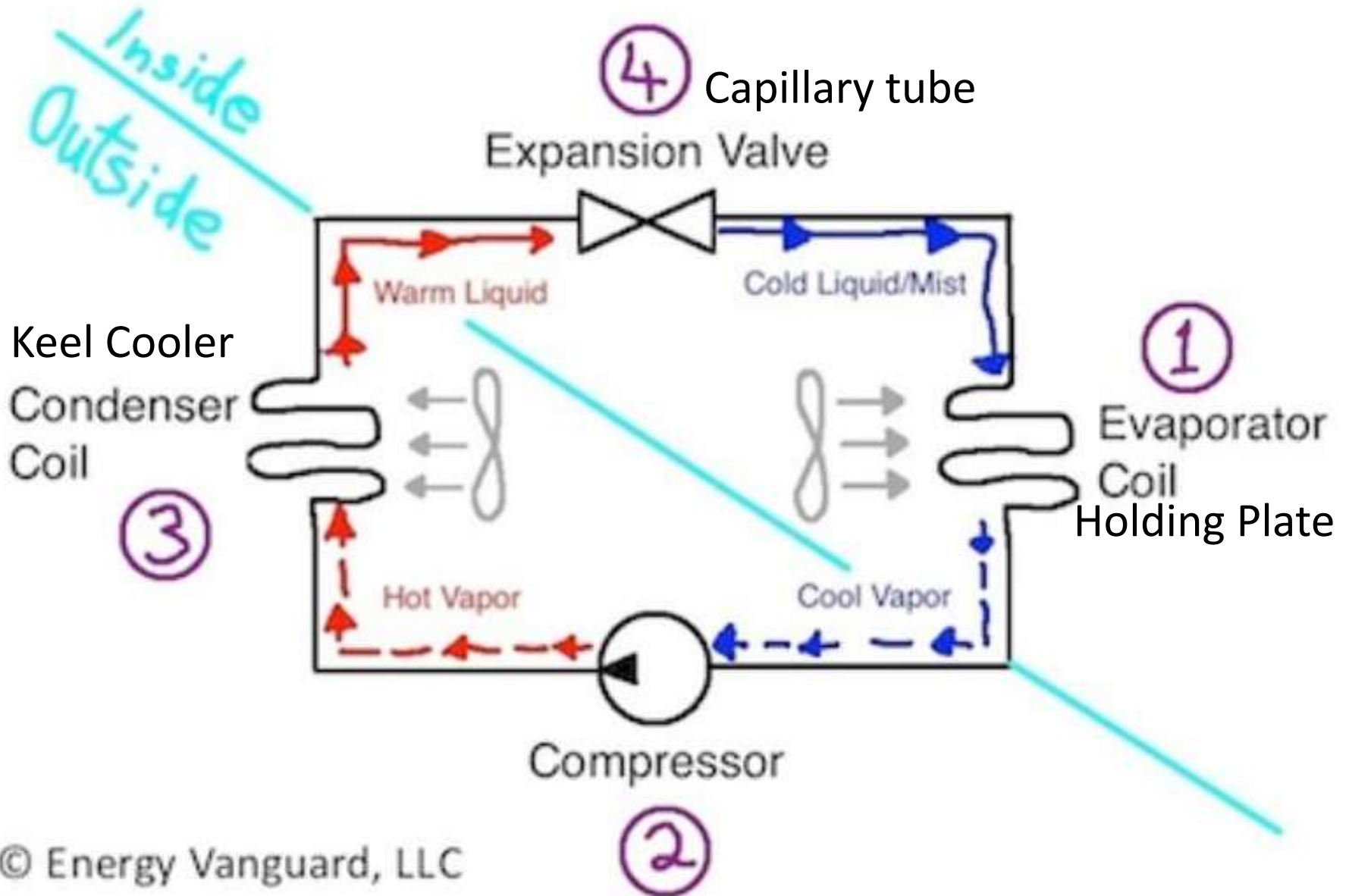
- **Heat Transfer-**

- BTU = Energy to raise temp 1# water 1 deg F
- $\text{BTU trans} = \Delta \text{Temp} \times \text{Thermal conductivity} \times \text{Time}$
- By Design:
 - » Min BTU's heat transferred into box
 - » Max BTU's heat transferred out of box
 - » Optimize heat transfers in refrigeration cycle

- **Vapor-Compression Refrigeration cycle -**

- Water boils at 32 deg F @ 29.74" Hg vac (1000 BTU/lb)
- R134a boils at -15deg F @ 0 psig (93 BTU/lb)

The Refrigeration Cycle



R134a Pressure – Temperature

Pressure	Temp	Pressure	Temp	Pressure	Temp	Pressure	Temp	Pressure	Temp	Pressure	Temp
psig/Hg"	Deg F	psig	Deg F	psig	Deg F	psig	Deg F	psig	Deg F	psig	Deg F
22	-62.38	13	11.77	37	42	61	62.75	145	109.4	265	150.6
20	-55.02	14	13.38	38	43	62	63.5	150	111.5	270	152
18	-48.85	15	14.94	39	43.98	63	64.24	155	113.6	275	153.4
16	-43.5	16	16.46	40	44.95	64	64.98	160	115.6	280	154.7
14	-38.76	17	17.95	41	45.91	65	65.71	165	117.6	285	156.1
12	-34.49	18	19.4	42	46.85	66	66.43	170	119.6	290	157.4
10	-30.6	19	20.81	43	47.78	67	67.14	175	121.5	295	158.7
8	-27.02	20	22.19	44	48.7	68	67.85	180	123.3	300	160
6	-23.7	21	23.55	45	49.61	69	68.55	185	125.2	305	161.3
4	-20.59	22	24.87	46	50.51	70	69.24	190	126.9	310	162.5
2	-17.67	23	26.16	47	51.39	75	72.62	195	128.7	315	163.8
0	-14.92	24	27.43	48	52.26	80	75.86	200	130.4	320	165
1	-12.31	25	28.68	49	53.13	85	78.98	205	132.1	325	166.2
2	-9.84	26	29.9	50	53.98	90	81.97	210	133.8	330	167.4
3	-7.47	27	31.1	51	54.82	95	84.87	215	135.5	335	168.6
4	-5.21	28	32.27	52	55.65	100	86.66	220	137.1	340	169.8
5	-3.04	29	33.43	53	56.48	105	90.37	225	138.7	345	171
6	-0.95	30	34.56	54	57.29	110	92.99	230	140.2	350	172.1
7	1.05	31	35.68	55	58.1	115	95.53	235	141.8	355	173.3
8	2.99	32	36.77	56	58.89	120	98	240	143.3	360	174.4
9	4.86	33	37.85	57	59.68	125	100.4	245	144.8	365	175.4
10	6.67	34	38.91	58	60.46	130	102.7	250	146.3	370	176.3
11	8.42	35	39.96	59	61.23	135	105	255	147.7	375	177.3
12	10.12	36	40.99	60	62	140	107.2	260	149.2	380	178.2

Refrigeration for the Cruiser

- **Maintenance-**

- Defrosting Evaporator: as needed, no sharp tools
- Warm water/hair dryer



- Condenser cleaning: vacuum & paint brush



Refrigeration for the Cruiser

Maintenance-

Keel cooler condenser- bio fouling, antifoul paint, change zincs



Refrigeration for the Cruiser

- **Maintenance-**

- Tools- v pump, gage set, temp gage, R-134a, charging rig with Schrader connection, Pocket Refrigeration manual



Refrigeration for the Cruiser

- **Maintenance-**

- Adding refrigerant: (134a)
- 12 oz cans, no leak detector fluid or oil
- Add vapor not liquid to compressor suction
- Frost line vs gages & superheat (4 psig=-5 deg)




Refrigeration for the Cruiser

- **Maintenance-**

- Superheat method setting freon charge can be found in any Refrig Handbook or on internet.
- Will provide the optimum freon charge defined by a suction press at a given box temp & condenser temp.
- Freezer: 2 psig suction press @18deg
- Refrig: 17 psig suction press @38deg

Refrigeration for the Cruiser

- **Maintenance-**

- Leaks???
 - Soap solution vs leak detector? Amazon- \$25
 - Quick connection O-rings,
 - Become hard with age & don't seal as well, especially when cold & at low press
 - Spares- rated for 134a?
 - O-ring tool?
- 
- Alum evaporator plate, tubing leaks?

Refrigeration for the Cruiser

- **Maintenance-**

- Electrical faults- cool/dry mounting, spade connectors, BD series LED diagnosis, spare motor controller



Refrigeration for the Cruiser

- **Maintenance-**

BD series LED diagnosis

- **One Flash** –Low Voltage, <10.4v
- **Two Flashes** - Overload on the Fan output.
- **Three Flashes** –Compressor cannot start due to high delta press
- **Four Flashes** –Compressor cannot reach min speed of 1,850 RPM.
- **Five Flashes** –Motor controller has exceeded 212 deg F

Refrigeration for the Cruiser

- **Maintenance-**

- Blocked cap tube- dreading, most likely frozen**

- Hair dryer or warm cloth on cap -you will hear it
 - Vacuum- temp vs time, min 2 hours, heat compressor, R134a hydroscopic & hard to remove moisture
 - Install filter/dryer,



- Foreign matter-replace cap tube/evap plate

Refrigeration for the Cruiser

- **Improvements-**

- Compressor muffin fan across top to remove heat



Refrigeration for the Cruiser

- **Improvements-**

- Filter dryer in HP line before cap tube
- Separate systems: freezer & refrigeration
 - Each can operate at best design point
- Interior fans- freezer, refrigeration, pros & cons
- Keel cooler & air cooling combo unit
- Air cooled unit- ventilate the space with a fan
- Box insulation- added at bottom better than top
- Better gasketing- dollar bill test, double for freezer
- Dark hull color/box side - added heat gain
- Seal tubing/wiring box refrigerant entrance hole well

Refrigeration for the Cruiser

- **Improvements-**

- Cold box drain- adds heat load, foot pump system



Refrigeration for the Cruiser

- **Improvements-**
 - Digital controls



Refrigeration for the Cruiser

- **Improvements-**
 - Freezer, heat xfer tube
 - Do not blanket evap plate with stuff.
 - Mesh bags for food, no plastic bags against evap plate.



Purchase Advice

- Be suspicious of dealers' claims of 'most efficient', ask for proof
- Similar size box, equipment and insulation value equals similar efficiency
- Explore company websites- Coastal Climate Control
- Ask owners about satisfaction and maintenance help
- Explore internet forums
- See engineering and construction quality at shows
- Buy new unit and keel cooler condenser for best efficiency

References

- 1 Boatowners' Mechanical & Electrical Manual 3rd/4th ed- Nigel Calder
- 2 Refrigeration Installation, service and repair manuals
- 3 SVSoggypaws.com/refrigeration.htm
- 4 Frigoboat website- www.coastalclimatecontrol.com