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Cold-Plus Case Study

A data center facility in McLean, VA, belonging to a global communications provider was the site of a *Cold-Plus* baseline and injection study in the summer of 2012. The facility contains multiple rooms and zones cooled by a variety of large and small direct exchange (DX) air conditioning units. An interior ground floor room housing the batteries for the site's Uninterruptible Power Supply (UPS) system was selected for the test.

The UPS room offers a few distinct advantages over the much larger A/C systems that cool the general server and hosting areas. First, it is a closed room serviced by three units controlled by their own thermostats in the center of the room. No other A/C units in the facility cool this room. Second, it is an interior room, insulated from the outside by a floor above, air-conditioned rooms on all four sides and a concrete slab floor. These conditions allow the UPS room to be viewed as a closed thermodynamic system for the purposes of this test, with constant, but minimal heat transfer through the walls, ceiling and floor.

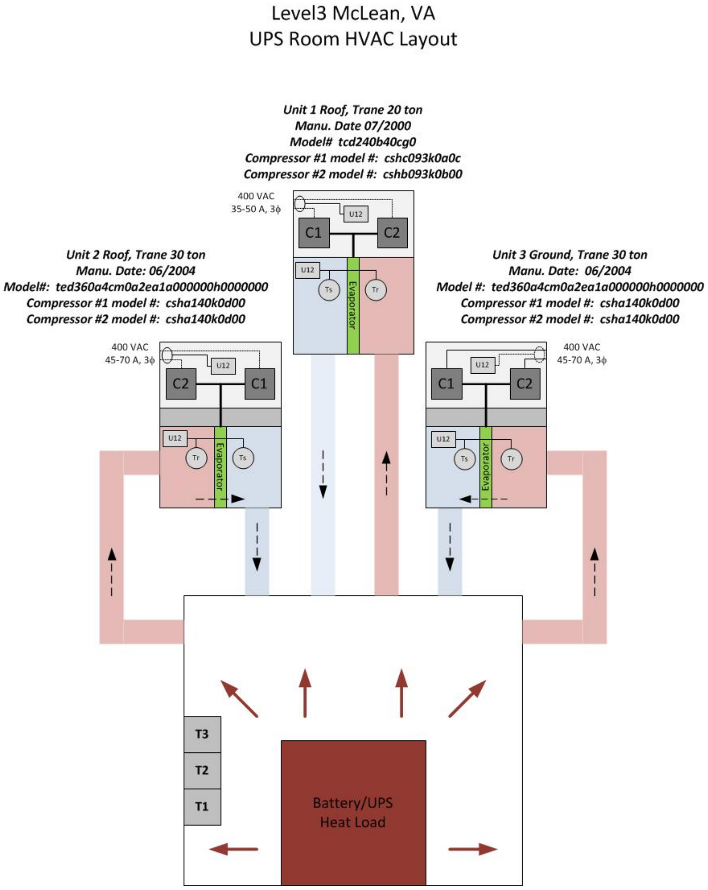

Figure 1.

Finally, the internal heat load in this room is constant, as determined by the electronics that run 24x7 to keep the UPS system charged and operational. This differs from a general air conditioning test on an office building where the A/C unit responds to varying inside temperatures (principally due to changes in the outside temperature, doors opening and closing, etc.) by turning the unit off and on to maintain the thermostat's setting. Also no equipment was changed in the UPS room during the test, unlike the general network equipment rooms, where servers and switches are often added or removed. In thermodynamic terms, this means the enthalpy or total system energy (the heat generated by the UPS system and removed by the A/C) is constant over time. This is important later in the analysis of the results.

The thermostats are all set to ~72˚F, with enough difference to load the units as follows: the 20-ton Trane Voyager roof unit in Figure 1 is the primary cooler and runs all the time on both compressors. This is the unit that was treated with ***Cold-Plus***. The 30-ton Trane Voyager roof unit also runs constantly on one or two compressors depending on the outside temperature. The 30-ton Trane Voyager unit on the ground essentially functions as a backup and did not run at all, as determined from the zero current draw measured on the 30 ton ground unit throughout the testing period. No settings or controls on any of the units were changed during the testing period. The vents and louvers were set to run the system in closed circulation, i.e. no outside air was mixed with the return air at any time.

Data Logging: HOBOware data loggers and probes from Onset Computers, Inc. were used to gather data over the periods of interest. Each unit had the following probes installed to record the data as shown in Figure 1:

- **Ts** (˚F) = air temperature of supply air, which is the cold air that goes into the UPS room. The probe was suspended in the air adjacent the evaporator coils.
- **Tr** (˚F) = air temperature of return air, which is the hot air coming from the UPS room. The probe was suspended in the air beside the air filters in front the evaporator coils.
- **ΔT** (˚F) **= Tr – Ts,** which is directly proportional to the amount of heat removed from the air by the A/C.
- **Iac** (A) = AC current clamp on the L2 conductors (red wire) supplying each compressor. Step changes in the current indicate the second compressor (or whole system) turning on or off.
- **Tamb** (˚F) = ambient temperature of fan-driven intake air in the compressor/condenser enclosure. The probe was not in direct sunlight or exposed to the elements and was placed well away from the compressors' plumbing.

The performance baseline was established over a 10 day period from 7/23/12 – 8/01/12 during which the average (day and night) temperature was 83.5 ˚F with a low temperature of 71˚F and a high temperature of 101˚F. The 20-ton roof unit continuously ran both compressors. The 30-ton roof unit also ran both compressors almost all the time, except for early in the morning (4–7 am) on a few of the coolest nights where the 2nd compressor in the unit would cycle off for 8-10 minutes per hour because the 1st compressor alone could supply sufficient cooling. During the day, the UPS room required both compressors on both the 20-ton and 30-ton rooftop units to run continuously.

Cold-Plus was injected into the 20-ton roof unit on 8/1/12 by a Johnson Controls technician using a standard HVAC manifold and no refrigerant or oil was added or removed from the unit during the process. Figure 2 shows the effect of ***Cold-Plus*** as it removes the oil fouling from the refrigerant plumbing of the 20-ton unit.

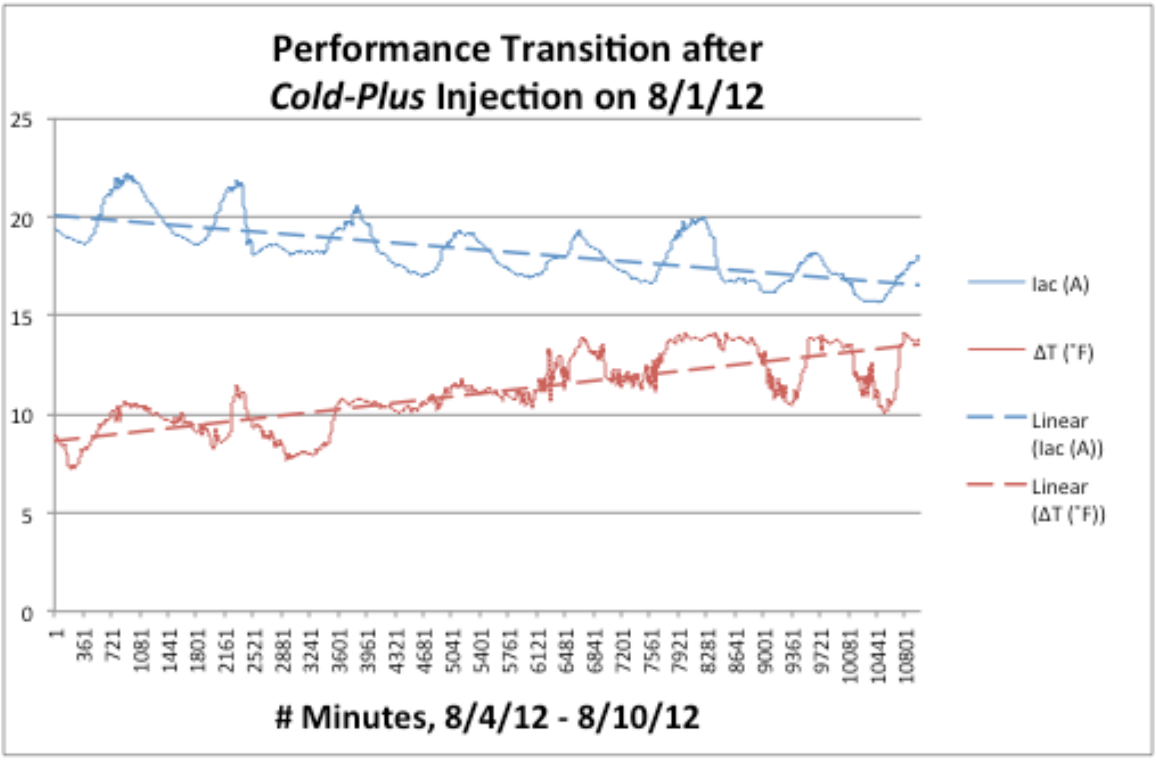

Figure 2.

The top line of the graph shows the current draw of the compressors steadily decreasing over this six day period (the day-night peak-trough fluctuations notwithstanding) while the bottom graph shows the ΔT between the supply and return air steadily increasing in the same time period. These are the performance changes that occur as ***Cold-Plus*** removes the accumulated oil fouling and coats the plumbing with a Teflon-like molecular layer to prevent recurrence. The thermally insulating oil is removed, so heat transfer across the heat exchangers improves, resulting in higher temperature differences across the condenser and evaporator. Refrigerant flow rates also improve due to reduced friction with the plumbing walls that contributes to the reduced load (and lower current draw) of the compressor.

Figure 3 most clearly demonstrates the performance improvement of the 20-ton Trane unit when treated with ***Cold-Plus***. The 12:00 – 3:00 pm period was selected on 7/25 and 8/28 because this three-hour window on both days had a very similar temperature profile as shown by the top two lines of the graph (and the same average temperature of 88.2˚F). This removes any differences in ambient temperature as a factor in the comparison of before and after performance. Also, these were neither the hottest, nor the coolest days during the data collection periods, and as such are representative of the test data overall.

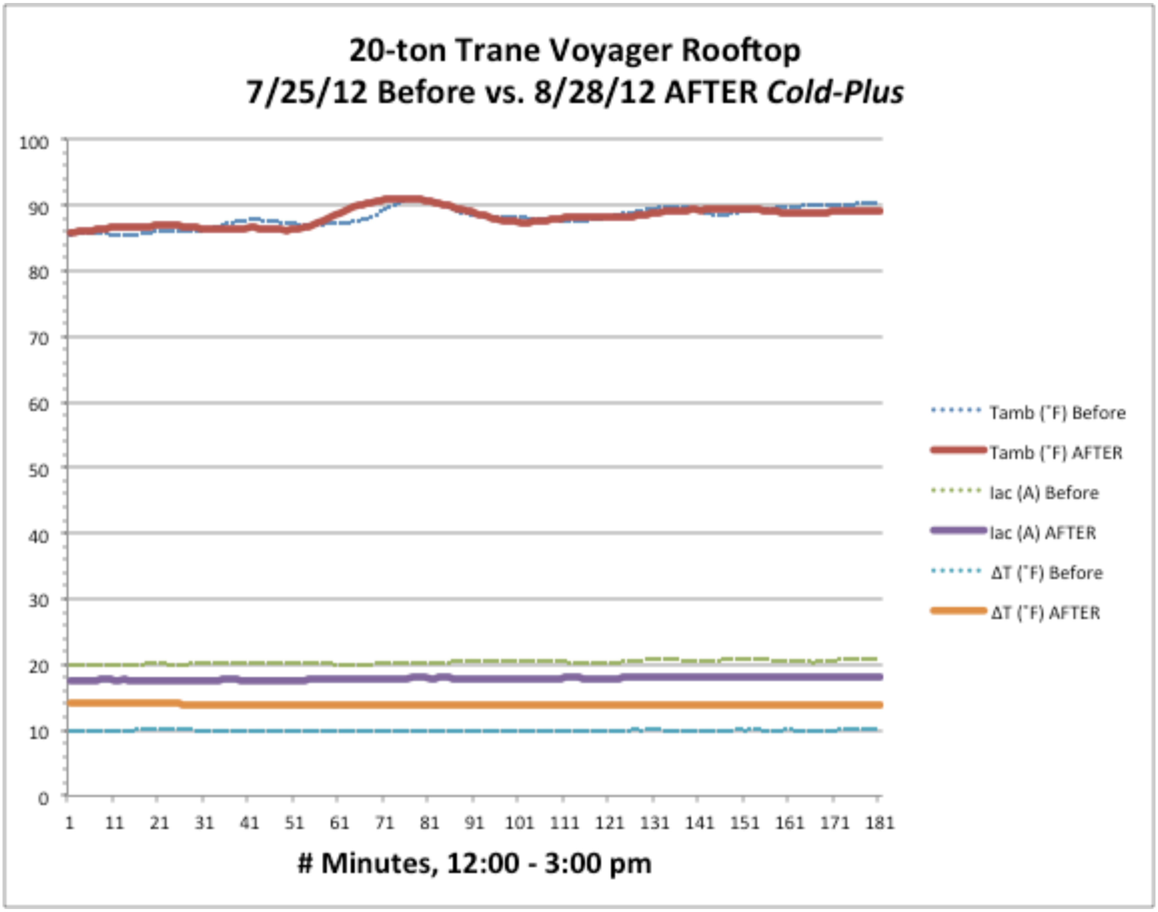

Figure 3.

During the baseline period on 7/25, the 20-ton rooftop Trane unit provided an average ΔT of 10˚F in cooling while consuming 20.4 Amps of AC current (at 480 VAC). After the ***Cold-Plus*** treatment, the unit delivered a ΔT of 13.9˚F in cooling while only consuming 17.9 Amps of current (at 480 VAC) under the same conditions. These two effects translate into a dramatic increase in efficiency as shown below.

Table 1 summarizes the data acquired during two 24-hour periods before and after the ***Cold-Plus*** treatment along with the relevant calculations. The numbers in bold, gray boxes are the average values of 1440 measurements of each variable per 24 hour period on 7/24 (before) and 8/24 (after).

Table 1.

McLean, VA	**Before**		**After**	
Trane Voyager Capacity (Tons)	20	30	20	30
Start Date Logging	7/24/12		9/1/12	
Start Time Logging	0:00		0:00	
End Time Logging	23:59		23:59	
Average Ambient Temp (°F)	**85.7**		**85.5**	

Cooling Power Delivered		**Before**		**After**	
Return Air Temp (°F)		**84.7**	**80.9**	**84.3**	**80.6**
Supply Air Temp (°F)		**74.5**	**61.6**	**70.4**	**63.5**
Air ΔT (°F)		10.2	19.3	13.9	17.1
Air Flow Rate v (cfm) *(Constant for each unit, Trane catalog values)*		7,000	12,500	7,000	12,500
Cooling Power (BTU/hr)	$=c_p*\rho*v*\Delta T$	76,289	257,455	103,836	228,108
Cooling Power (kW)	$=c_p*\rho*v*\Delta T$	22,360	75,460	30,434	66,858
Total Cooling Power (kW) *(20 ton + 30 ton)*		97,821		97,293	
Cooling Power Distribution		23%	77%	31%	69%

Electric Power Consumed		**Before**		**After**	
AC Voltage (V)-*Measured but not logged*		480	480	480	480
Average AC Current (A)		**19.8**	**36.7**	**17.1**	**30.4**
Average Power (kW)	=V*I*1.732/1000	16.5	30.5	14.2	25.3
Total Electric Power (kW) *(20+30 ton)*		47.0		39.5	

HVAC Figures of Merit	**Before**	**After**
EER Energy Efficiency Ratio (Btu/hr/W) *=Cooling Power (Btu/hr)/Electrical Power (W)*	4.6	7.3
EER Improvement		**58%**
CoP (Coefficient of Performance)	1358	2141
CoP Improvement		**58%**

Savings and ROI	***After Cold-Plus***
Electric Power Savings (kW)	7.5
Electric Power Savings %	***16%***
# Hours run per year (24 x 365)	8,760
Seasonal Load factor	0.75
Electricity Cost ($/kWh)-*VA average thru 7/2012*	$0.0803
Annual Savings	**$3,947**
ROI length (months)	***19***

Simply put, the ***Cold-Plus*** treatment results in a 58% increase in the Energy Efficiency Ratio (EER), a standard figure of merit for HVAC systems. EER is simply the ratio of Cooling Power delivered/Electrical Power consumed in the most commonly used units (Btu/hr) / (kW). Another HVAC figure of merit, the Coefficient of Performance, is the dimensionless ratio of heat removed to electrical energy used both measured in kilowatt-hours.

What is also noteworthy is that the Trane literature specifies an EER of 10 for this 20-ton Voyager unit, and the ***Cold-Plus*** treatment has returned the unit to an EER of 7.3. To regain so much of the lost capacity of a heavily used A/C unit with ~100,000 hours in operation illustrates how the effects of oil fouling accumulate, with this 20-ton Trane unit's performance being degraded by over 50% in a 12-year timeframe. It is worth noting that this unit was disabled for several years in that 12-year period due to a broken compressor. That compressor was replaced a couple of years ago and the unit was then returned to service.

So how does the efficiency increase from ***Cold-Plus*** translate into energy savings for a global communications network? The net effect on the overall system of the increased performance of the 20-ton Trane unit was to allow the 30-ton Trane unit to shut off its second compressor much more frequently and run just on a single compressor more often. Figure 4 is another comparison graph of identical time periods (8:00 pm to 4:00 am) on two different days, (7/25-26 before and 8/27-28 after the ***Cold-Plus*** install) with similar temperature profiles and the same average temperature of 85.5˚F.

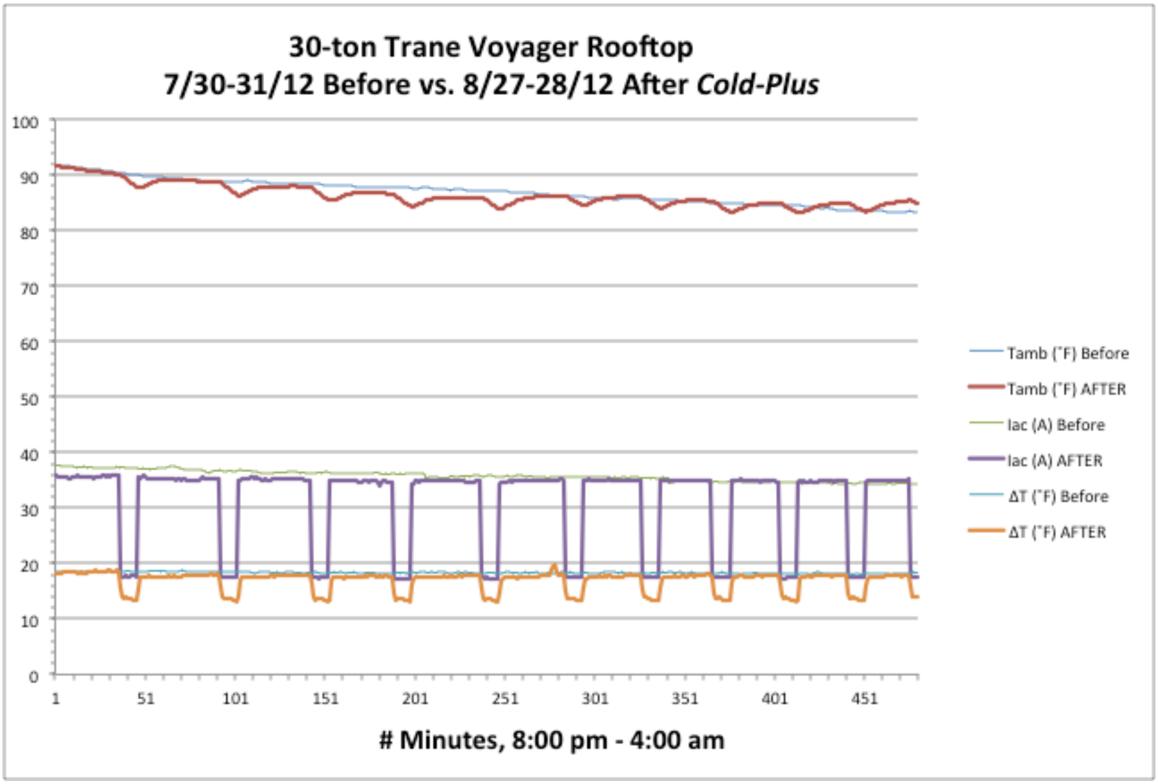

Figure 4.

On 7/25-26, before ***Cold-Plus***, both compressors on the 30 ton unit had to run to remove the constant heat load from the UPS room and unit's controller could only shut off the 2nd compressor on the coolest nights between 4 and 7 am (not shown on this graph). Whereas after the ***Cold-Plus*** installation on 8/27-28, the second compressor shuts off for 8-10 minute periods each hour throughout the night since only a single compressor is needed on the 30-ton unit, because of the INCREASED CAPACITY of the 20-ton unit that was treated with ***Cold-Plus***! Once the 30-ton roof unit is treated with ***Cold-Plus***, and its performance improves, it is easily conceivable that the 2nd compressor on the 30-ton unit never comes on at all in the evenings or during the cooler months.

Referring to Table 1, it is easily seen that the Total Cooling Power delivered by 20 and 30-ton units is the same before and after ***Cold-Plus*** was installed, which is to be expected since the internal heat load from the UPS room is constant. Treating the 20-ton unit with ***Cold-Plus*** increased its capacity and reduced the cooling required of the 30-ton unit as shown in Table 1 by the increased percentage of cooling done by the 20-ton unit.

Continuing down Table 1 to the electricity used to deliver that amount of cooling power, a reduction in the total electrical power used is observed after the ***Cold-Plus*** installation, which reflects the 30-ton unit turning off the 2nd compressor as shown in the Figure 4. 7.5 kW of electric power was saved, which translates into 16% reduction in electricity usage after the installation of ***Cold-Plus***! The reduced electric power consumption can be converted into monetary savings with a few additional numbers. Since the UPS equipment is on 24x7, that heat load has to be removed on a year round basis, but some seasonal factor should be applied to account for the A/C units not having to work as hard in the spring, fall and winter, because of a lower ambient temperature than the summer months. A seasonal factor of 75% was applied using the following assumptions. Spring and fall's lower temperatures will reduce the compressor load by 25% and winter by 50%, resulting in an overall seasonal load factor of 75% to reduce the amount of electricity consumed over the year relative to the peak values measured in the summer during this study.

Electricity costs are calculated in kilowatt-hours (kWh), and the US Department of Energy gives a year to date average through July 2012 of $0.0803 per kWh for commercial electricity rates in the state of Virginia, which is one of the lowest rates in the country. So saving 7.5 kW over the year turns into an annual electrical savings of $3900 on the 20-ton unit. These savings translate into a Return on Investment of (ROI) of 19 months for ***Cold-Plus***. The projected ongoing annual electricity savings would be at least $195/ton of cooling power for air conditioning units at data center facilities when ***Cold-Plus*** is installed. The ROI and savings are calculated purely from electricity savings alone. Table 2 below contains 2012 average utility rates to use for calculating projected savings in different states and regions. These rates were taken from the US Energy Information Agency's website: www.eia.gov/electricity/monthly where utility rates for the US can be found broken out by state, sector, year, etc.

Table 2.

Average Utility Rates through July, 2012 (¢/kWh)	**Residential**	**Commercial**	**Industrial**
New York	18.57	16.52	7.14
New Jersey	16.16	13.67	11.63
Pennsylvania	12.70	9.28	7.29
Delaware	13.34	10.09	9.03
Maryland	13.00	10.60	8.40
Virginia	11.52	8.03	6.87
North Carolina	11.01	9.03	7.13
By Region			
New England (CN, ME, MA, NH, RI, VT)	15.49	13.85	12.50
Middle Atlantic (NJ, NY, PA)	15.80	13.87	7.76
East North Central (IL, IN, MI, OH, WI)	12.05	9.59	6.83
West North Central (IA, KS, MN, MR, NE, ND, SD)	11.43	9.17	6.88
South Atlantic (DE, DC, FL, GA, MD, NC, SC, VA, WV)	11.62	9.53	7.08
East South Central (AL, KY, MO, TN)	10.18	9.79	6.76
West South Central (AR, LA, OK , TX)	10.36	8.02	5.72
Mountain (AZ, CO, ID, MT, NV, NM, UT, WY)	11.56	9.43	7.05
Pacific Contiguous (CA, OR, WA)	13.41	13.22	8.37
Pacific Noncontiguous (HI, AK)	30.51	26.03	27.83
U.S. Total	**12.04**	**10.44**	**7.18**

In conclusion, the performance claims made by the manufacturer of ***Cold-Plus*** were validated by increasing the Energy Efficiency Ratio from an oil-fouled value of 4.6 to 7.3 as compared to Trane's factory new specifications of an EER of 10. By removing the accumulated oil-fouling from the heat exchangers and plumbing, the increased heat transfer and refrigerant flow restored much of the degraded cooling capacity of a 12 year old Trane 20-ton Voyager A/C unit with ~100,000 hours of operation. ***Cold-Plus*** is a one-time treatment; the Teflon-like coating of molecules left behind by ***Cold-Plus*** ensures that oil-fouling does not recur so that the unit will maintain this level of performance for the remainder of its useful life. Qualitatively, it has been observed that the reduced load on the unit after treatment with ***Cold-Plus*** also results in longer operational lifespan and fewer service calls. Those claims could not be validated in the relatively short testing window, and were NOT factored into the ROI calculation. No service was performed on the units immediately before, during or after the testing period.

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