

## Evaluation of Cold-Plus® in Perdue 18760 and 18794

The two trailers were the subject of a test run from 5/13/2014 until 5/24/2014 according to the protocol in attachment 1. The following information was collected:

- Ambient Temperature
- Ambient Relative Humidity
- Supply Air Temperature
- Return Air Temperature
- Thermo King Hours
- Compressor Hours
- Fuel consumed daily

The units were refueled at 08:45am so the 24 hour periods start at that time and not the usual midnight. The fuel sheet is attachment 2.

Every effort was made to duplicate the actual operating conditions that the Thermo King units experience. Historically unit number 18760 has the compressor operating 37.69% of the time while 18794 is slightly higher at 38.48%. A heater producing 4800 Btu was added to each trailer as a false heat load to get the unit to cycle on-off as in normal use. The period from 5/13 to 5/19 was the base period and 5/19 to 5/24 was after treatment. There was a significant difference between the average temperatures for each test day between the base period and the after installation period.

### Unit 18794 Baseline

24 Hr Periods	Amb. Temp, °F	Amb. RH, %	Fuel	Comp Hrs	TK Hrs	Daily Comp hrs	Daily TK hrs	gph	gph TK hrs
1	68.294	71.593	8.9	16750	43522	8	24	1.113	0.371
2	65.154	85.907	7.2	16758	43546	8	24	0.900	0.300
3	73.698	77.216	7.4	16767	43570	9	24	0.822	0.308
4	62.948	85.305	7.6	16776	43594	9	24	0.844	0.317
	67.523	80.006	7.775			8.5	24	0.920	0.324

**Unit 18760 Baseline**

24 Hr Periods	Amb Temp, °F	Amb RH, %	Fuel	Comp Hrs	TK Hrs	Daily Comp hrs	Daily TK hrs	gph	gph TK hrs
1	68.294	71.593	7.8	16701	44305	8	23	0.975	0.339
2	65.154	85.907	6.8	16709	44329	8	24	0.850	0.283
3	73.698	77.216	7.3	16717	44353	8	24	0.913	0.304
4	62.948	85.305	7.8	16725	44377	8	24	0.975	0.325
	67.523	80.006	7.425			8	23.75	0.928	0.313

This chart shows the ambient conditions for the same hours as the fuel fill ups so the fuel used was during the same hours as the recorded ambient. The gallons per hour (gph) and the gph TK Hrs (unit control switched on) are divisions of fuel consumed by the hours from the hour meter. As you can see there is significant variance in the gph consumed by each period which does not relate directly to ambient conditions. This is not what we expected to see since there are only two heat loads on the space. The first is from the ambient conditions and the other from the 4800 btu false heat load in each trailer. Using all the measurement periods for the trailers produce a reasonably similar picture of the gallons used.

As we look at the data produced after the injection we see a similar pattern where the ambient and fuel used do not correlate well.

**Unit 18794 after injection**

24 Hr Periods	Amb Temp, °F	Amb RH, %	Fuel	Comp Hrs	TK Hrs	Daily Comp hrs	Daily TK hrs	gph	gph TK Hrs
1	66.886	48.754	8.00	16799	43667	9	25	0.889	0.32
2	70.968	53.098	7.70	16808	43689	9	22	0.856	0.35
3	71.134	72.164	9.00	16817	43713	9	24	1.000	0.375
4	72.758	69.290	8.50	16826	43737	9	24	0.944	0.354
5	71.607	47.646	7.20	16835	43761	9	24	0.800	0.3
	70.671	58.190	8.08			9	23.8	0.898	0.340

**Unit 18760 after injection**

24 Hr Periods	Amb Temp, °F	Amb RH, %	Fuel	Comp Hrs	TK Hrs	Daily Comp hrs	Daily TK hrs	gph	gph TK Hrs
1	66.886	48.754	7.3	16746	44450	8	25	0.913	0.292
2	70.968	53.098	7.2	16754	44473	8	23	0.900	0.313
3	71.134	72.164	8.1	16763	44497	9	24	0.900	0.338
4	72.758	69.290	8.3	16771	44545	8	24	1.038	0.346
5	71.607	47.646	7.3	16779	44545	8	24	0.913	0.304
	70.671	58.190	7.64			8.2	24	0.933	0.319

When you compare the numbers you see that there is no significant difference in the fuel usage even though the average ambient temperature is 3.1°F warmer than the base data. That should be enough difference in heat load to increase fuel usage after injection but it did not.

In order to determine the effects of the Cold-Plus® on the performance of compressors, the average values of the Amb Temp and the gph for each unit were used.

The average values take into account the variations due to start-stop, ambient temp and humidity changes and any other variations that occur in the operation of the unit over the given time.

To determine the effects of the Cold-Plus® on the performance of the units, the ratio, gph/Tamb was used to compare the before and after tests. This ratio provided a direct measure of the performance of each unit since the other operating parameters essentially remained the same.

The ratio normalizes the fuel usage with the ambient temperature and humidity variations so that there is a direct comparison of the performance of the units with and without the Cold-Plus®.

Calculations:

Unit 18794 Baseline:  $\text{gph}/T_{\text{amb}} = 0.920/67.523 = 0.01362$

Unit 18794 After Injection:  $\text{gph}/T_{\text{amb}} = 0.898/70.671 = 0.01271$

% Difference = **7.16%** reduction in fuel use using the Cold-Plus®.

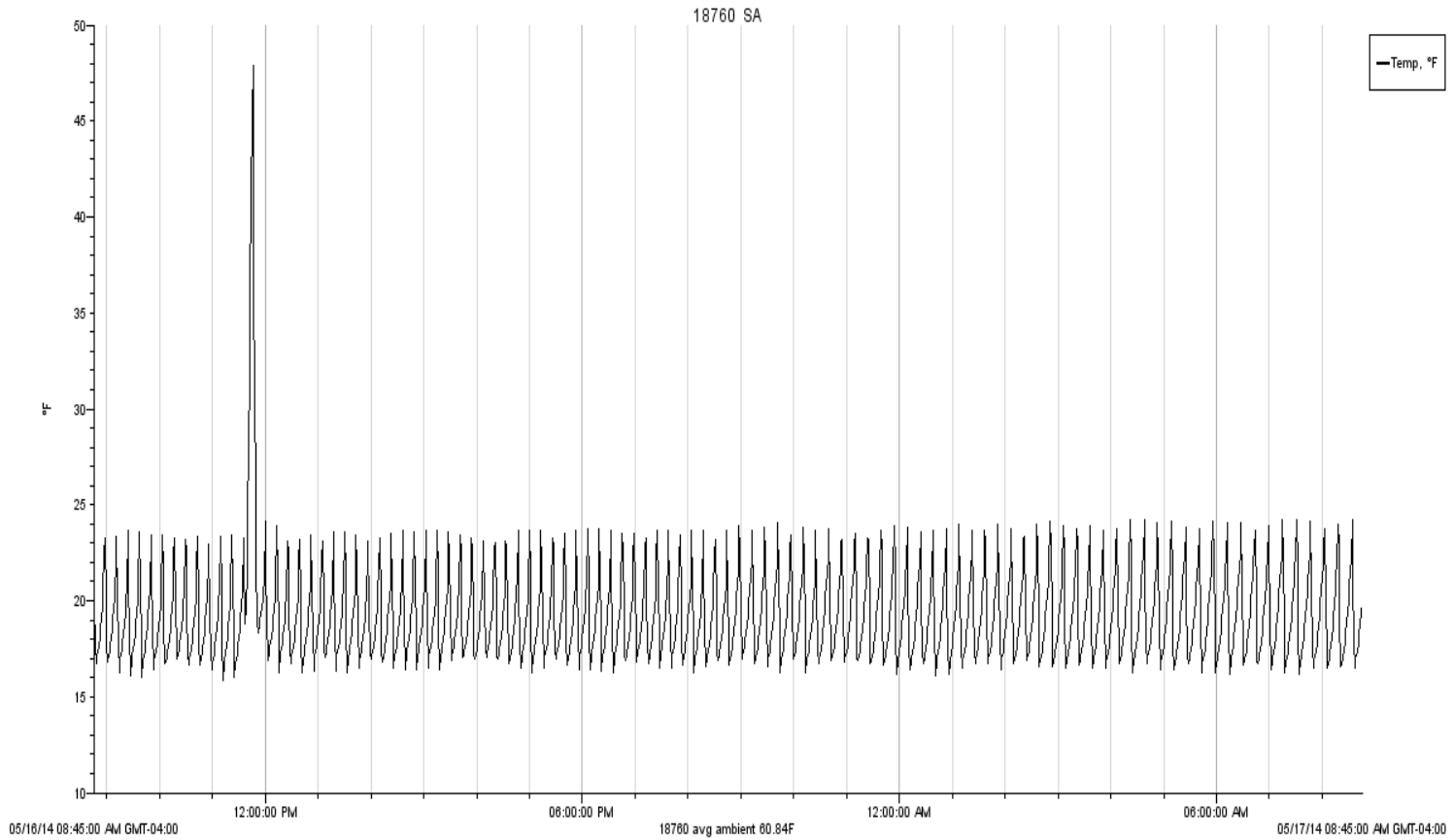
Conclusions:

1. Using the Cold-Plus® in the 18794 unit resulted in a fuel savings of 7.16% compared to the operation of the Baseline unit.
2. Using the Cold-Plus® reduces the load on the engines so that two operating conditions can take place:
  - a. The engine load can remain the same and provide lower temperatures.
  - b. The engine load can be reduced for the same cooling temperatures.

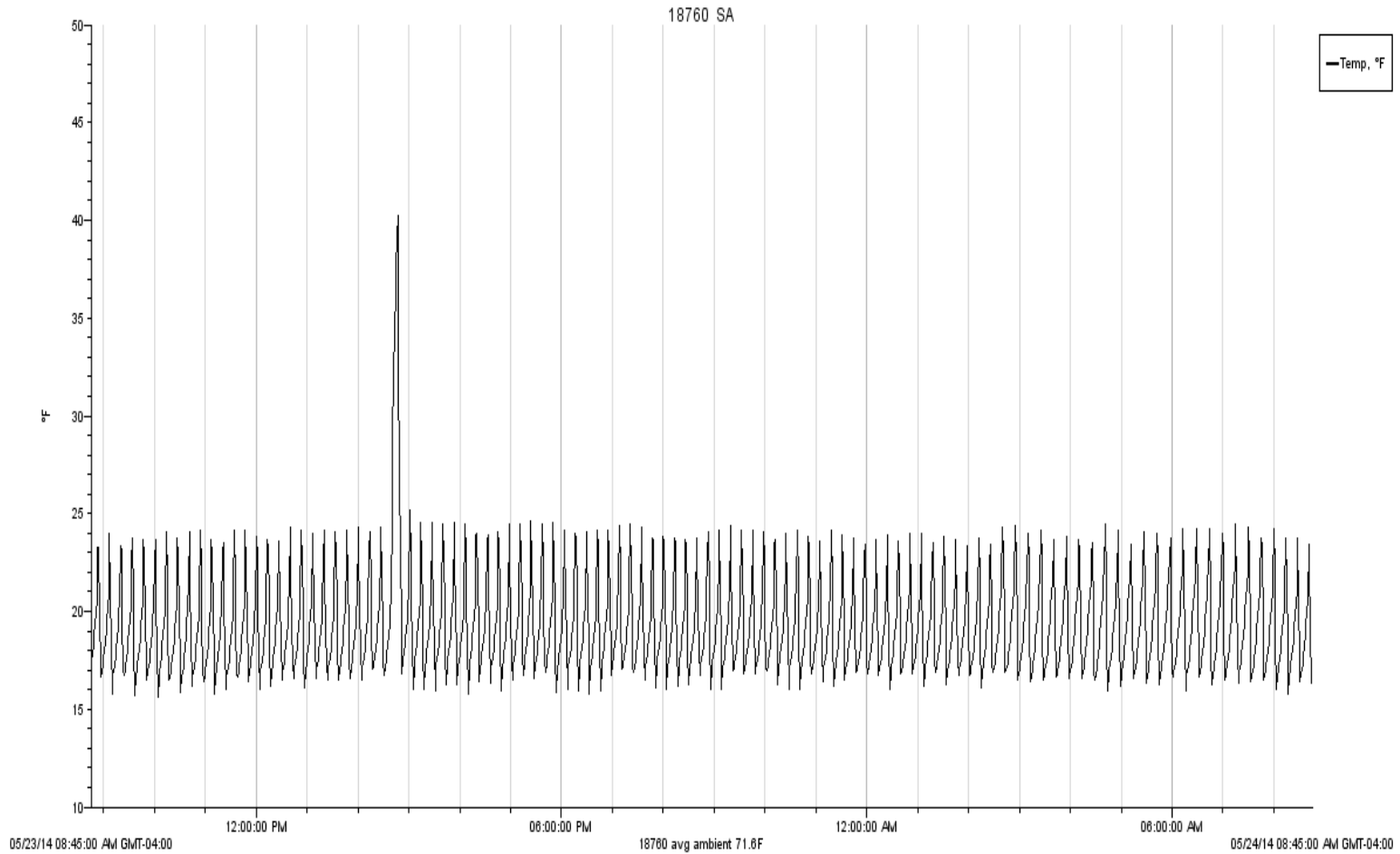
In either mode of operation, there will be savings in the operation of the units using Cold-Plus®.

Please refer to attachment 3 for a complete explanation of how this was calculated (P.E. Jenkins, Ph.D., P.E. evaluation)

Since we have other data to look at, supply air (SA) and return air (RA), we can see if any changes occur there.

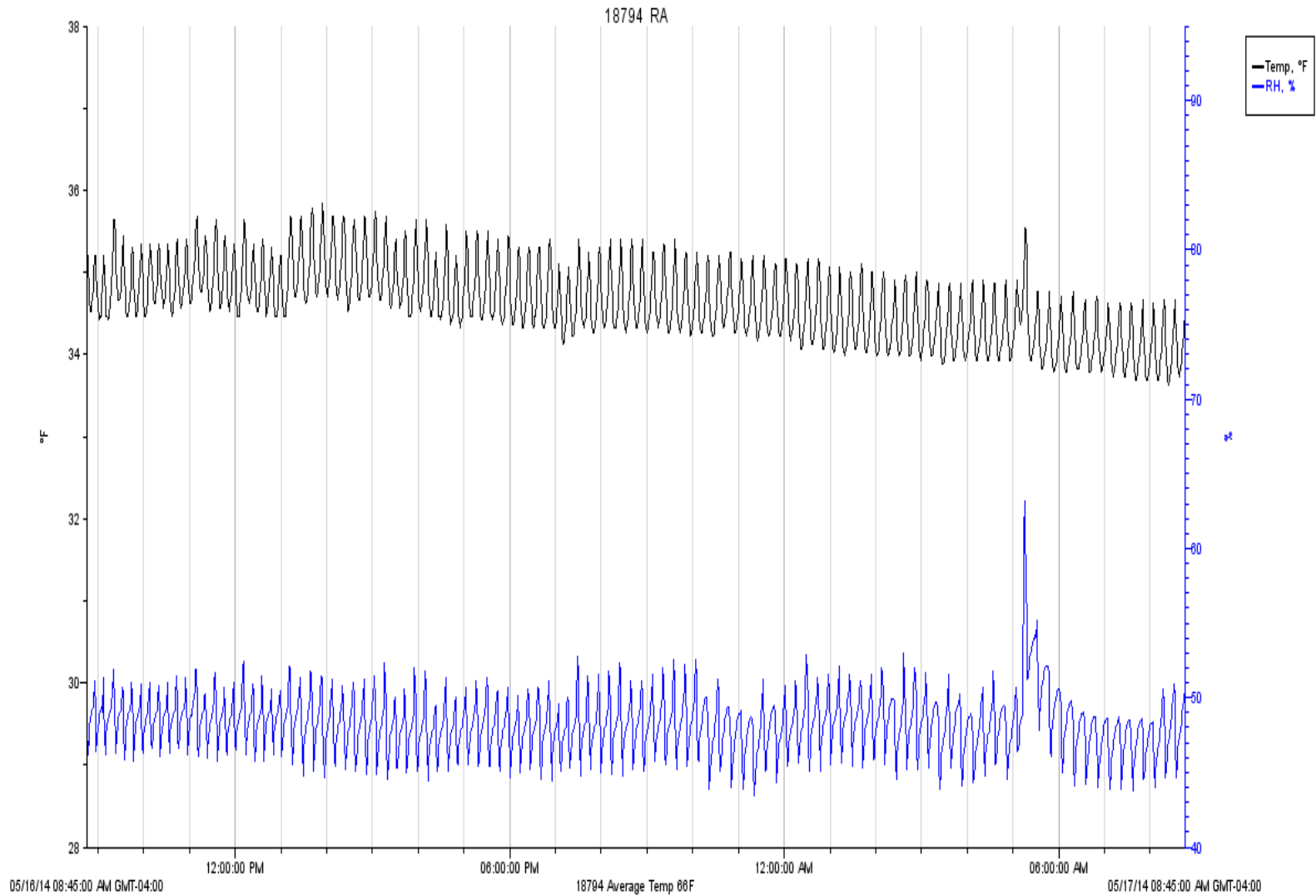


You can see from the chart that the SA averaged 20°F with lows of 17°F and highs of 24°F during the base period. There is a defrost cycle indicated at a little before noon.

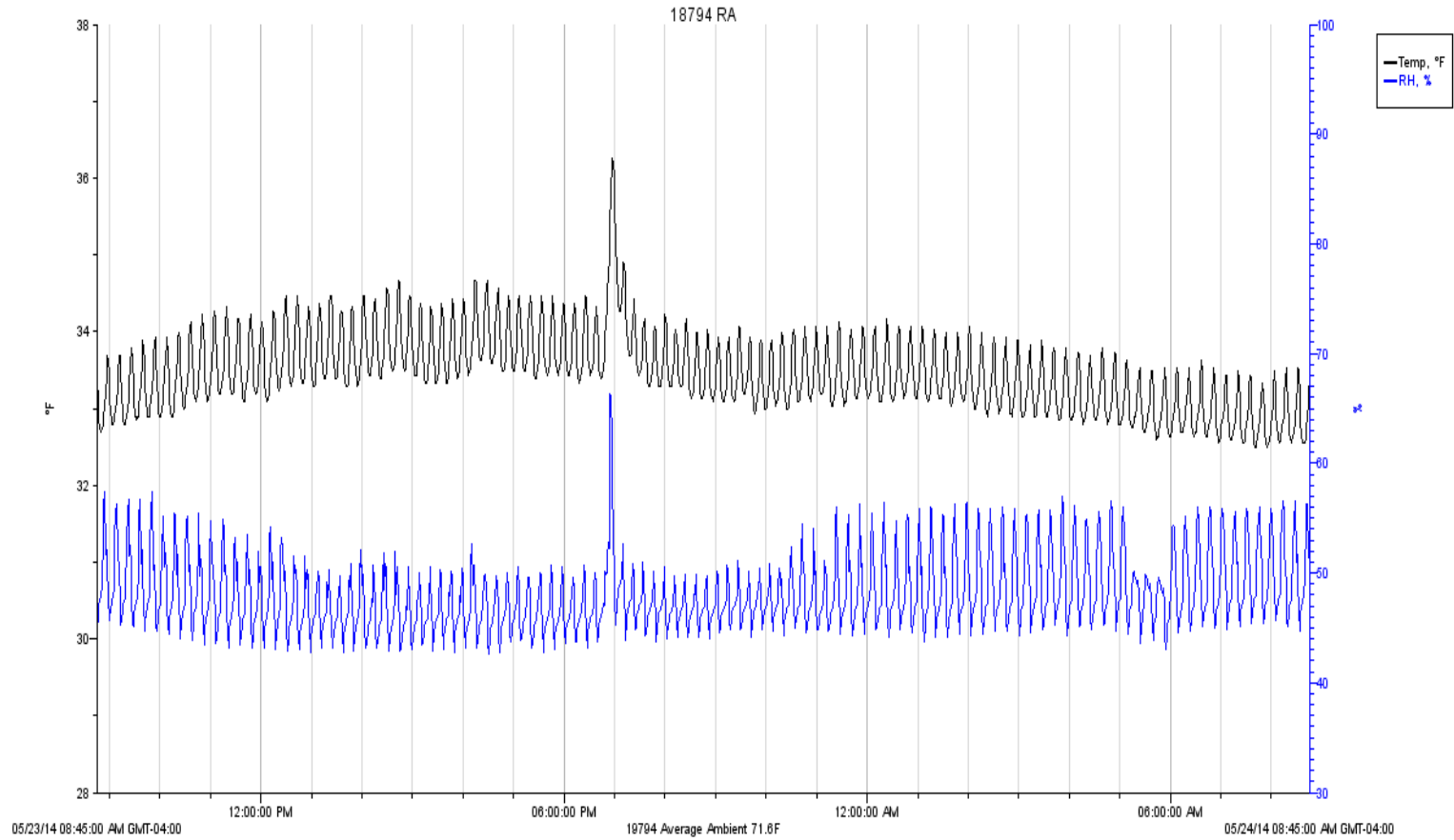


The graph for after injection basically shows a 1°F drop in the in both the lows and highs. There is however a considerable difference in the ambient temperature of 60.84°F in the base line graph to 71.6°F in the after injection ambient.

As we look further into the return air (RA) we see similar results. The following are charts for a 24 hr period with the same ambient as above. The averages that correspond to the graphs below are 35.041°F for the baseline RA and 33.52°F after injection for a 1.5°F drop. The ambient are the same as the charts above.



After injection we see that the RA temperature is averaging a degree F cooler than the base line. What we also see here is an increase in RA temperature in the warmest part of the day. It is more pronounced in the chart below because of the almost 11°F difference in the ambient between the two charts.



## Perdue Reefer Test

### Test Units:

Units 18794 & 18760 equipped With Thermo King SB-210 refrigeration units with 404A refrigerant and POE oil.

### Test Protocol:

The purpose of this test is to measure fuel consumption at the set point of 28 degrees F both before and after the addition of Cold-Plus®. In order to do this both trailers are equipped with a false heat load to simulate loaded status. Data loggers are installed in each trailer to measure supply air (SA) temperature and relative humidity (RH), Return Air (RA) temperature and relative humidity (RH). An additional logger is placed under the trailer towards the front along the cross members to record ambient temperature and relative humidity.

Each trailer fuel tank will be filled to the predetermined level prior to the test beginning and the TK hours recorded. As the test progresses the tanks will be refilled and the fuel consumed as well as the TK hours for both the baseline and after installation test.

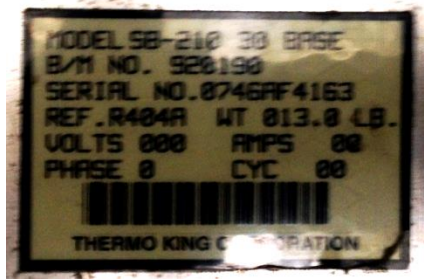
The false heat load (heater) will be turned on when the test segment begins and run until that segment is complete so that each segment of the test will be run under heat load.

After a baseline of 5 days, each unit will be injected with 18 fl.oz. of Cold-Plus® and the units will be operated for an additional 5 days to complete the test.

Test data to include operating hours, fuel consumption, operating temperatures and ambient conditions will be utilized to determine the effect that Cold-Plus® had on the operation of the unit and the savings as well as determining a ROI for the project.

Every effort will be made during the test to duplicate the conditions under which the units would normally operate such as set point of 28 degrees F and operated in on-off mode.





### Test Schedule:

May 1<sup>st</sup>, 2014 - Identify units 18794 & 18760 and position them at the end of the shop where they will have power available for the false loads. Position HOBO data loggers in trailers and set to start recording at 9:00am on May 13<sup>th</sup>. Status - complete

May 8<sup>th</sup> - Ship 40 fl.oz. of Cold-Plus® and injection pump as well as the two heaters for the false heat load to:

Ed Welch

Director of Transportation

Perdue Farms Inc

7036 Zion Church Road

Salisbury, MD 21804

Phone: 410-341-2593

May 13<sup>th</sup> at 9:00am – insert heaters in the center of the trailers, turn them on, and start the units with the 28 degree F set temperature and on-off cycle. Units should be full of fuel and have the hour meter reading recorded at the time initiating the test.

May 19<sup>th</sup> at 9:00am – turn off the units and heaters. Thermo King Technicians will do the installation of Cold-Plus®. They will need to remove 18 fl.oz. of oil from each unit. The units will be restarted and 18 fl.oz. of Cold-Plus® will be pumped into the suction port of each unit. Loggers will be downloaded and reset. The heaters will be turned on and the second phase of the test will begin. Recording of fuel consumed and hour meter readings will be done until May 27<sup>th</sup>.

May 27<sup>th</sup> – The testing period will end and data loggers will be removed and downloaded, tanks filled and the trailers returned to service.

Attachment 2

Cold plus test <sup>Full</sup> 4.3 gal | 4.1 gal } *Zinc Turned on Heat,*  
 0845 AM 16693 HR 16742 HRS  
 44282 HR 43498 HRS

	Unit #	8586	8620
Date	Trailer #	18760	18794
0845 AM Tuesday 5/13/14	Fuel gal.	Full 4.3 gal	Full 4.1
	engine hrs.	16693 HR	16742 HR
	Switch on hrs.	44282 HR	43498 HR
0848 AM Wednesday 5/14/14	Fuel gal.	7.8	8.9
	engine hrs.	16701	16750
	Switch on hrs.	44305	43522
0845 AM Thursday 5/15/14	Fuel gal.	6.8	7.2
	engine hrs.	16709	16758
	Switch on hrs.	44329	43546
0845 AM Friday 5/16/14	Fuel gal.	7.3	7.4
	engine hrs.	16717	16767
	Switch on hrs.	44353	43570
0845 AM Saturday 5/17/14	Fuel gal.	7.8	7.6
	engine hrs.	16725	16776
	Switch on hrs.	44377	43524
Sunday 5/18/14	Fuel gal.		
	engine hrs.		
	Switch on hrs.		
0845 AM Monday 5/19/14	Fuel gal.	12.3	13.9
	engine hrs.	16738	16790
	Switch on hrs.	44425	43642
0845 AM Tuesday 5/20/14	Fuel gal.	7.3	8.0
	engine hrs.	16746	16799
	Switch on hrs.	44450	43667
0845 AM Wednesday 5/21/14	Fuel gal.	7.2	7.7
	engine hrs.	16754	16808
	Switch on hrs.	44473	43689
0845 AM Thursday 5/22/14	Fuel gal.	8.1	9.0
	engine hrs.	16763	16817
	Switch on hrs.	44497	43713
0845 AM Friday 5/23/14	Fuel gal.	8.3	8.5
	engine hrs.	16771	16826
	Switch on hrs.	44521	43737
Saturday 5/24/14	Fuel gal.	7.3	7.2
	engine hrs.	16779	16835
	Switch on hrs.	44545	43761

### Attachment 3

Date: June 5, 2014

TO: Mr. Ed Welch  
Director of Transportation  
Perdue Farms, Inc

FROM: P.E. Jenkins, Ph.D., P.E.  
President  
Jenkins & Associates

SUBJECT: Evaluation of Cold-Plus® Reefer Tests at Perdue

This evaluation is based on the recent testing done at the Perdue facilities at Salisbury, MD using Cold-Plus®. The units tested were the 18794 & 18760 units equipped with the Thermo King SB-210 refrigeration units using 404A refrigerant and POE oil.

The following testing protocol was used to evaluate the units with and without the Cold-Plus® injection.

#### Test Protocol

The tests were conducted to measure the fuel consumption at the set point of 28 degrees F both before and after the addition of Cold-Plus®. In order to do this both trailers were equipped with a false heat load to simulate a loaded status. Data loggers were installed in each trailer to measure supply air (SA) temperature and relative humidity (RH), Return Air (RA) temperature and relative humidity (RH). An additional logger was placed under the trailer towards the front along the cross members to record ambient temperature and relative humidity.

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The false heat load (heater) was turned on when the test segment began and run until that segment was completed so that each segment of the test was run under a constant heat load.

After a baseline test of 5 days, each unit was injected with 18 fl.oz. of Cold-Plus® and the units were operated for an additional 5 days to complete the test.

The test data of operating hours, fuel consumption, operating temperatures and ambient conditions were used to determine the effect that Cold-Plus® on the operation of the unit and the fuel savings.

Every effort was made during the test to duplicate the conditions under which the units would normally operate, such as a set point of 28 degrees F and operating in the on-off mode.

## Evaluation Results

The following test results were used to evaluate the effects of using the Cold-Plus® on the performance of the units. The Baseline and After Injection test results were compared for the 18794 Unit.

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