1. Each Project has four Phases:
    a. PHASE I – PRELIMINARY CONDITION ASSESSMENT AND INTIAL PRICE DETERMINATION
    b. PHASE II – PROJECT EXECUTION -- SNAPSHOT TESTING AND TREATMENT
    c. PHASE III – DATA ANALYSIS, MODELING, AND REPORTING
    d. PHASE IV – FINANCIAL SETTLEMENT

2. PHASE I -- PRELIMINARY CONDITION ASSESSMENT -- involves cursory visual inspection of all units provisionally in scope. No instrumentation is used.
    a. PRELIMINARY CLASSIFICATION: All Units are assigned to one of four classes, based on assumed suitability for and benefit from ProaTEQ Treatment:
        i. Out of Scope
        ii. Poor
            - Unit is untreatable
        iii. Fair:
            - Likely Treatable
            - May or May not be Measurable
            - Likely not Capacity Qualified for Payback Guarantee
        iv. Good
            - Likely Treatable
            - Likely Measurable
            - May or May not be Capacity Qualified for Payback Guarantee
        v. See ***Note 1*** for detailed criteria that determine whether a unit is placed in each class.
    b. EXAMPLE: Table 1 displays this data for the recent Huntsville Project. Note column (F) only addresses the "Fair" and "Good" Candidates. The other units are accounted for in the "gray" columns.

TABLE 1

	(A) Out of Scope	***(B) Poor***	***(C) Fair***	***(D) Good***	***(E) Totals***	***(F) Price(s) at $80/Ton***
1. Units	**28**	**4**	**14**	**41**	**55**	**Initial Price**
2. Tons	**N/A**	**N/A**	**312.0**	**1,000.5**	**1,312.5+**	**$105,000**

    c. INITIAL PRICE DETERMINATION: GUE's "***Initial Price***" is set as the Tonnage in the Fair and Good classes at the per-ton rate of $80/Ton. See Table 1, Cell 2F.

3. PHASE II – PROJECT EXECUTION -- SNAPSHOT TESTING AND TREATMENT. For all units in the Fair and Good Classes from PHASE I, the following scope is performed:
    a. TREATABLE CONFIRMATION:
        i. PHASE 1 FAIR AND GOOD units are assumed likely TREATABLE.
        ii. In Phase II each unit's Treatability is confirmed.
        iii. Factors unknown in Phase I may render a Fair or Good Unit UNTREATABLE on detailed inspection.
        iv. See ***Note 2*** for Factors that render a unit UNTREATABLE.
    b. MEASURABLE DETERMINATION:
        i. Some TREATABLE Units may be UNMEASURABLE

    ii. See ***Note 3*** for Measurement Procedures and ***Note 4*** for conditions under which a unit is UNMEASURABLE.

c. BASELINE CAPACITY:
    i. If a unit is TREATABLE and MEASURABLE, perform Snapshot Pre-Treatment (BASELINE) Estimation of Cooling Capacity (Btuh and Tons) and kW/Ton Performance.

d. CAPACITY QUALIFICATION:
    i. Determine, after Pre-Treatment Cooling Capacity Estimation, whether unit is CAPACITY-QUALIFIED for the PAYBACK GUARANTEE.
    ii. ***A unit must have a Baseline Capacity of at least 60% of rated Capacity to Qualify for the Payback Guarantee***.
    iii. See ***Note 5*** for a Description of the Mechanism of Energy Savings, and Rationale for the Capacity Qualification

e. DECLINED UNITS:
    i. PPG will provide "Rules" at the start of the Project to address when a TREATABLE unit would be DECLINED for treatment
    ii. If a TREATABLE unit is found to be UNMEASURABLE in Phase II, does PPG still want GUE to Treat the Unit?
    iii. It is assumed that the Capacity (Tons) Improvement and Specific Power Use (kW/Ton) Reduction found for MEASURABLE UNITS will be extrapolated to all TREATED units, whether MEASURABLE or not
    iv. PPG will prove a rule for GUE to determine when PPG would DECLINE to treat an UNMEASURABLE unit
    v. If a TREATABLE and MEASURABLE unit is found in Phase II to have Pre-Treatment Capacity below 60%, such that it would be excluded from the Payback Guarantee, does PPG still want GUE to Treat the unit?
    vi. What, if any is the lower limit for Pre-Treatment Capacity below 60% below which PPG would DECLINE to Treat the Unit?

f. PROATEQ TREATMENT:
    i. It is understood that all TREATABLE units, unless specifically DECLINED under 2e, will be TREATED
    ii. GUE will determine the ***Treated Units Price*** based on all TREATABLE units not DECLINED per 2e; PPG will be advised of this price.
    iii. GUE will perform ProaTEQ TREATMENT on all units that are TREATABLE and not DECLINED per 2e

TABLE 2

PHASE II CLASSIFICATIONS:		*PHASE I CLASSIFICATIONS:*				*(E) Totals (Fair and Good Only)*	*(F) Notes and Prices @ $80/Ton*
		(A) Out of Scope	*(B) Poor*	*(C) Fair*	*(D) Good*		
1. PHASE I PRELIMINARY CONDITION ASSESSMENT	UNITS	28	4	14	41	55	*INITIAL PRICE*
2. PHASE I PRELIMINARY CONDITION ASSESSMENT	TONS	N/A	N/A	312.0	1,000.5	1,312.5	$105,000
DISPOSITION OF FAIR AND GOOD UNITS BY TREATMENT IN PHASE II							
3. PHASE II UNTREATABLE OR DECLINED	UNITS			(2)	(3)	(5)	*UNTREATED/DECLINED UNITS*
4. PHASE II UNTREATABLE OR DECLINED	TONS			(44)	(75)	(119)	*UNTREATED/DECLINED TONS*
5. PHASE II TREATED	UNITS			12	38	50	*TREATED PRICE-ALL TREATED UNITS*
6. PHASE II TREATED	TONS			268	925.5	1,193.5	$95,480
DISPOSITION OF PHASE II TREATED UNITS BY MEASURABLE AND CAPACITY QUALIFIED -- FOR ILLUSTRATION ONLY							
7. PHASE II TREATED + MEASUREABLE	UNITS			6	30	36	*CAPACITY & PERFORMANCE GUARANTEE UNITS*
8. PHASE II TREATED + MEASUREABLE	TONS			140	750	890	*CAPACITY & PERFORANCE GUARANTEE TONS*
9. PHASE II TREATED + MEASURED + CAPACITY QUALIFIED	UNITS			3	20	23	*PAYBACK GUARANTEE PRICE POOL*
10. PHASE II TREATED + MEASURED + CAPACITY QUALIFIED	TONS			60	500	560	$44,800
TREATED UNITS NOT IN CAPACITY GUARANTEE – BASIS OF CAPACITY PRICE POOL – FOR ILLUSTRATION ONLY							
11. TREATED LESS CAPACITY GUARANTEE UNITS	UNITS			9	18	27	*CAPACITY AND PERFORMANCE GUARANTEE PRICE POOL*
12. TREATED LESS CAPACITY GUARANTEE TONS	TONS			208	425.5	633.5	$50,680

POST-TREATMENT CAPACITY:

  iv. GUE will conduct Post Treatment Capacity Measurement following procedures in ***Note 3***
  v. Post-Treatment values of Capacity (Tons) and Specific Power (kW/Ton) will be determined***.***

g. DETERMINATION OF GUARANTEE EXPOSURE POOLS: Units comprising the ***Treated Units Price – All Treated Units*** will further fall into two classes, which define Guarantee Price Pools.
  i. ***Payback Guarantee Units*** – These are TREATED units with Baseline Capacity of 60% or more of Rated Capacity
    1. These units form the basis of the Payback Guarantee
    2. The ***Payback Guarantee Price Pool*** is the Treatment Price for ***Payback Guaranteed Units***.
  ii. ***Capacity and Performance Improvement Guarantee Units*** -- These are TREATED units with Baseline Capacity below 60% of Rated Capacity
    1. These units are excluded from the ***Payback Guarantee***
    2. These unit will achieve guaranteed Capacity Increases and kW/Ton reductions
    3. However, these units will not provide sufficient Hard Savings to justify a Payback Guarantee.
    4. See ***Note 5*** for the Mechanism of Energy Savings
    5. The ***Capacity and Performance Improvement Guarantee Price Pool*** will be the Treatment Price of these units
       Perform ProaTEQ Treatment of TREATABLE units unless DECLINED per 2e above
  iii. TABLE 2, above, illustrates the four Prices and Price Pools identified above. It is based on Huntsville and illustrative data

h. EXAMPLE:
  i. ***INITIAL PRICE*** : The Good and Fair units from Phase I, 55 units comprising 1,312.5 Tons, from the ***INITIAL PRICE*** of $105,000, see cell F2
    1. See cells E3 and E4
  ii. ***TREATED PRICE – ALL TREATED UNITS***
    1. It is assumed, in Phase II, that 5 units comprising 119 Tons, are found UNTREATABLE or DECLINED
    2. TREATED UNITS are 50 units comprising 1,193.5 Tons, cells E5, E6
    3. ***TREATED PRICE – ALL TREATED UNITS*** is $95,480, cell F6.
  iii. ***PAYBACK GUARANTEE PRICE POOL***:
    1. The ***Payback Guarantee*** applies to the subset of TREATED units and Tons that are CAPACITY QUALIFIED
    2. This is 23 units, 560 Tons, See cell E9, E10
    3. The Treatment Price for the CAPACITY QUALIFIED UNITS is ***Payback Guarantee Price Pool*** $44,800, cell F10
  iv. ***CAPACITY & PERFORMANCE GUARANTEE PRICE POOL***:
    1. All TREATED AND MEASURABLE UNITS will be used in computation of Capacity and Performance Improvement

        2. The dollars at risk under the ***Capacity and Performance Guarantee*** will be:
            a. The ***TREATED PRICE – ALL TREATED UNITS*** of $95,480, cell F6
            b. **LESS** the ***Payback Guarantee Price Pool*** which dollars are already at risk under the more demanding Payback Guarantee
            c. Thus, ***the Capacity and Performance Guarantee Price Pool*** is $50,680, cell F12

    i. Table 2 illustrates how the Phase I Preliminary Condition Assessment leads to rough classification only, and this classification is refined in Phase II.
    j. Finally, ***note that when a unit becomes a PHASE II UNTREATABLE OR DECLINE, GUE receives no pay for that unit***. Thus our Phase I work is uncompensated.
    k. ***This ensures that PPG only pays for Treated Units and GUE assumes the cost and risk of determining the TREATABLE Population***
    l. The ***Final Price to PPG*** will be determined after the application of ***Offsets Due to Performance Guarantees***, if any

4. PHASE III – ANALYSIS, MODELING, AND REPORTING
    a. For every treated unit, based on field measurements; GUE estimates:
        i. Capacity Recovery (Tons)
        ii. Performance Improvement (kW/Ton)
    b. GUE then computes the ***Fleet Average Capacity Increase*** and the ***Fleet Average Performance Improvement.*** See ***Note 6*** for Details of these computations
    c. For the units that are CAPACITY QUALIFIED GUE performs Energy Analysis using the GUE Bin Model. See ***Note 7*** for details of the GUE Bin Model's computations
    d. From the GUE Bin Model, GUE determines the Annual Hard and Soft Savings achieved by each treated unit in a Typical Weather Year
    e. GUE may, at its discretion, model each CAPACITY QUALIFIED unit, or model selected units that can reasonably be used to represent others;
    f. For example, with two units of similar size, serving similar loads, with similar Pre-Treatment capacity, GUE may model one, with the results extrapolated to both.
    g. GUE will report the results of the data analysis and modeling in a report and final presentation to PPG

5. STATEMENT OF GUARANTEES: Prior to addressing PHASE IV, FINANCIAL SETTLEMENT, GUE provides three Guarantees are stated here
    a. NO DAMAGE GUARANTEE: GUE's Treatment of PPG's equipment will result in no damage to any PPG Equipment. If there is any damage, shown to be attributable to GUE's work or the ProaTEQ Treatment, GUE will compensate PPG subject to the terms of its Agreement for On-Site Services; GUEs insurance, and that of GUEs subcontractors and suppliers.
    b. PAYBACK GUARANTEE: The scope of the Payback Guarantee ***is limited to the CAPACITY-ELIGIBLE units, and any Offset due under this Guarantee is applied to the Payback Guarantee Price Pool, Table 2, cell F10***.
        i. For all Capacity-Eligible Units, GUE will perform Energy Use and Cost modeling according to ***Note 7***.
        ii. Annual Hard and Soft Savings for a NOAA Typical Year for the Plant Location will be estimated per the GUE Bin Model

        iii. The total Estimated Annual Hard Savings of the CAPACITY ELIGIBLE units will be at least 33.3% of the Payback Guaranteed Price, $44,800 in Table 2, as an example based on Illustrative Data
        iv. In the event the Estimated Annual Hard Savings for the CAPACITY ELIGIBLE units is less than 33.3% of the Payback Guaranteed Price, the difference, or shortfall, will be the Payback Annual Offset
        v. The total Payback Guarantee Offset will be 3 times the Payback Annual Offset
        vi. The provision of this offset ensures PPG that the Payback Period on the expense incurred to treat CAPACITY ELIGIBLE UNITS will have a 3-year Payback Period or better.
        vii. For example, the Payback Guaranteed Price is $44,800. One third of that is $14,933. If the Estimate Annual Savings were found by modeling to be 12,933, then the Payback Annual Offset would be $2,000
        viii. In the example, the Total Payback Guarantee Offset would be three times the Payback Annual Offset, or $6,000
    c. FLEET CAPACITY INCREASE AND SPECIFID POWER REDUCTION GUARANTEE: After the implementation of ProaTEQ Treatment to the TREATED UNITS, GUE Guarantees that:
        i. Fleet Average Capacity, in Tons, measured according to ***Note 6***, for the MEASURABLE UNITS, will increase by at least 10%
        ii. If the Fleet Average Capacity Increase is not at least 10%, the shortfall will be determined. For example, if the Fleet Average Capacity Growth is 8%, the Capacity Growth shortfall is 2%
        iii. Fleet Average Specific Power Use, in kW/Ton, measured according to ***Note 6***, will diminish by at least 10%
        iv. If the Fleet Average Specific Power Reduction is not at least 10%, the shortfall will be determined. For example, if the Fleet Average Specific Power Reduction is only 7%, the shortfall is 3%
        v. The Capacity and Specific Power Guarantee Offset, if any, will be based on the largest Shortfall. In this example, the largest shortfall is 3%.
        vi. The shortfall, expressed as a proportion of the goal, that is 3% shortfall relative to 10% goal, is 30%.
        vii. The guarantee provides that an ***Offset of that percentage will be applied to the Capacity and Performance Guarantee Price Pool***.
        viii. In this example, the 3% shortfall on the Capacity and Performance Guarantee would lead to a 30% Offset to the Treatment Price of 95,480.
        ix. The Offset would be $28,644

6. PHASE IV – FINANCIAL SETTLEMENT BASED ON OFFSETS DUE TO PERFORMANCE GUARANTEES: In Phase IV the computations will be performed to determine the Offsets, if any, Due to PPG
    a. Computations will be done by GUE
    b. An Offset Proposal will be submitted to PPG
    c. A meeting and/or negotiation will be held
    d. The parties will agree on Offsets
    e. GUE's final bill to PPG will be the Treated Price less the Agreed Offsets
    f. If the unbilled amount at the time is not enough to cover the Offsets; GUE will make a payment to PPG to fully cover the Offset

Note 1: Criteria for Phase I Classification

1. OUT OF SCOPE
    a. Not refrigeration equipment
    b. Not currently in operation

2. POOR
    a. Excessive noise
    b. Excessive heat to the touch in places where it shouldn't be
    c. Failed in inoperable drainage of condensate
    d. Excessive damage to external components, such as fins on condenser

3. FAIR
    a. Minor external damage
    b. New

4. GOOD
    a. Aged 5-10 years
    b. No major external damage
    c. Appears and sounds like running properly

Note 2: Factors that Render a Unit Untreatable

1. It has suffered damage since the CONDITION ASSESSMENT
2. It has been taken out of service at the time of treatment, e.g., for annual maintenance or periodic overhaul
3. Other reason as determined by PPG
4. GUE may determine it is not treatable based on detailed observation in the EXECUTION phase of the project

Note 3: Measurement Procedures

1. Measure Wet bulb and Dry Bulb temperature in supply and return air streams before treatment
2. Compute specific enthalpy in supply and return air streams before treatment from tabulated enthalpy as a function of Wet bulb temperature data from normal reference sources
3. Compute change (reduction) in specific enthalpy across evaporator coil based on difference between return and supply air.
4. Measure supply air flow rate (CFM) using an anemometer probe in three positions across supply air stream and averaging the measured values.
5. Compute the pre-treatment Heat Extraction (Cooling Capacity) as $BTU/HR = \rho * 60 * CFM * \Delta H$

    Where:

    ρ is specific density of dry air, 0.0765 lbm/cubic foot (CF)
    60 is conversion from minutes to hours (60 min/hr)
    CFM is the air flow rate in cubic feet per minute
    ΔH is the change in specific enthalpy $H_{return} – H_{supply}$ (Btu/lbm)

6. The “Tons” of cooling before treatment is then computed using the engineering conversion of 12,000 BTUH/Ton
7. These measurements and computations are done before treatment and again about 30 minutes after treatment. The change in capacity due to the treatment is deemed as the difference between the two BTUH values.
8. Volt and amp measurements on all three legs are made. Suction and discharge pressures are measured on each compressor as a check on the enthalpy values.
9. kW is computed from volt and amp measurements, by averaging the (nearly identical) line voltages, then using

   $Vp = VL/1.73$; and
   $Pp = Vp * Ip * PF$

   Where:
   Pp is the power on each phase
   Vp is the phase voltage computed as above from measured line voltages
   Ip is the phase current, measured
   PF is assumed power factor of 0.85
   Then
   $Power = \Sigma Pp$
   Total Power (kW) is the sum of the phase power values.

10. Finally, the kW/Ton and change in kW/Ton is computed using the capacity as in 7f and the kW as in 7i

<u>Note 4: Factors that Render a Treatable Unit to be Unmeasurable</u>

1. The physical configuration of the unit renders the return or supply air streams ***inaccessible*** for temperature probes or anemometer probes;
2. The unit has ***severe underflow***, such that the CFM is far below what is recommended for the rated capacity (approximately 400 cfm/Ton) and thus the empirically estimated Cooling Capacity is far below the rated capacity for reasons unrelated to oil fouling.
3. The unit is ***fixed to take 100% outside air***, even in the hot season, so return air is 100% exhausted, and it is impossible to take supply and return air readings;
4. There is a ***maintenance problem*** with the unit leading to undesirable moisture being introduced; for example, a unit’s condensate drain line is blocked and there is water puddling in the base of the unit’s cabinet, artificially adding excess humidity to the air stream.

All of these are examples of situations where our protocol won’t give valid capacity measurements. This isn’t to say the unit performance won’t be improve by ProaTEQ – it will…. but the field measurement protocols we use won’t provide valid measurements of the affects for purposes of proving performance.

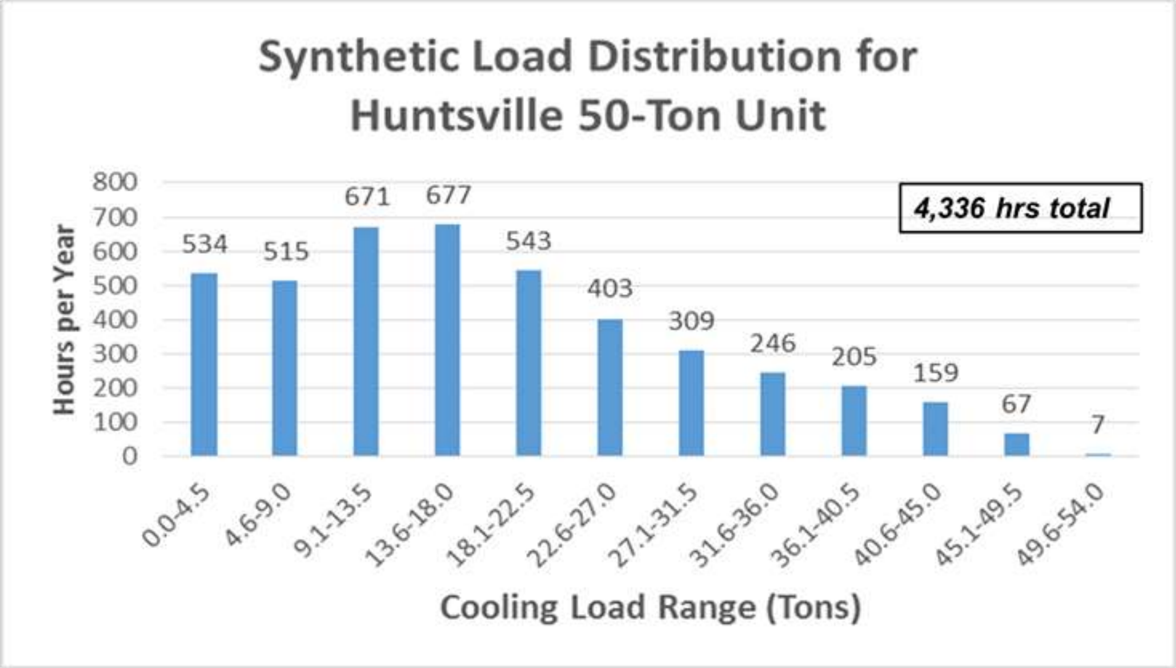
Note 5: Description of ProaTEQ Energy Savings Mechanism and Rationale for Capacity Qualification

1. A unit will be deemed CAPACITY QUALIFIED IF:
   a. The unit is TREATABLE
   b. The unit is MEASURABLE; and
   c. The PRE-TREATMENT CAPACITY IS AT LEAST 60% OF THE RATED CAPACITY.
2. It is important to realize that for older units, there may be many reasons why a unit has capacity below 60% of its rating.
   a. Portions of the unit may be inoperative;
   b. the unit may have suffered damage; etc.

   ProaTEQ Polarized Refrigerant Additive does not address all these defects; it only remedies the effects of oil fouling.
3. ASHRAE literature states that oil fouling will reduce capacity as follows:
   a. 7%-8% in the first year
   b. 5% in the second year
   c. 2-4% annually thereafter, up to a maximum of 30%

   So by ASHRAE standards, 30% capacity loss is attributable to oil fouling and thus addressable by ProaTEQ. This would imply a unit is a candidate for ProaTEQ when it is up to 70% below rated capacity. GUE goes beyond the ASHRAE guide and will guarantee 3-year payback on units up to 60% below rated capacity.
4. Beyond 60% capacity loss, GUE has to take the position that the unit is suffering from deficiencies far beyond Oil Fouling, and a Polarized Refrigerant Additive will help recover some capacity ***but will not deliver hard savings***.
5. Figure 1 below shows the Synthetic Cooling Load distribution for a 50 Ton unit in Huntsville. The following things are apparent from this chart:
   a. There are 4,336 hours in the year when cooling is required
   b. The Cooling requirement ranges from 0-4.5 Tons for 535 hours/yr to 49.6 to 54.0 Tons for 7 hours/yr
   c. The 50-Ton unit was probably designed for a 45.5 Ton load. That would be the load that was not exceeded for all but 74 hours per year; or about 2% of the year
   d. Because of the oversizing, the 50-Ton unit would meet the load for all but 7 hours, or about 0.2% of the year.

FIGURE 1



6. Figure 2 below shows how the 50-Ton Unit, OPERATING AT RATED CAPACITY meets the load. It shows the ***Run Time Per Hour at the Load Levels in each Bin***. It is important to note that the 50-Ton unit has two cooling circuits, one at 16.67 Tons, the other at 33.3 Tons. So for low load, it operates the first circuit and is a 16.7 Ton machine; and higher load it runs the second circuit and is 33.3 Tons. At the highest loads it runs both Circuits and delivers 50 Tons. Also note that for the load bins, the ranges are replaced with the midpoints. So the 0.0-4.5 Ton bin is labeled 2 Tons; the 4.6-9.0 Ton bin is labeled 7 tons, etc. That said, the following points are noted:
   a. For the 534 hours in Bin #1, where the load averages 2.25 Tons, the unit runs Circuit #1, delivers 16.67 Tons. So the unit will run 2.25/16.67 = 13.5% of the time or 60*0.135=8.1 minutes per hour. The chart simplifies it to 8 minutes per hour.
   b. For the 515 hours in Bin #2, the load averages 6.85 Tons, the unit dispatches Circuit on at 16.67 Tons. So the unit will run 6.85/16.667=41.1% of the time, or 60*0.411=24.7 minutes of each hour; the chart shows it at 24 minutes per hour.
   c. For the 403 hours in Bin #6, where the load averages 24.85 tons, the system will run Circuit #2, delivering 33.3 Tons capacity, and thus runs 24.85/33.3=74.6% of the time; so will run 44.8 minutes of each hour.
   d. For the 159 hours in Bin #10, where the average load is 42.85 Tons, the unit will dispatch both Circuits, delivering 50 Tons capacity; it will thus run 42.85/50=85.7% of the time, or 51 minutes per hour.
   e. For the 7 hours in Bin #12, where the average load is 51.85 Tons, the system dispatches both Circuits, delivering 50 Tons. It would take 51.85/50=103.7% of the minutes in an hour to meet that load, or 62.2 minutes. But the hour only has 60 minutes. So the system runs the full hour and never meets the load. That means it does NOT cycle on and off, and it does not hold the set point for the conditioned space. If the thermostat is set at 74F, the system will not maintain that temperature. Cooling services is lost. The space will be, say 75-76F for all of those hours.

f. Note the "saw tooth" shape of Figure 2. That reflects the fact that the GUE Bin model accurately models the cycling logic of the 50-Ton unit.

FIGURE 2

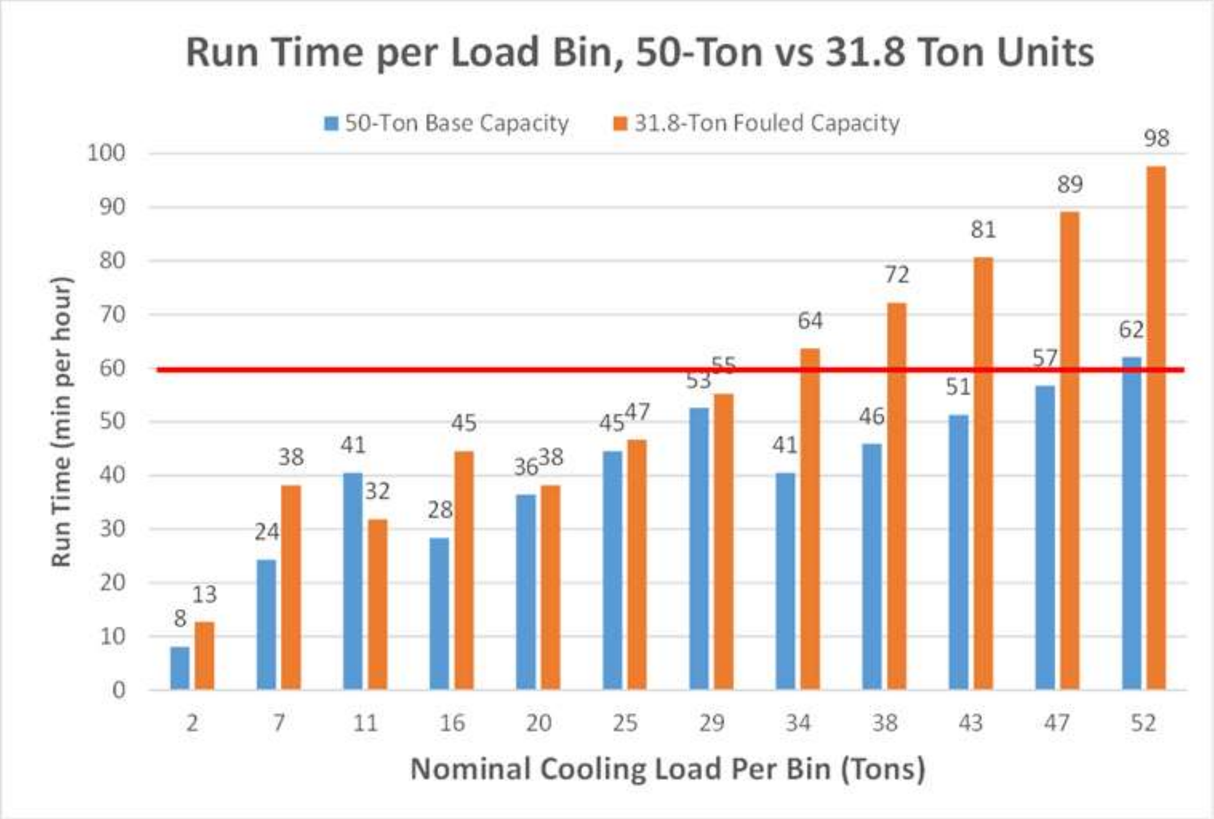
7. Figure 3 compares how the oil-fouled 31.8-Ton unit meets the load, versus the original 50-Ton unit. When the demo 50-Ton unit was treated, it was measured in the Pre-Treatment test at 31.8 Tons. It was TREATABLE AND MEASURIABLE, and, on Pre-Test, it was found to be GUARANTEE-ELIGIBLE. The Blue bars on Figure 3 show the run-time of the full-capacity 50-Ton unit, identical to Figure 2. The Tan bars on Figure 3 show the run time for the reduced capacity 31.8-Ton, oil-fouled unit. This is the operation as encountered in July of 2015. It was assumed that the oil fouling affected each circuit equally, so Circuit #1 ran at 10.6 Tons; Circuit #2 ran at 21.2 Tons. Run together, both Circuits delivered 31.8 Tons as measured following the procedures in #7 above. The following is important to note from Figure 3:
   a. For Bin #1, while the unit at full capacity ran 8 minutes/hour, the oil-fouled unit ran 13 min per hour. That is based on 2.25 Ton load and 10.6 Ton capacity, therefore need to run 2.25/10.6=21.2% the time, or 60*0.212=12.7 minutes per hour, rounded to 13 minutes per hour for presentation in Figure 3.
   b. In Bin #2 the base full-capacity unit (blue bar) ran 24 minutes/hour; the oil-fouled unit ran 38 minutes per hour.
   c. In Bin #3, with load of 11.35, for the 50-Ton unit, Circuit #1 met that load, but for the oil-fouled unit, the degraded capacity of Circuit #1 was 10.6, which did NOT meet the load of Bin #3, so the unit had to "shift gears" earlier, and dispatch circuit #2 in Bin #3, whereas the full-capacity unit didn't use Circuit #2 until Bin #4. This doubles the kW load and the kWh usage for all those run-time minutes.

d. In Bin #6, with load of 24.85 Tons, the oil-fouled system could NOT meet the load with Circuit #2, which provide only 21.2 Tons capacity, and had to run both circuits. From bin #6 to #12, both circuits were running. The full capacity unit didn't have to dispatch both circuits until bin #8. Again this means that for all the hours in bins #6 and #7, the oil-fouled unit ran at much higher kW to meet the load than the base unit.

e. For all the 684 hours in Bins #8, #9, #10, #11, and #12, the unit DID NOT MEET THE COOLING LOAD. This is a major amount of cooling service loss. The effect of oil fouling is to increase run time (and energy use and cost) by up to 50% in some bins, and then to impose major loss of cooling service in bins with higher loads.

f. Even in the bins where the run time seems the same, like Bins #5, #6, and #7, remember that the base unit is running Circuit #2 only, at about 46 kW, but the oil-fouled unit was running both circuits, at 69 kW. So every hour of running the oil fouled unit cost 50% more kWh and dollars. Than the same hours running the base unit.

FIGURE 3

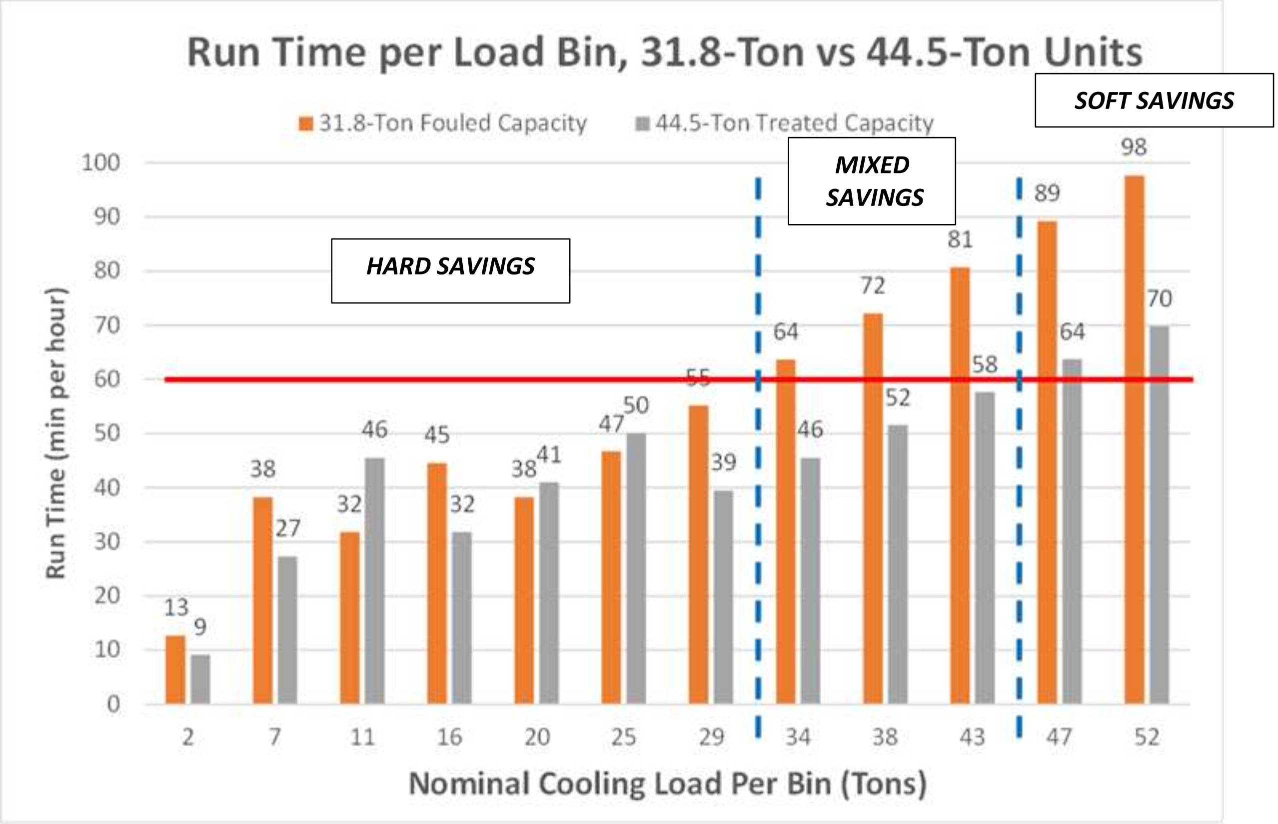


8. Figure 4 shows the effect of the ProaTEQ treatment on the oil-fouled unit. The Blue bars are gone, but the Tan bars (run time of the fouled, 31.8 Ton unit) are shown. Added are the Gray bars, which show the run time of the unit after treatment with ProaTEQ. The unit had lost 18.2 Tons of capacity, from 50.0 to 31.8. The ProaTEQ treatment recovered 12.7 Tons of capacity, or 69.8% of the lost capacity. GUE normally represents that we will recover 50-70% of the capacity lost due to oil fouling. ProaTEQ will NOT address capacity loss due to other factors. The data on Figure 4 are VERY INFORMATIVE relative to "savings" from ProaTEQ. The fouled unit delivered 10.6 Tons in Circuit 1, 21.2 Tons in Circuit 2, and 31.8 Tons when running both. Each circuit required 23 kW of electrical

power. After treatment, Circuit #1 delivered 14.8 Tons, Circuit 2 delivered 29.7 Tons; and combined they provided 44.5 Tons.

a. The “Run Time Fraction” resulting from an increase in capacity from 31.8 to 44.5 Tons is 31.8/44.5=0.7146=71.5%. That is, the treated unit will run only 71% as long as the fouled unit needed to run, to meet the same load.
b. The “Savings” is the “Run time NOT REQUIRED”. It is just 1- (31.8/44.5) = 28.5%. That is, after treatment, the run time will be 28.5% less than before treatment. The reduction in run time translates directly into energy and cost savings.
c. In the 50-Ton pilot, then, in any bin where both the fouled unit and the treated unit met the load, we would expect a 28.5% reduction in run time after the treatment.
d. So look at Bin #1. The load is 2.25 Tons. The fouled unit had a 10.6 Ton capacity in Circuit #1, so ran for (2.25/10.6)*60 = 12.7, say 13 minutes. The Treated unit had 14.8 Tons in Circuit 1 so ran (2.25/14.8)*60=9.12 minutes. The reduction in run time was 12.7-9.1=3.6 minutes/hour, out of 12.7 minutes, or 28.4%, just as predicted
e. In Bin #2 the same thing is observed. The load is 6.85 Tons. The fouled unit runs (6.85/10.6)*60=38.7 minutes. The treated unit runs (6.85/14.8)*60=27.7 minutes. The reduction is 38.7-27.7=11.0 out of 38.7, or 28.4%; again just as predicted.
f. In Bin #3, the Treated unit (gray bar) appears to run more time, indeed it does, but that is because the treated unit is still running Circuit 1 only, while the fouled unit runs Circuit #2. So the fouled unit uses (32 min * 46 Kw)/60 = 24.5 kWh, while the treated unit runs only Circuit #1, using (46 min *23 Kw)/60 = 17.6 kWh. So the treated unit uses ((24.5-17.6)/24.5) = 28.2% less; as predicted within rounding errors on circuit capacities, kW values, and run times.
g. Indeed, for Bins #1 through #7, ***where both the fouled and the treated unit meet the load***, the treated unit will use 28.5% less energy. One is tempted to speculate that the treatment will deliver 28.5% savings based on the capacity ratios. That is a big mistake.
h. Looking at bins #8, #9, and #10. In those bins, the fouled unit fails to meet the load, but the treated unit does meet the load. Consider bin #8, for example. The fouled unit “commands” 64 minutes of operation, and the treated unit uses 46. The reduction for treatment is – as predicted – (64-46)/64, or 28.2%. However, the fouled unit doesn’t run 64 minutes in an hour. It can only run 60 minutes. So the run time reduction is abridged. It is (60-46)/60 = 23.3%. A portion of the benefit of the capacity recovery has been used to meet the load, recover the cooling service; the balance is used to reduce run time.
i. If we look at bin #10, we see the most dramatic example. The fouled unit calls for 81 min; the treated unit calls for 58 min. The “theoretical savings” is (81-58)/81 = 28.4%. However, the actual savings are much less because the fouled unit cannot run but 60 min. So the actual savings are (60-58)/60=3.3%.
j. The behavior of the two systems as revealed in bins #8, #9, and #10 show that the theoretical savings can’t be met when the load is unmet. The system will first meet the load then reduce run time. ***When load is badly unmet, as in bin #10, the theoretical run time reduction (81 vs 58 min) will be as predicted, near 28.5%, but the actual run time reduction is only 3.3%.***
k. Finally, consider bins 11 and 12. Both the fouled and the treated units call for more than 60 seconds of run-time. They each run for the full hour and fail to meet the load. The savings are 0. More precisely, the “hard” savings are $0. The treated unit meets more of the load than the untreated. It delivers far more cooling service recovery. It delivers much more “soft cost” savings. And GUE estimated that for the 50-ton unit the soft savings had a value of $0.34/Ton-hr.

FIGURE 4



9. GUE has named the three regimes of Figure 4.
    a. The ***HARD SAVINGS REGIME*** is the set of bins where both fouled and treated units meet load. The capacity recovery manifests itself 100% in run time reduction which is "Hard" Savings.
    b. The ***MIXED REGIME*** is the set of bins where fouled unit fails to meet load but treated unit meets load. In this regime the capacity recovery manifests itself in a mix of Cooling Service Recovery and run time reduction (Hard Savings).
    c. The ***SOFT SAVINGS REGIME*** is the set of bins where neither the treated unit NOR the fouled unit meet the load. The capacity recovery manifests itself 100% in Cooling Service Recovery. The Recovery of Cooling Service has an economic value. In the case of the Huntsville 50-Ton unit, it was estimated at $.34/Ton-hour. There is NO run time reduction possible. There are NO Hard Savings Possible
10. Depending on the severity of Capacity loss, the composition of the three regimes on the load distribution will vary.
    a. For the 50-Ton unit, with 36.4 capacity loss, the ***HARD SAVINGS REGIME*** encompassed seven of 12 bins.
    b. For the 12.5 Ton unit, with 42.4% capacity loss, the ***HARD SAVINGS REGIME*** encompassed only six of 12 bins.
    c. When a unit has considerable capacity loss it is possible the ***HARD SAVINGS REGIME*** is so small that the simple payback of 3 years cannot be achieved.

Implications for Hard-Savings Guarantee. If a unit has capacity loss in excess of 40% of rated capacity, it is unlikely that the capacity loss is restricted to Oil Fouling phenomenon that can be treated successfully with ProaTEQ

<u>Note 6: Computation of Fleet Averages</u>

1. We will guarantee ***at least a 10% Capacity Increase (Btuh or Tons)*** relative to Pre-Treatment Baseline.
    a. The Capacity will be computed across the full fleet of units treated, on a capacity-weighted basis
    b. The Baseline Capacity will be based on our Pre-Treatment "Snapshot" measurements, involving air flow (CFM) across the Evaporator Coil, and wet bulb temperatures in the Supply and Return air streams, to capture the enthalpy change across the coil and the total Tons of Cooling
    c. The measurements above in b) will be made approximately 30 min before treatment, and 30-60 min after treatment, to ensure approximately constant ambient conditions on the Condenser for both measurements. Ambient temperatures will be recorded and reported to confirm this.
    d. The Volts and Amps on all legs of the power supply to the unit will be measured before and after treatment. The kW will be computed based on the Volts and Amps with an assumed and mutually agreeable power factor. Where possible, true kW metering will be used.
    e. The foregoing measurements will be made on 100% of treated units, unless unit condition renders the unit non-measurable. The non-measurable units may be treated or not treated at PPG's discretion.
    f. GUE reserves the right to exclude units from treatment based on our Pre-Treatment Condition Assessment.
    g. The measurements on treated and measurable units shall be deemed to apply in the aggregate, to the set of all treated units, measurable or not.
2. We will guarantee ***at least a 10% Performance Improvement (Btuh/Amp)*** relative to Pre-Treatment Baseline across the fleet of treated units on a capacity-weighted basis
3. We will guarantee ***at least a 10% Specific Power Use Reduction (kW/Ton)*** relative to Pre-Treatment Baseline, across the fleet of treated units, on a capacity weighted basis

<u>Consequences of Failure to Meet Capacity, Performance, and Specific Power Use Reductions</u>

1. In the event any of these are unmet, Georgetown Utilities Enterprise will provide a proportional refund to PPG
    a. The Performance Shortfall will be based on the ***largest shortfall*** of the three guarantees
    b. The Performance Shortfall shall govern the Percentage refund.
    c. The Percentage refund shall apply to the total project price.
2. Example:
    a. Assume the Project Price is $100,000.
    b. If the ***Capacity Increase*** (Btuh or Tons -- Item 2 above) on aggregate is 9% versus 10% guaranteed, then there is a one part in 10 shortfall; or 10% shortfall on the Capacity Increase guarantee;
    c. If the ***Performance Improvement*** (Btuh/Amp -- Item 3 above) on aggregate is 8% versus 10% guaranteed, then there is a 2 parts in 10, or 20% shortfall, on the Performance Improvement guarantee
    d. If the ***Specific Power Reduction*** (item 4 above) is 7% versus 10% guaranteed, then the shortfall is 3 parts in 10, or a 30% shortfall on the Specific Power Reduction guarantee

    e. In this case, The Performance Shortfall for purposes of this guarantee is the largest of the three, that being the 30% shortfall on Specific Power Reduction.
    f. The Refund will be 30% of the Project Price, or $30,000.
3. GUE will re-visit the site on the first, second, and third anniversary of the treatment, and will perform the same measurements as outlined in 2a. through 2g. above.
    a. GUE will report these measurements, individually and in aggregate, to PPG.
    b. GUE will confirm that the guarantees on performance improvement are still being met.
    c. If the guarantees are still being met, PPG will reimburse GUE for the costs of the measurement effort; labor and expenses.
    d. If the guarantees are not met, GUE will absorb the cost of measurement and will be subject to providing the refunds outlined in 6a. through 6f. above.

We note that that this guarantee applies to ProaTEQ treatment of DX Packaged and Split-System Units used in Comfort Cooling Applications. If the project contains other Tasks besides ProaTEQ treatment of DX Packaged and Split-System Units used in Comfort Cooling Applications, then the "ProaTEQ Treatment Task Price" shall be deemed to be only the price of the Task or Tasks involving ProaTEQ Treatment of DX Packaged and Split-System Units used in Comfort Cooling Applications.

Note 7: Documentation of GUE Bin Model Computations

INTRODUCTION

Several points in this discussion refer to pages in the "Briefing". This is the October 13, 2015 Briefing from GUE to PPG regarding the results of the pilot test of 50-Ton and 12.5 Ton units.

The FIRST thing to realize is that the savings analysis that is reported on in both the Oct 13, 2015 briefing and the January 2016 "Read Ahead" has THREE MAIN PARTS. These are:

1. The ***Capacity tests before and after the treatments, as reported to PPG in the "Snap-Shot Reports"*** done during the project. Those reports were delivered to Chris when prepared and are attached
2. The ***Cooling Load Distribution for each unit, that was synthesized by Georgetown Utilities, based on Huntsville Weather data***. That distribution and the supporting weather data is shown on pages 13 and 14 of the briefing, and are detailed on the tab "HSV Weather Anal" on the EXCEL Workbook; and
3. The ***HVAC Unit operational and cost simulator*** that was built by GUE for the analysis. That is on one tab of the attached Excel Workbook.

CAPACITY TESTS

Capacity tests were made before and after installation of ProaTEQ on each unit. They are attached. They show the baseline capacity of the units as encountered before ProaTEQ treatment; and the capacity after treatment.

COOLING LOAD DISTRIBUTION

Direct your attention to the briefing, pages 13 and 14.

4. Slide 13 is the hourly temperature distribution for Huntsville International Airport (IAP) for the 12 months ending August 31, 2015, the period when our work was done. This was actual weather data for the period of the test, as recorded by NOAA, and was the basis for the

synthetic cooling load distribution that GUE created for the analysis. On the "Project Analytical Workbook, there is a tab named ***"HSV Weather Anal"*** which has the statistical analysis of the weather data and the formation of the temperature bins based on the temperature frequency distribution. It is plotted graphically on Slide 13 of the briefing.

5. The weather data showed that there were 4,336 cooling hours annually (hours when temperature was >65F. ***Note this is not FULL LOAD COOLING HOURS. There are fewer of those. This is just total hours when the system would call for cooling at any load level, full load or part-load.***
6. GUE created a 12-bin frequency distribution for the hours with temperatures in excess of 65F. The bin size was 3degF. So the lowest bin was 66-68, then 69-71, then 72-74, etc. The 4,336 hours were distributed by hourly temperature as shown on slide 13. ***This slide contains no assumptions of any kind. This is the actual distribution of the 4,336 cooling hours over the temperature bins from 66F to 101F, as recorded by the US Dept. of Commerce, NOAA, at Huntsville IAP for the 12-month period in which the study was done.***
7. Slide 14 shows the ***<u>Synthetic Load Distribution</u>*** GUE created for the 50-ton unit, based on this weather data. It must be realized that the cooling load distribution on the unit is not known, nor could it be measured within the budget constraints of this study. But it is not necessary to do so. A synthetic load distribution, reasonably constructed, is sufficient for the analysis. The ***Synthetic Load Distribution*** was based on the following rules:
    a. There has to be some load distribution. That is, over a year the unit faces loads from 0 to likely up to 55 tons. They are distributed in some manner over the hours in the year.
    b. The unit will see the lowest loads infrequently and the highest loads infrequently; the majority of hours the unit will see loads in the middle of the distribution. But whatever the details, no one can dispute that there will be a load distribution that the unit reacts to over the year.
    c. The variation of the load distribution will more likely follow the weather than any other "forcing function"; this would not be so with a process unit. But with an HVAC unit, the weather is arguably the main forcing function, and will likely be the main driver of the variation in the load distribution.
    d. That said, GUE created 12 bins representing load intervals the unit faces in a year. The bins are 0-4.5 tons, 4.6-9.0 tons, 9.1-13.5 tons, etc. They are 12 bins with a uniform interval size of 4.5 tons.
    e. The assumption is that the 50-ton unit is about 10% oversized to its design size; so the design size is likely about 45.5 tons.
    f. The design size is the size that will meet the load 95% of the time. Five percent of the time, the load will exceed the design size. The oversizing will take care of that most of the time, but it is possible that the load may even exceed the capacity of the oversized unit; this is well known. But the principle in sizing is that the design size meets the 95th percentile of load; and then oversizing of 10% is generally applied, which will meet all but the worst hourly loads in the 5% not accounted for by the design size.
    g. Following those principles, 5% of the 4,336-hour cooling load distribution is 217 hours.
    h. From slide 13, it is seen that the upper 3 bins, 93-95, 96-98, and 99-101 contain a combined 233 hours, or 5.4% of the hours in the year. Thus, the 95th percentile of the temperature distribution is a little above the mid-point of the 10th bin, the 93-95 deg bin, say about 94 to 95 deg F.
    i. So we place the frequency of the 10th temperature bin, 159 hours, on the 40.6-45.0-ton load bin. We assign the frequency of the 11th temperature bin, 67 hours, to the 11th load bin,

45.1-49.5 tons; and we assign the frequency of the 12th temperature bin, 7 hours, to the 12th load bin, 49.6-54.0 tons.

j. We then assign the frequency of the 1st through 9th temperature bins to the corresponding 1st through 9th load bins.

k. The result is a ***Synthetic Load Distribution***. It is shown above in Figure 1. It has the following characteristics:
    i. 95% of the hours have loads below the design load of 45.5 tons
    ii. 5% of the hours have loads above the design load of 45.5 tons
    iii. For the 74 hours above the design load, 67 of them have loads under the oversized value of 50 tons, and are thus expected to be met; and
    iv. Of the 74 hours above the design load, only 7 hours have loads above the oversized value of 50 tons, and would not be met by the installed equipment; this is less than two tenths of one percent of all cooling hours.
    v. The remainder of load bins follow the frequency distribution of the hourly temperatures as would be expected
    vi. The synthetic load distribution thus created provided 1,587 full-load cooling hours at 50 tons capacity.
    vii. The EPA tabulated full load cooling hours for Huntsville AL is 1,464, and that is for a commercial/retail type application with typical office/retail operating hours.
    viii. The longer hours and more intense internal loads of the PPG industrial application were judged to sufficiently justify the 8% variance from the EPA figure and ensure that this synthetic load distribution was a reliable approximation of the unknown actual load distribution faced by the 50-ton unit, for purposes of this analysis.

The Synthetic Cooling Load Distribution is essential to the analysis. Considerable effort went into getting that as "right" as could be with the data and time allotted. A similar analysis was used to create a synthetic cooling load distribution for the 12.5 ton unit. The synesthetic load distribution for the 12.5 ton unit is NOT shown in the briefing. It is provided in the excel workbook. See below.

EXCEL WORKBOOK: SIMULATION OF THE HVAC UNITS' OPERATION, COST, AND SAVINGS

On the attached EXCEL workbook, there is a tab entitled ***"151001 ROI and Savings Estimate"***. This tab is divided into five regions, separated on the worksheet by thick yellow bars:

8. ***Cells B12:K84 contain high level parameters used throughout the work***
9. ***Cells B90:BS175 contain the analysis of the 50-ton unit***, including the synthetic load distribution, all computations, and all graphics that appear in the Briefing and the Program Announcement.
10. ***Cells B178:BT345 contain all the analysis of the 12.5-Ton unit***, including all graphics that appear in the briefing and the Program Announcement relative to that unit.
11. **Cells *B349:BS378 contain all the analysis of the two units combined***, including all graphics that appear in the briefing and Program Announcement relative to both units combined.
12. ***Cells B382:R418 contain all analysis for the application of ProaTEQ to an assumed total 1,250 Tons of HVAC cooling equipment*** at Huntsville. Note that the results shown in this section will NOT match that in the briefing on slide 39, because the analysis in this section was updated and improved in the course of preparing our October 23, 2015 proposal to perform full HVAC analysis at Huntsville. Between October 10-13, when the briefing was developed, and October

14-23 when the proposal was submitted, PPG provided us additional data on the HSV HVAC fleet. That better intel was incorporated and so the results in Cells B382:R418 will match the proposal dated October 23 2015 rather than the briefing dated October 13.

Cells below row 420 should be ignored. They contain fragments and incomplete analyses.

Note that columns B-G contain data relevant across the analysis, and columns H-BS contain the bin analyses. ***Importantly, in columns B-G, we have derivations of the economic value of lost cooling service. That plays a key role in this study, though the value of ProaTEQ is well established without consideration of that factor.***

In the section containing the analysis of the 50-Ton unit, the following are key features of the analysis:

13. ***Cells H90:BS175 contain the 50-ton HVAC Unit simulation and the resulting engineering-economic analysis***
    a. Cells ***H90:AU108 contain the analysis of the baseline unit, 50 ton capacity***; in this section you will find:
        i. Analysis of the run-time per bin, taking account of the fact that the three-stage compression system will dispatch one compressor, then two, then all three as the load increases.
        ii. Note, for example, column P rows 95-106, for the lower loads, in bins 1-3, only once compressor is dispatched. In bins 4-7, two compressors are dispatched; and in bins 8-11, all three compressors are dispatched.
        iii. Analysis of the total kW and kWh per bin, including run time per bin with proper amount of compression dispatched; and sequential dispatch of the condenser exhaust fans depending on the number of compressors running
        iv. Analysis of the “theoretical” and “actual” run times. That is, for example, for bin 12 the reference load is 52 tons. With 50 tons dispatched (see column Q, row 106) the theoretical run time is 62 minutes for each hour at that load (row 106, column R). The actual run time is 60 minutes and the load is not met (row 106, column S). This results in unmet cooling load or “lost refrigeration service”.
        v. Note that the theoretical run time per hour is under 60 minutes in all bins but #12. The 50-ton unit thus meets the load in bins 1-11.
        vi. Column AI row 107, shows that 79,367 Ton-hours of cooling were theoretically required; column AJ row 107 shows that 79,354 Ton-hours of cooling were delivered. There were only 12 ton-hours of unmet load, only 0.02% of the load is unmet. This is illustrated in Figure 2 above, also, where the theoretical run time exceeds 60 min for only a small number of hours in bin #12.
        vii. As designed, at 50 tons capacity, the unmet cooling load is very small. ***That changes dramatically in for fouled unit case, and then is recovered dramatically in the treated unit case***.
    b. Cells ***H112:AU128 contain the analysis of the fouled unit, 31.8 tons capacity***
        i. Comparing columns R and S in rows 115-126, it is seen that the fouled unit meets the load in bins 1-7, but starting in bin 8 and through bin 12, the load is not met. This is also illustrated in Figure 3 above.
        ii. Due to the reduced capacity of the unit, the second compressor comes on in bin 3, and the third comes on in bin 5. The unit is “swamped” by the time the load grows

to that of bin 7, and thereafter, with all three compressors running, the fouled unit fails to meet the load.

        iii. The fouled unit uses 167,700 kWh (see AB127) which is much more than the base unit of 121,549 kWh (AB107). ***But the "penalty" from fouling is not just the increased kWh and kW cost…it is the lost cooling***
        iv. The fouled unit has 4,718 Ton-hours of cooling required but not delivered (AK127). This is an additional "penalty" of fouling.
        v. The economic penalty of fouling is an increase of annual operating cost from $17,419 (AH107) to $20,351 (AH127) – an increase of $2,932 annually -- ***PLUS*** an annual lost cooling service valued at $1,596 (AL127) – which nearly doubles the penalty
    c. ***Cells H132:BS150 contain the analysis of the treated unit, at 44.5 tons capacity***
        i. It is seen how much of the lost service is recovered.
        ii. The substantial annual cost savings are documented.
    d. **Cells H152:BS175 contain the summary of the savings, comparing baseline to fouled unit then fouled unit to treated unit**. The graphics from the briefing and the Program Announcement are provided.

In Cells B178 to BT345, comparable structure is provided for the 12.5 Ton unit. The 12.5-ton unit was simulated in three stages just as the 50-ton was done.