Carrier

A United Technologies Company

XRV Capacity and Surge prevention control

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October 2012

XRV CAPACITY & SURGE PREV CONTROL

Overview

Capacity Control

VFD Speed Change

Surge Prevention Algorithm

Primary/Secondary System

Variable Primary Flow

Variable Primary Flow Software

XRV CAPACITY & SURGE PREV CONTROL

Capacity Control

Ramp Loading

Temperature ramp loading – Controlled based on Leaving chilled water and entering chilled water at a given rate

Motor ramp loading – Controlled based on Average line current or Motor percent KW at a given rate

Chiller with VFD

Capacity control algorithm evaluates and controls capacity based on

Actual Guide Vane Position

Target VFD Speed

Hot Gas Bypass

Surge Prevention

Surge Prevention Algorithm

Overrides

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Capacity Control

Guide Vane Characteristics

1. Target Guide Vane Pos is evaluated every 5 Sec
2. Guide Vane Increase/Decrease will have maximum rate change of 2% every 5 sec

Target VFD Speed Characteristics

1. Controlled between VFD Min & VFD Max speed
2. Change at a rate of 2%xVFD Gain every 5 sec
3. Target VFD speed will increase when SURGE COUNT increases and will increase by VFD Increase step under surge condition
4. Will increase If surge counts exceed 4
5. If forced, capacity control will use guide vane
6. Will not decrease in speed under HGBP/Surge prevention. Capacity control will use Guide Vane

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Capacity Control

Normal condition

VFD speed will change based on guide vane position x VFD gain

Increase in Capacity:

If Actual guide vane position is less than 99.6% of Guide vane travel limit, the guide vane will be opened

If guide vane reaches Guide Vane travel Limit, VFD will speed up based on Target VFD Speed

Decrease in Capacity

If Target VFD Speed is greater than VFD Min Speed, Speed boost is not in effect, VFD speed will decrease.

Once VFD speed reaches VFD Minimum Speed, guide vane will decrease

If Surge is anticipated, Speed will be locked, Guide Vanes will close instead

If lower speed causes Surge, Speed Boost will occur and, Guide Vanes will close

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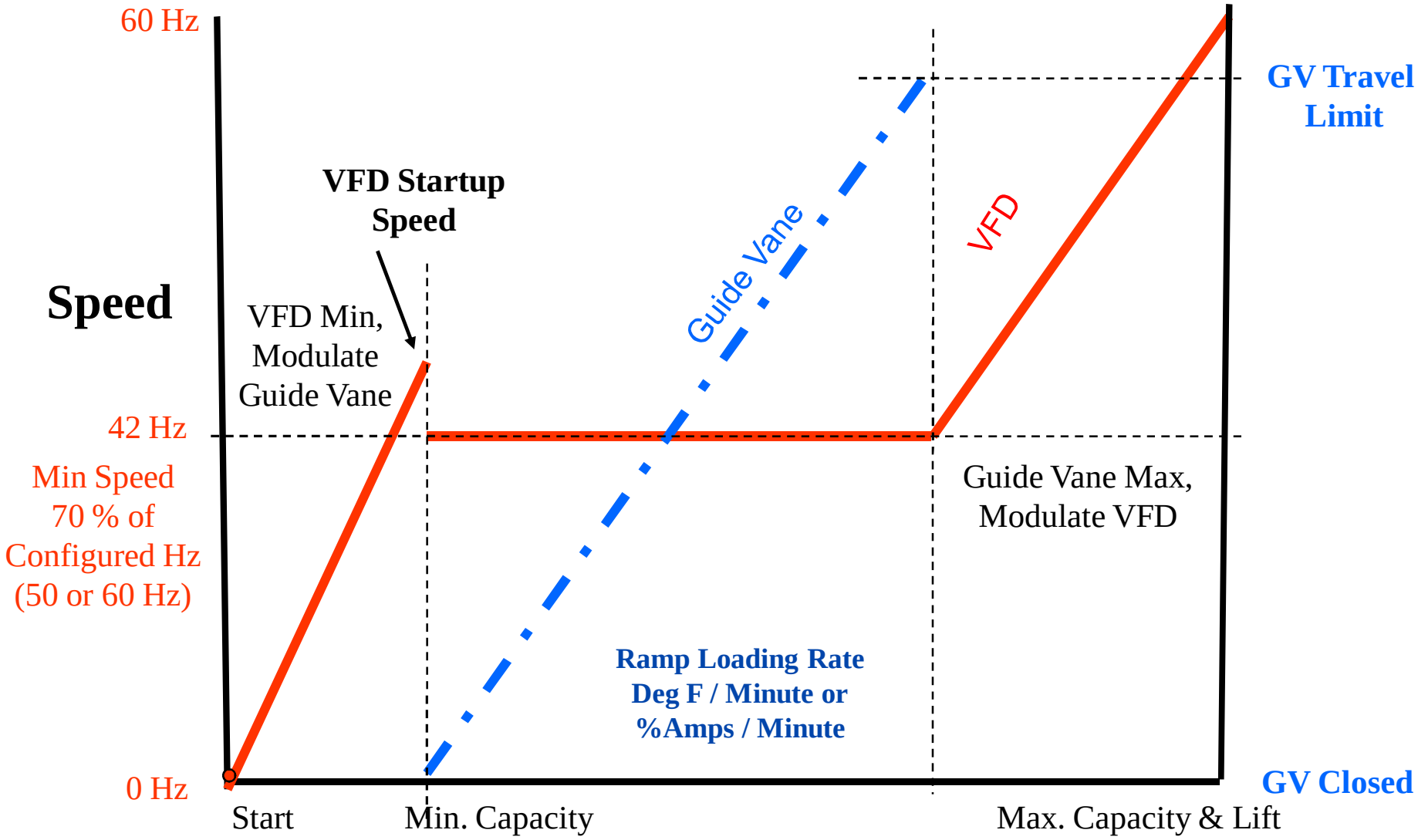
Capacity Control



Speed & Guide Vane Control

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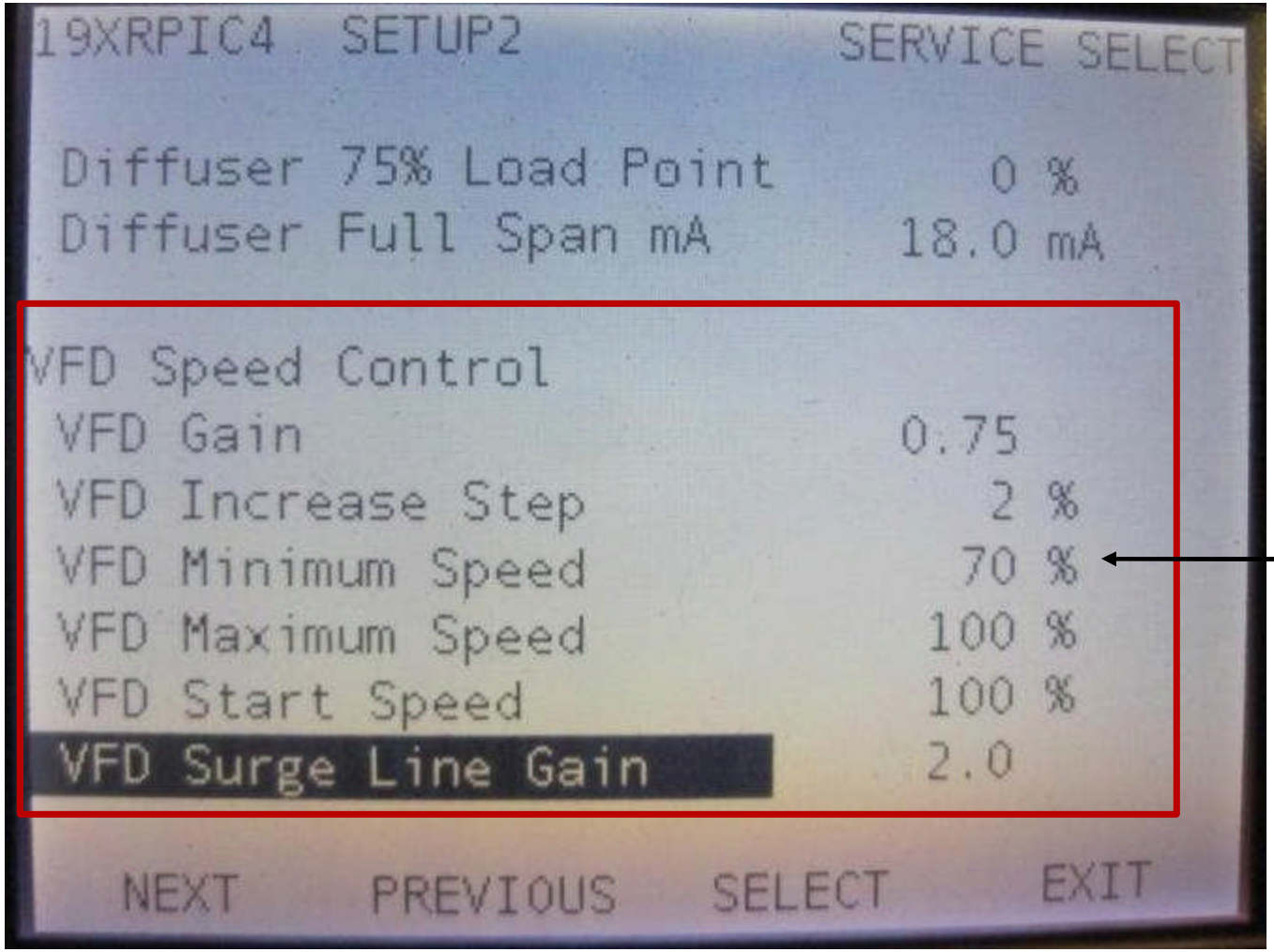
VFD Control



Never set minimum speed below 70%. This is minimum torque required to turn the motor

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VFD Control

VFD Speed change

1. Is based on calculated change in **GV delta x VFD Gain** under normal condition
2. Is based on **VFD Increase Step** under surge prevention High Operation.
3. Is based on **GV Delta x VFD Gain** under surge prevention Low Operation

VFD Surge line Gain

Rate the surge line is adjusted in response to change in Actual VFD Speed

Increase VFD Surge Line Gain reduces the surge prevention area

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Surge Prevention/HGBP

- Surge prevention algorithm
  - Controller sees that chiller is operating close to surge and action is put in place to prevent chiller from surge
  - Configured for specific compressor size as maximum lift impeller wheel can perform varies from compressor to compressor
  - Surge prevention functions operate differently with hot gas bypass and VFD
  - Surge limit/HGBP Option
    - 0. No HBBP
    - 1. HGBP for Surge Prevention
    - 2. HGBP for low load operation

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Surge Prevention/HGBP

0. No HBBP

No HBBP in the system and surge prevention does not take HGBP into control consideration

1.HGBP for Surge Prevention

HGBP relay shall turn to ON if

Surge prevention active

VFD Target Speed = VFD Maximum Speed or

If VFD Target Speed is forced

2**. HGBP for low load operation**

HGBP does not need surge prevention to be active and energize hot gas bypass relay based on chilled water delta T defined in settings

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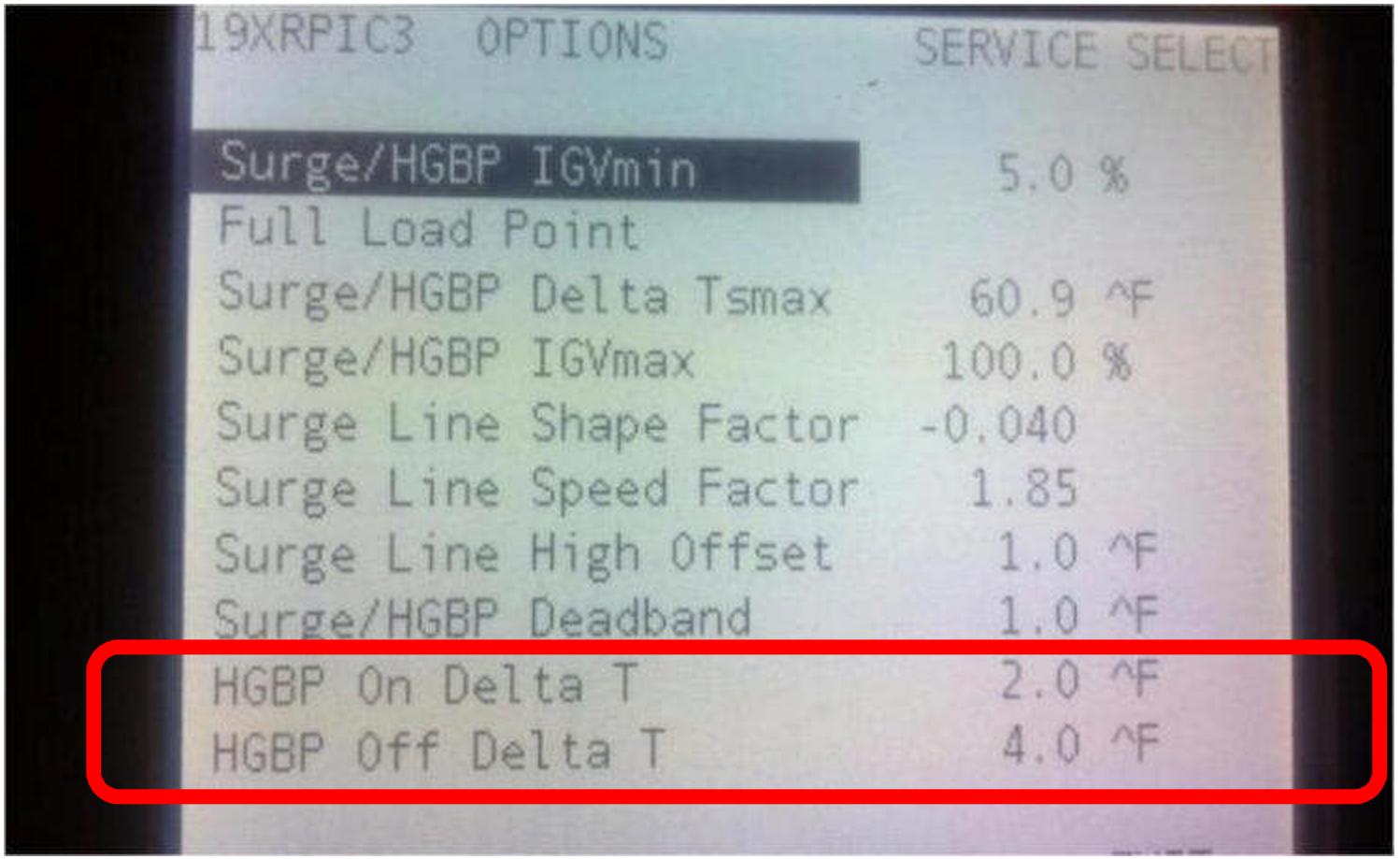
Equipment service → Options

Settings for HGBP for low load operation



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VFD Control

Surge Prevention High Operation

When Surge prevention is more than 1ºF of surge prevention region.

Target VFD speed change by Increase Step

Surge prevention Low Operation

When surge prevention is active, surge count is >0 or high VFD current.

Target VFD speed change by Delta GV x VFD Gain

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Capacity Control for VFD & Guide Vane

Surge Prevention High Operation

Event	HGBP Relay	Target VFD Speed	Guide Vane Response	VFD Speed Response
Capacity Increase Request During Ramp Loading	OFF	Forced or Max	Target GV = Actual GV + Delta	(Fixed)
		Not Forced and Not Max		Target VFD = Target VFD + Increase Step

XRV CAPACITY & SURGE PREV CONTROL

Capacity Control for VFD & Guide Vane

Surge Prevention Low Operation

Capacity Control Table for VFD Speed and Guide Vane Position				
Event	**HGBP Relay**	**Target VFD Speed**	**Guide Vane Response**	**VFD Speed Response**
Capacity Increase Request During Ramp Loading	OFF	Forced or Max	Target GV = Actual GV + Delta	(Fixed)
		Not Forced and Not Max		Target VFD = Target VFD + (Delta * VFD Gain)
Capacity Increase Request	OFF	Forced or Max		(Fixed)
		Not Forced and Not Max		Target VFD = Target VFD + (Delta * VFD Gain)
		Forced or Max	Target GV = Actual GV + Delta	(Fixed)
		Not Forced and Not Max		Target VFD = Target VFD + (Delta * VFD Gain)
Capacity Decrease Request	Either	Any or Forced	Target GV = Actual GV + Delta	

XRV CAPACITY & SURGE PREV CONTROL

Capacity Control for VFD & Guide Vane

Normal Operation

Event	GV Position	Target VFD Speed	Guide Vane Response	VFD Speed Response
Surge Event	Any	Forced or Max		(Fixed)
		Not Forced and Not Max		Target VFD = Target VFD + Increase Step
Capacity Increase Request	Any	Forced or Rampdown	Target GV = Actual GV + Delta	(Fixed)
	< Travel Limit	Not Forced	Target GV = Actual GV + Delta	
	>= Travel Limit			Target VFD = Target VFD + (Delta * VFD Gain)
Capacity Decrease Request	Any	Forced or Rampdown	Target GV = Actual GV + Delta	(Fixed)
	Any	> Min		Target VFD = Target VFD + (Delta * VFD Gain)
		#NAME?	Target GV = Actual GV + Delta	

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How to use PIC to avoid surge ?

Pressure transducers to monitor lift

Temperature sensors to monitor load

Guide vanes to keep the head pressure down

Controller to calculate the map

Use the P1,T1 and P2, T2

- P is Condenser Pressure minus Cooler Pressure.
- P1 at Low Load, P2 at Full Load.
- T is Chilled Water Temp In minus Chilled Water Temp Out.
- T1 at Low Load, T2 at Full Load

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Status→ Heat Exchange Screen

19XRPIC2 HEAT_EX	POINT STATUS
Cond Refrig Temp	88.0 °F
Condenser Pressure	100.0 PSI
Condenser Approach	1.8 ^F
Hot Gas Bypass Relay	On
Surge / HGBP Active	Yes
Active Delta P	65.0 PSI
Active Delta T	4.5 °F
Surge / HGBP Delta T	6.0 °F
Head Pressure Reference	100 %
Evaporator Saturation Temp	40.5 °F

Can you determined what is Lift, Delta T, HGBP on or off ?

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Surge prevention Algorithm

Surge protection count – no more than 5 surges within "Surge time period" setting (default is 8 mins)

Surge count resets at startup

Surge prevention mode is determined based on Active Chilled Water Delta T/Active Delta P relative to surge prevention line

Normal control if Active Delta T > Surge/HGBP Delta T

Surge Prevention Mode if Active Delta T < Surge/HGBP Delta T

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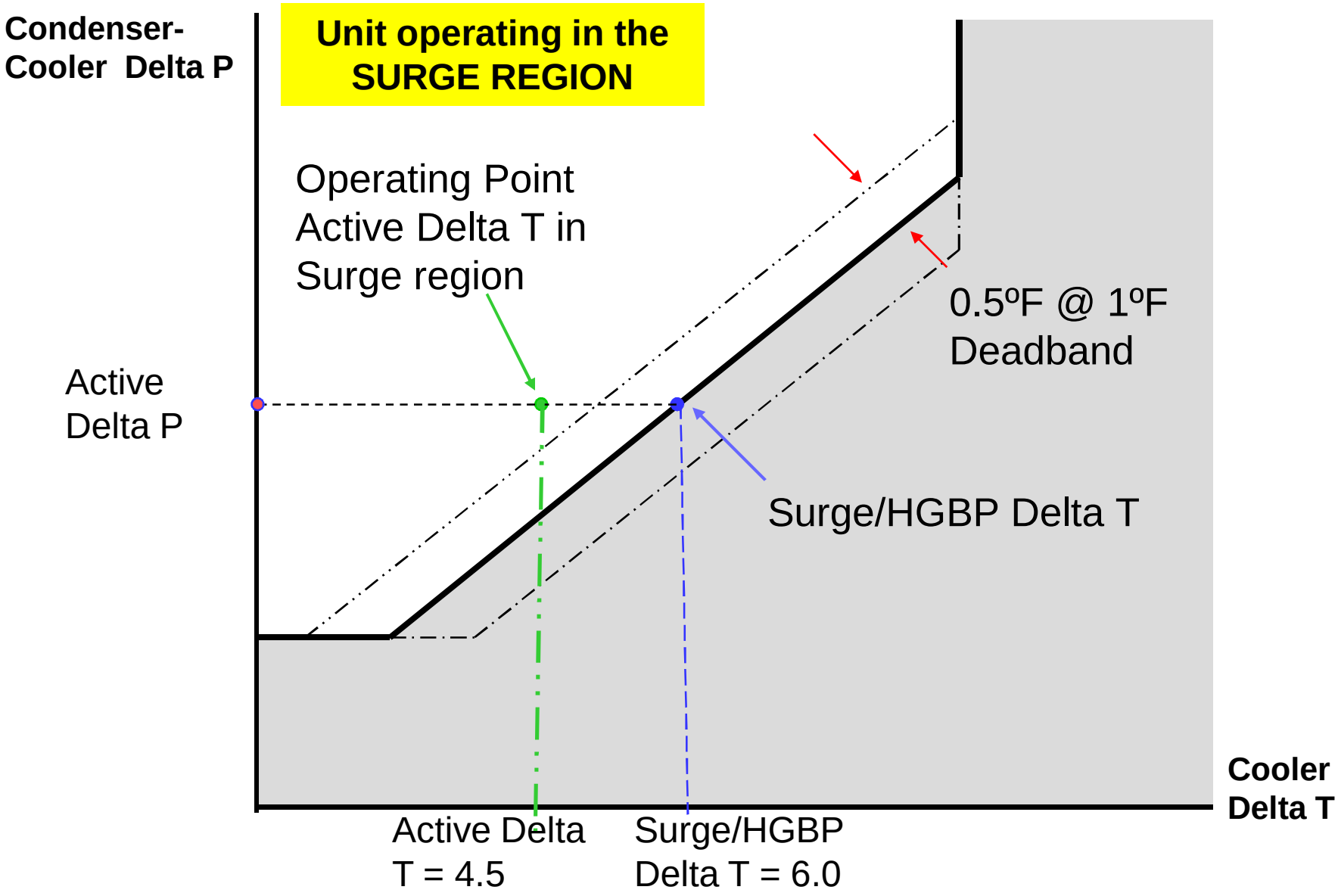
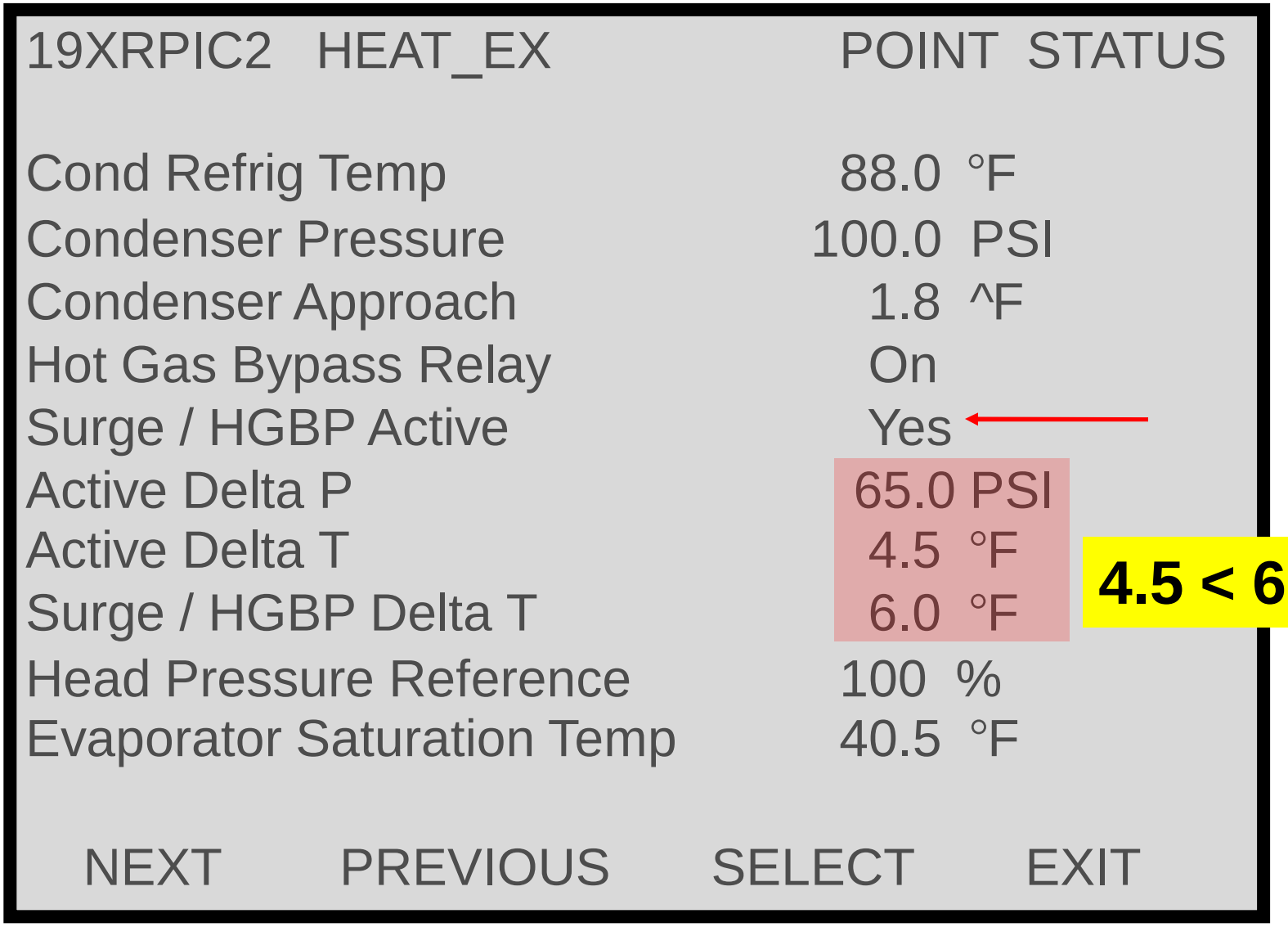
Surge Prevention



XRV CAPACITY & SURGE PREV CONTROL

Surge Prevention



4.5 < 6.0

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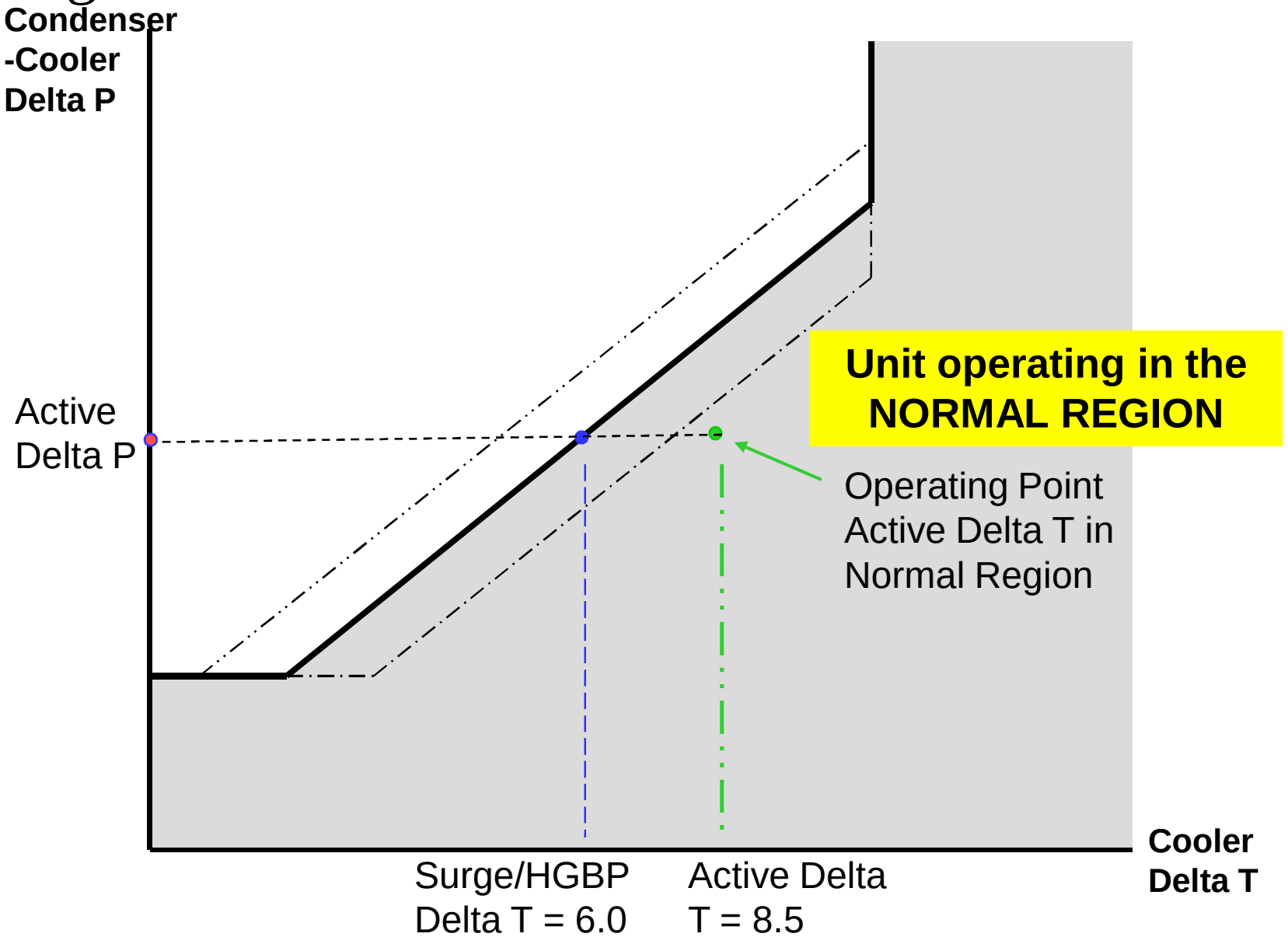
Surge Prevention



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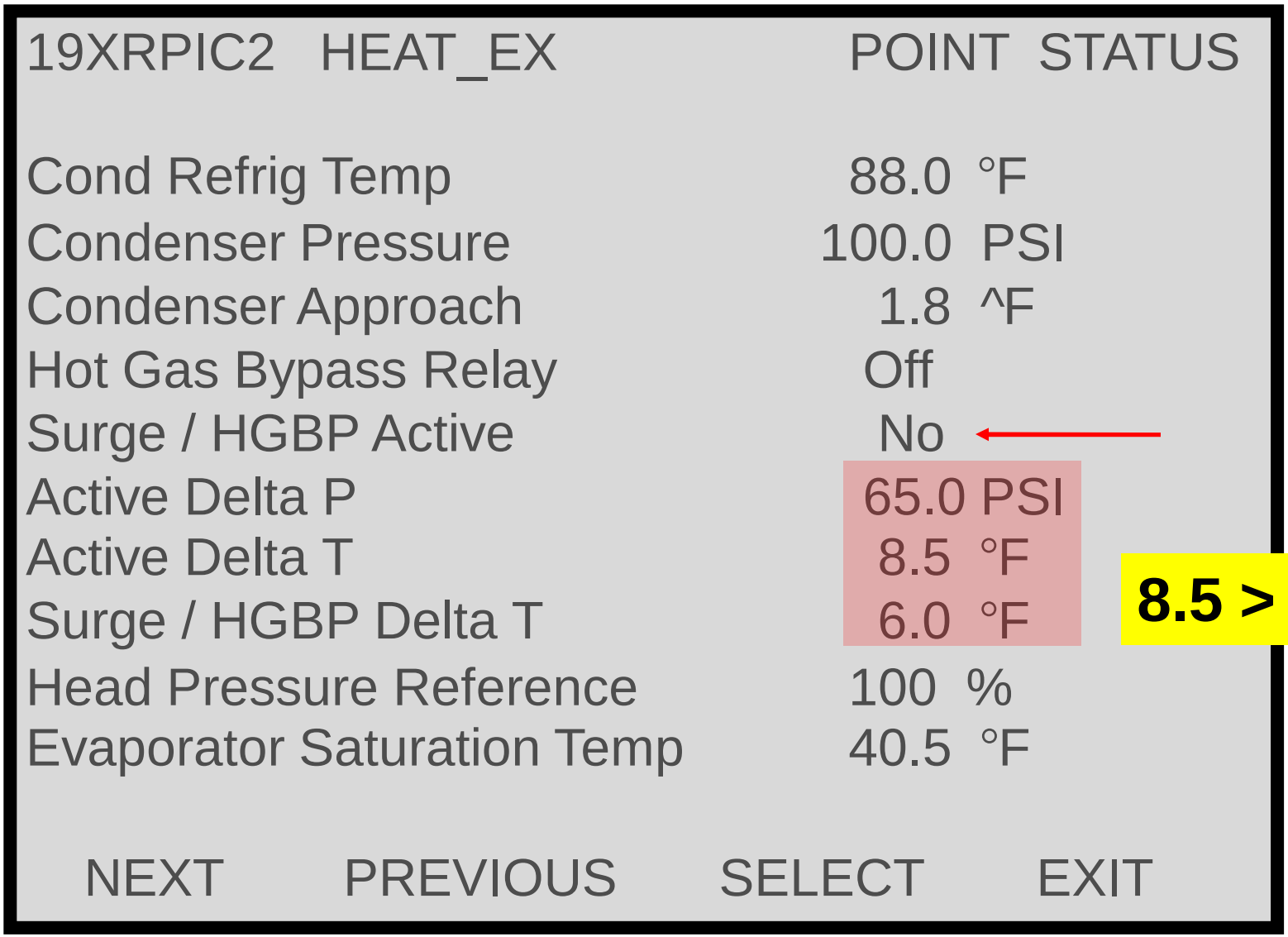
Surge Prevention



8.5 > 6.0

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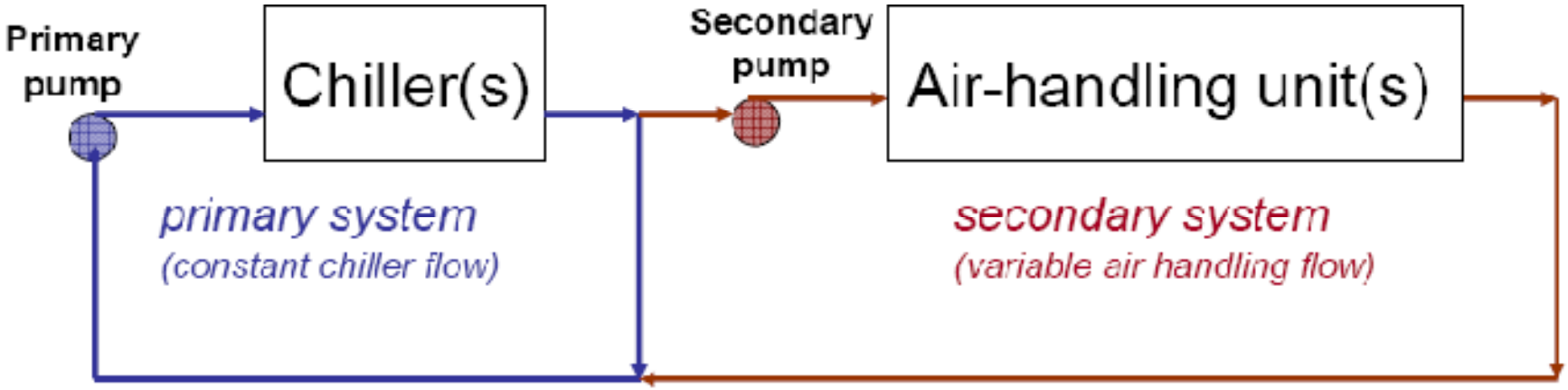
Primary-Secondary System



Primary loop – production loop, usually contained in mechanical room, often short

Secondary loop – building loop, runs throughout the building and serves the coil loads

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Primary-Secondary System

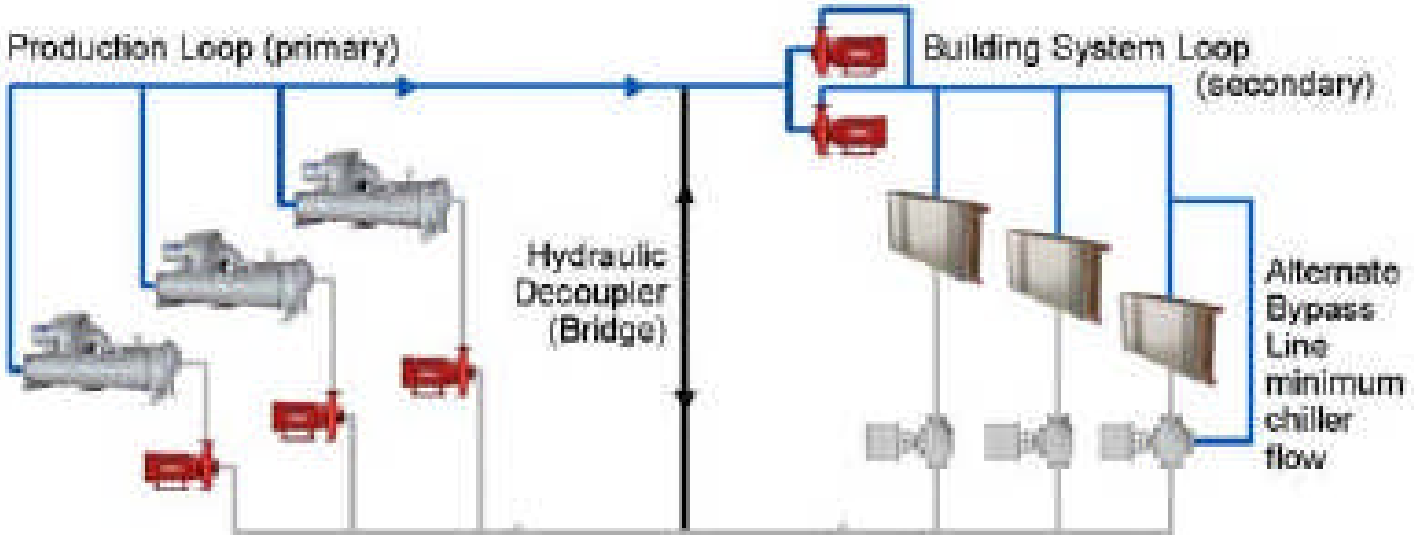
Traditional way of piping

Bridge is used, water can flow both ways

- •Primary Fow > Secondary Flow, water flow from discharge→suction
- •Primary Flow < Secondary Flow, water flow from suction → discharge

VFD on secondary pumps

3 way control valves with bypass in case VFD fails



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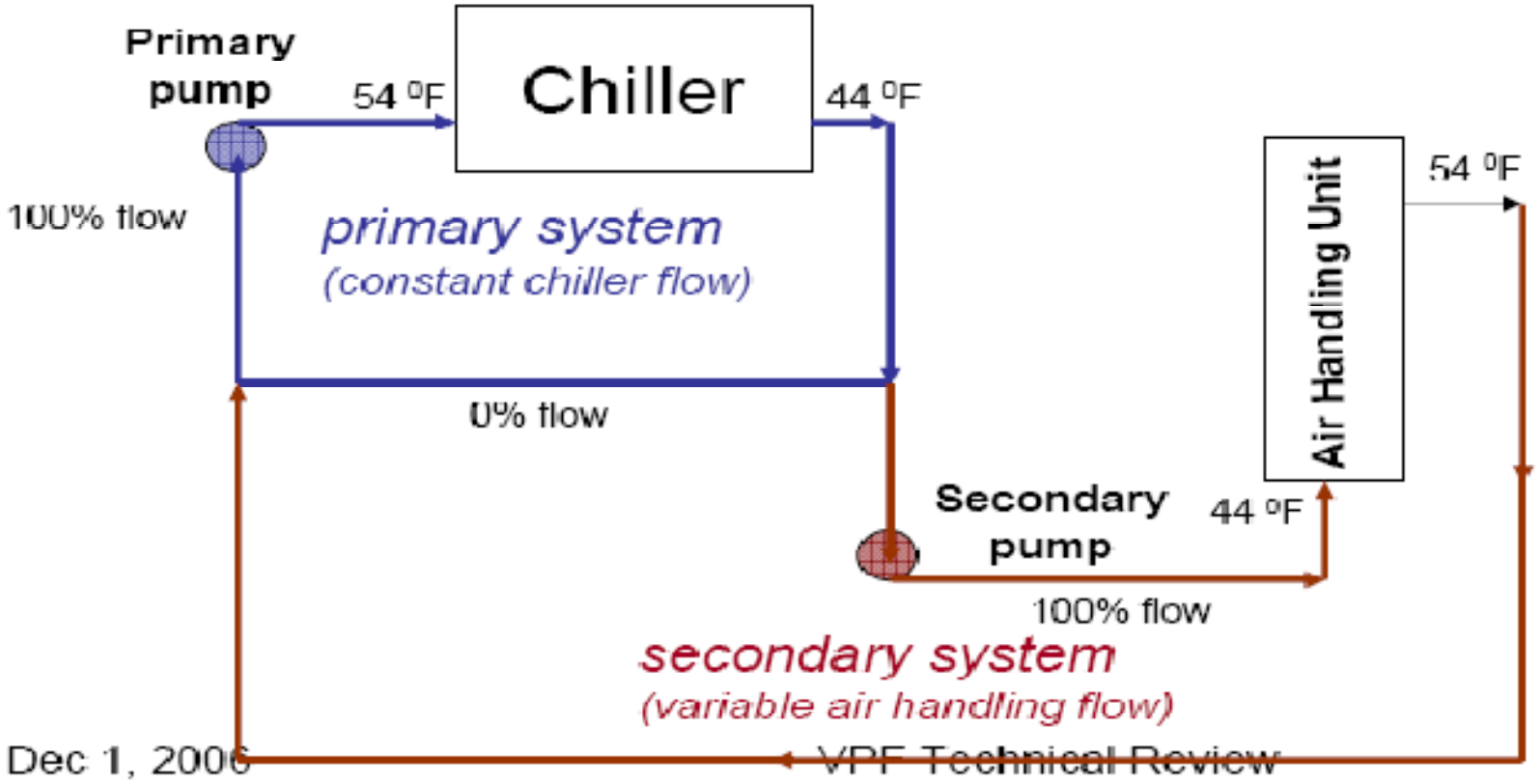
Primary-Secondary Systems @100% load



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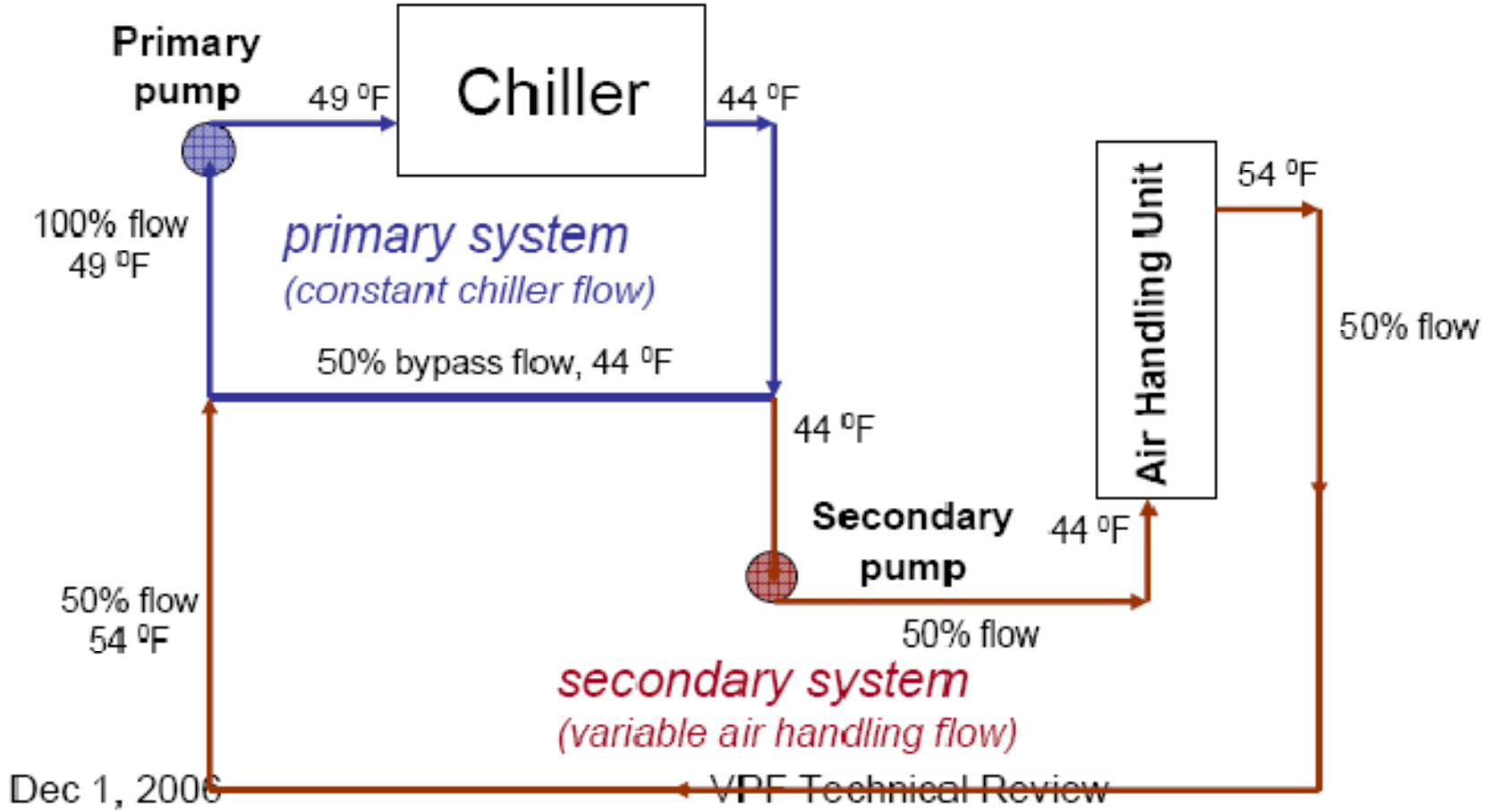
Primary-Secondary System@50% load



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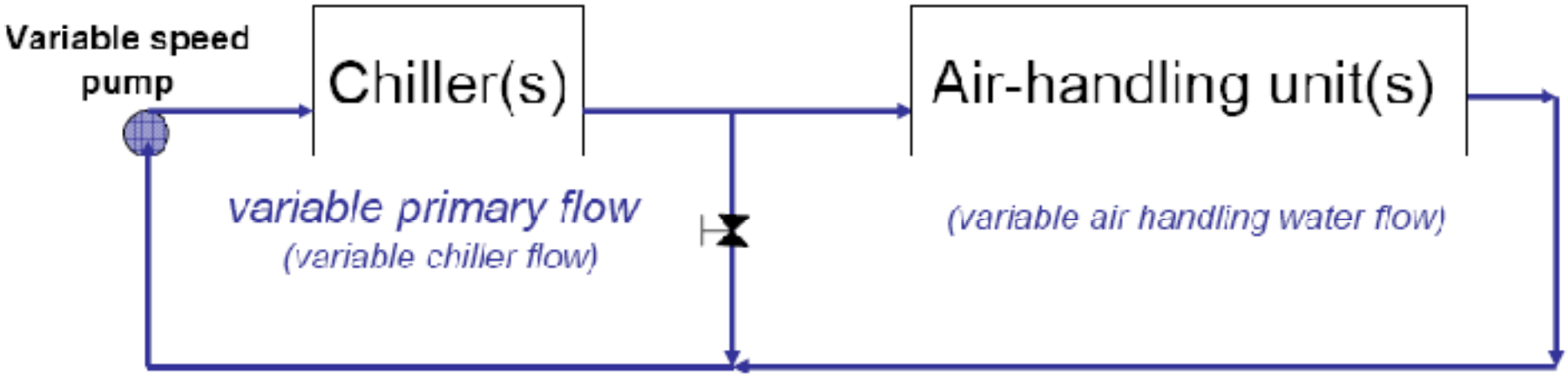
Variable Primary Flow



Variable primary flow

- Take advantage of the ability to modulate flow through chiller evaporator
- Eliminate the need for 2 sets of pumps
- Few pumps, lower cost and fewer floor space
- Pump power savings at part load

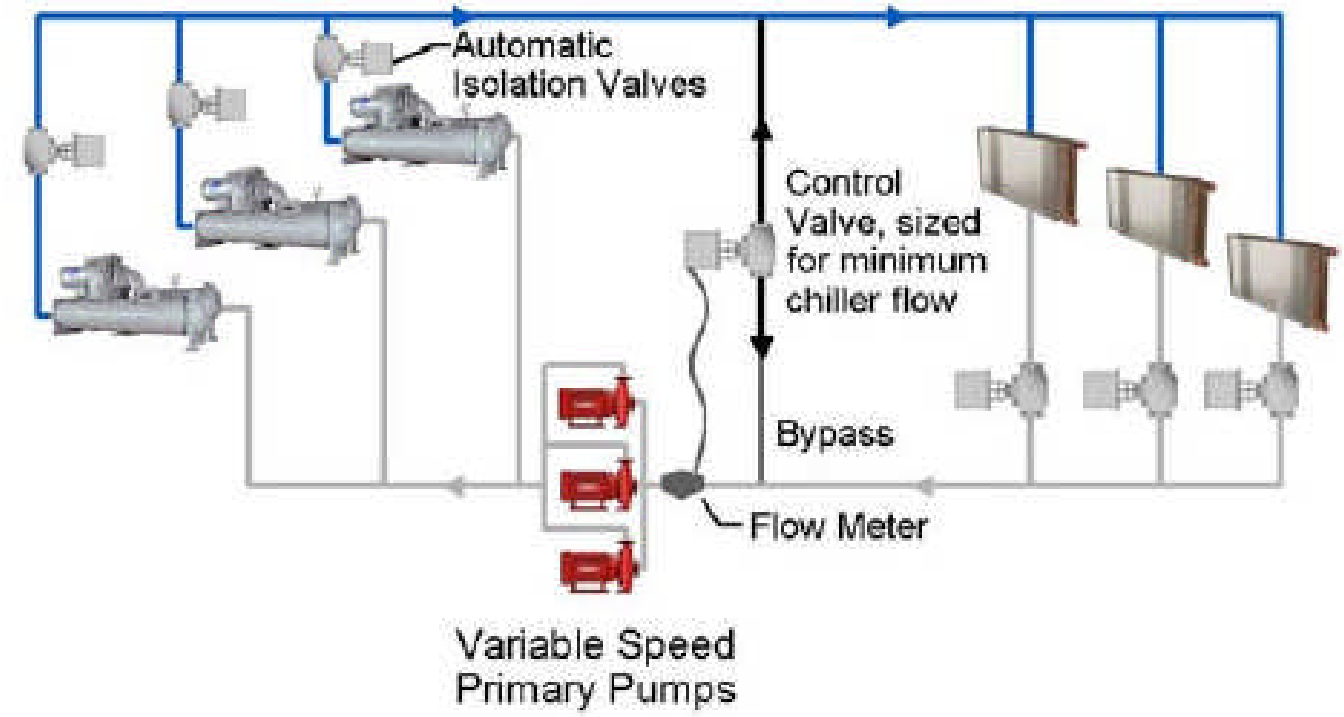
XRV CAPACITY & SURGE PREV CONTROL

Variable Primary Flow

Two way control valves on coil

Bridge – control valve to ensure minimum flow rate to chiller

There is limitations, must understand the recommended chilled water flow range



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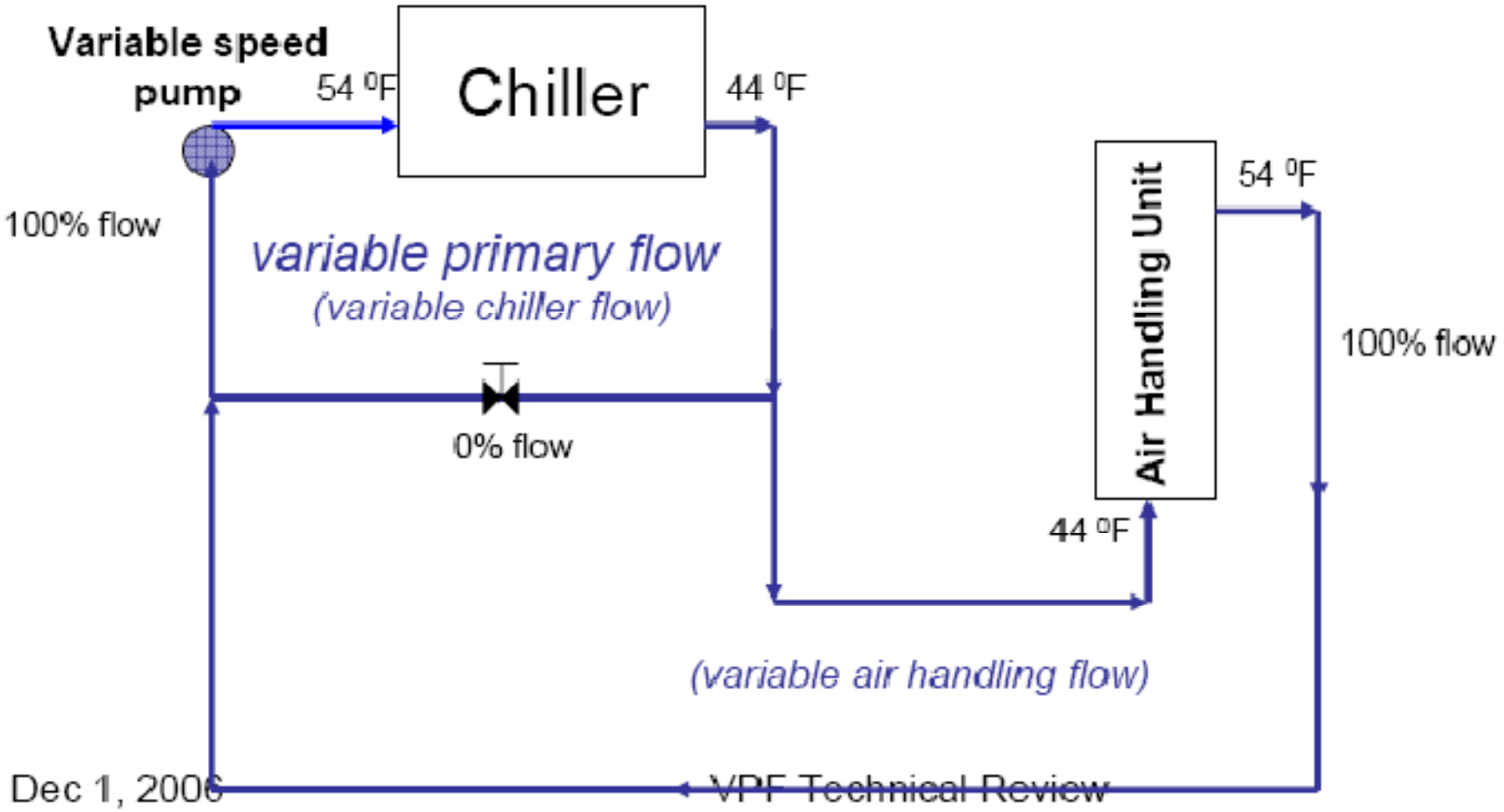
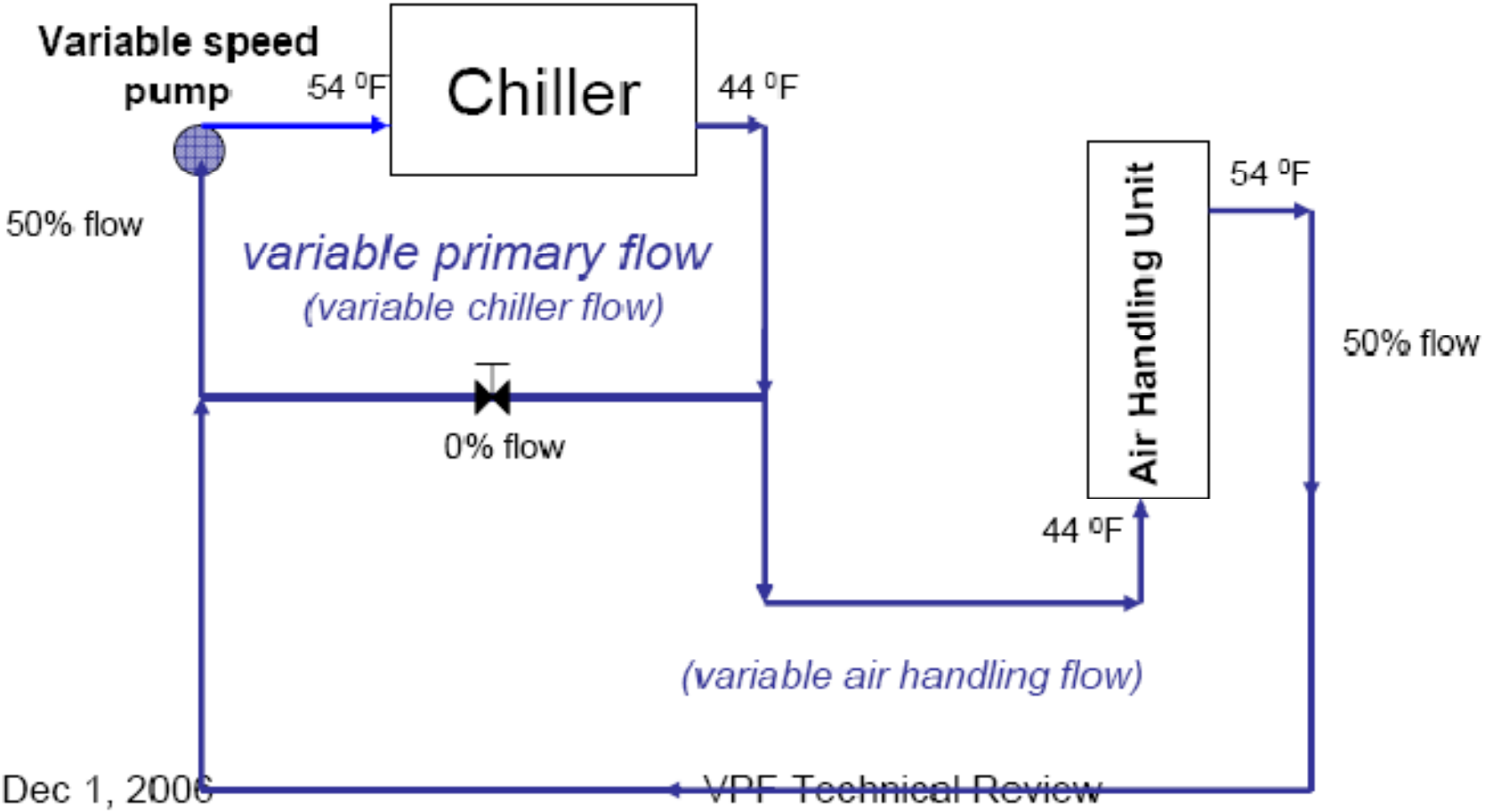
Variable Primary Flow System@100%



XRV CAPACITY & SURGE PREV CONTROL

Variable Primary Flow System@50%



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ARTI-21CR/611-20070-01 report

VPF systems reduce

- total annual plant energy by 3 to 8 %
- first cost by 4 to 8 %
- life cycle cost by 3 to 5 %

Benefits are larger for

- chilled water plants with fewer chillers
- longer, hotter cooling season
- less than design chilled water ΔT

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Variable Primary Flow

$$\text{Tons} = \frac{\text{GPM} \times \Delta T \times \text{Specific Gravity} \times \text{Specific Heat}}{24}$$

If GPM is constant, changes in ΔT is good indication of changes in Tons
If GPM varies, changes is ΔT is not a good indication of changes in Tons

Example:

For Water, SG=1, SH=1 for water

$$\Delta T = \frac{\text{Tons} \times 24}{\text{GPM}}$$

If Tons=200, GPM=600GPM, ΔT=8ºF
If Tons=200, GPM=400GPM, ΔT=12ºF

With the same load the greater the flow rate the lower the Delta T, and the lower the flow rate the greater the Delta T.

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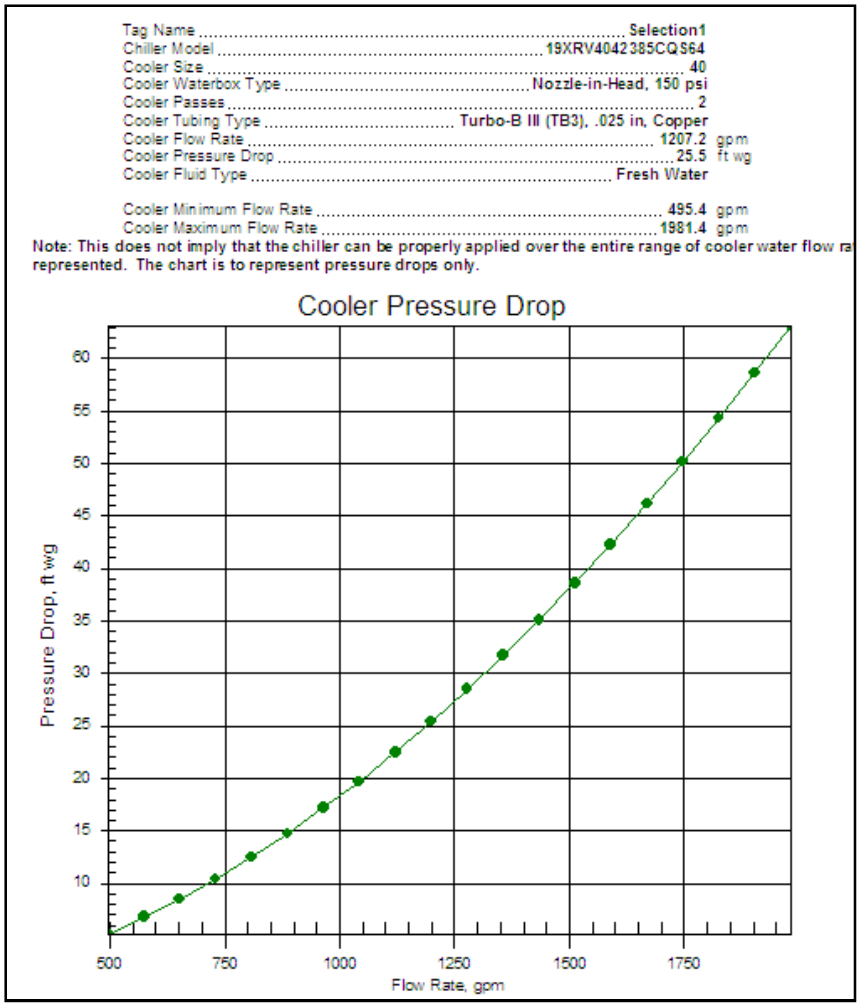
Variable Primary Flow

The new method of control uses guide vane position (GV) and pressure differential(Ts) between the cooler and condenser to better determine the load and therefore the surge line of the compressor. *(Starting April 12th, 2010)*

Flow rate of change should be no more than 30% of design flow per minute

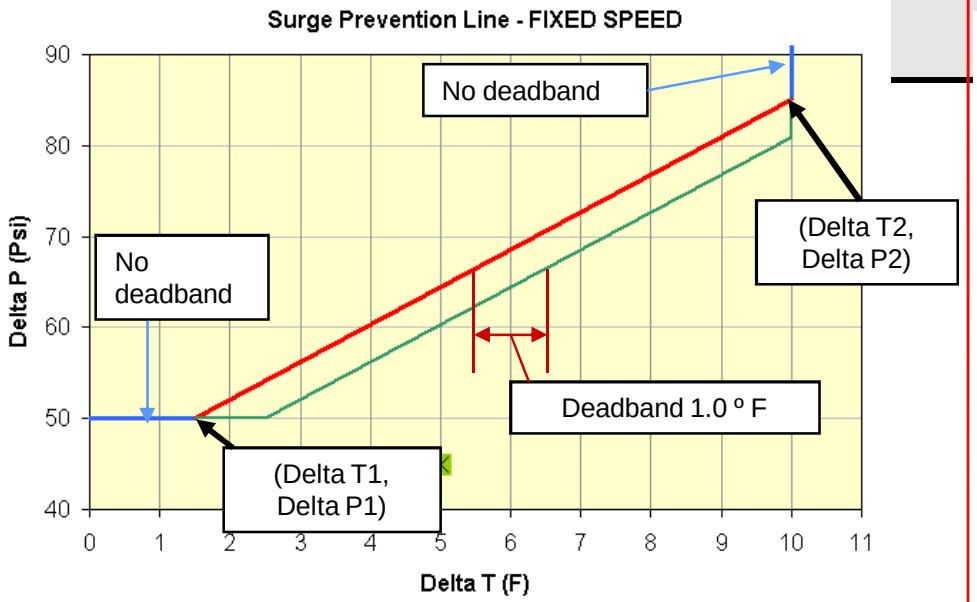
Flow rate should not drop below minimum flow rate for HX

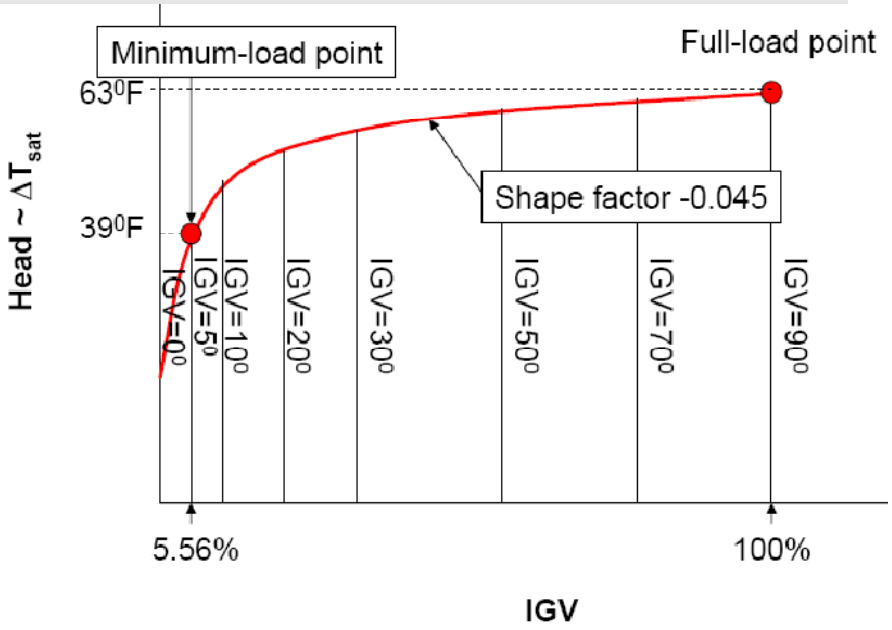


XRV CAPACITY & SURGE PREV CONTROL

Variable Primary Flow Software

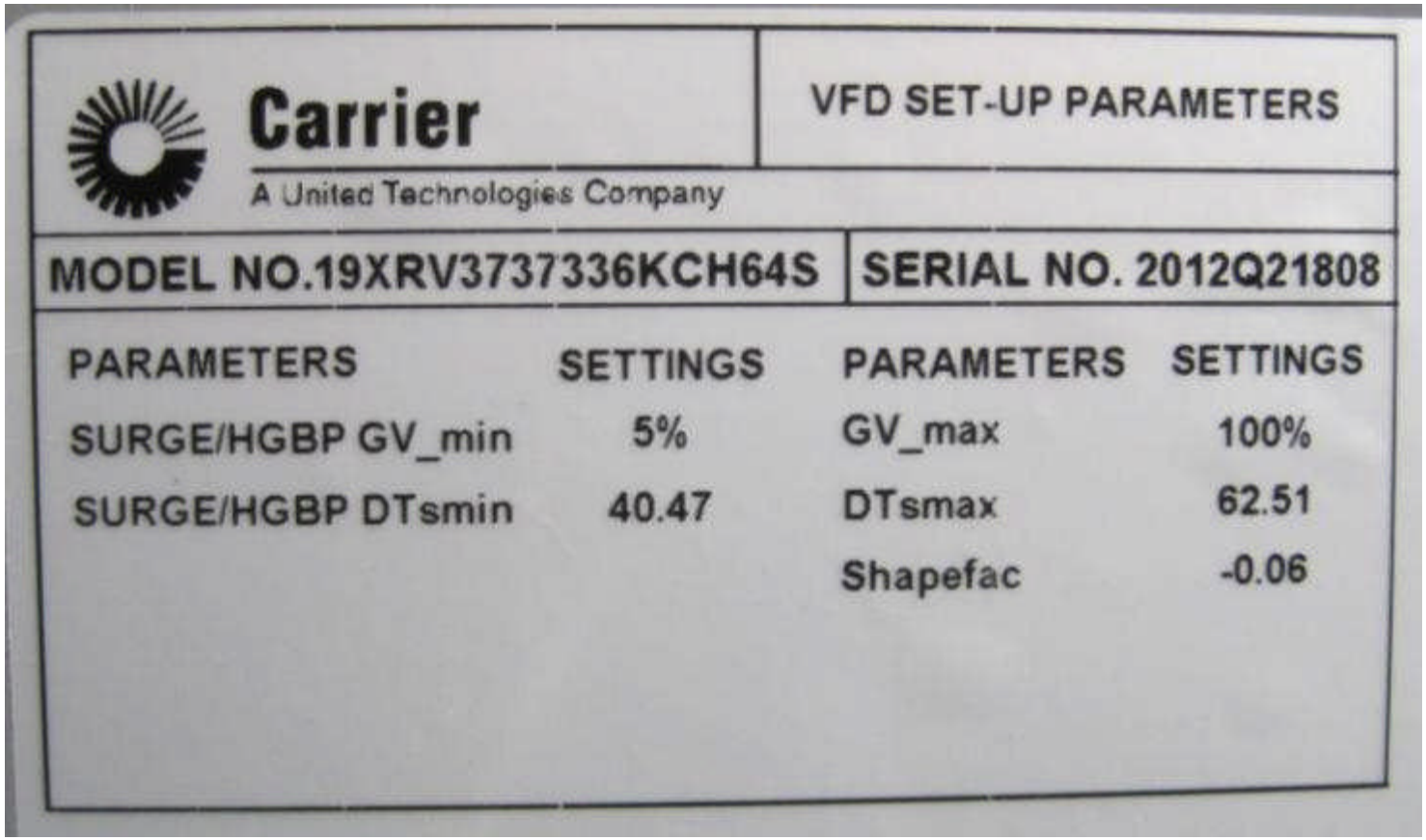
Older Version Software	New Variable Primary Flow
Delta T across evaporator	Guide vane position
Delta P between cooler and condenser	Delta P between cooler and condenser
Last revision CESR131294-07 (PIC II), CESR131350-03 (PIC III)	Latest revision CESR131294-10 (PIC II), CESR131350-04 (Pic III)





XRV CAPACITY & SURGE PREV CONTROL

Variable Primary Flow Software



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VFD SET-UP PARAMETERS

MODEL NO.19XRV3737336KCH64S | SERIAL NO. 2012Q21808

PARAMETERS	SETTINGS	PARAMETERS	SETTINGS
SURGE/HGBP GV_min	5%	GV_max	100%
SURGE/HGBP DTsmin	40.47	DTsmax	62.51
		Shapefac	-0.06

XRV CAPACITY & SURGE PREV CONTROL

Variable Primary Flow Software

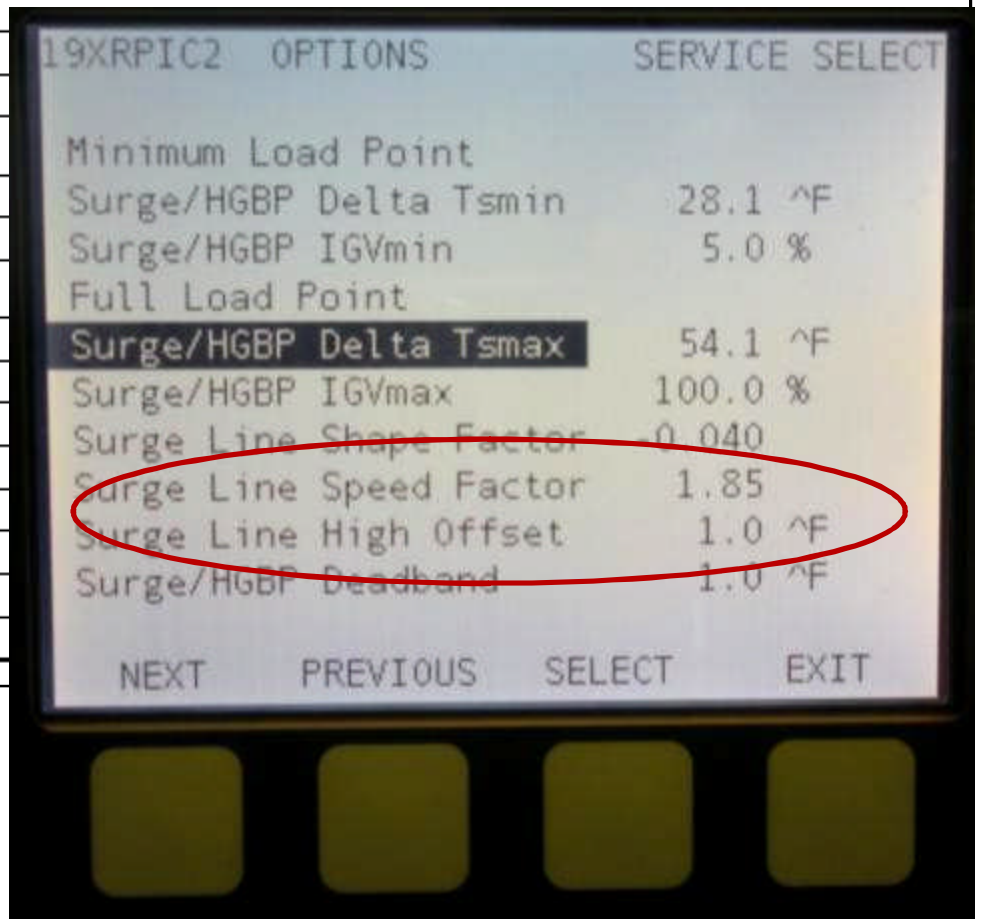
Carrier

Evergreen Chiller Performance Outputs

Project Name: heifer
Sales Office: Dallas TX

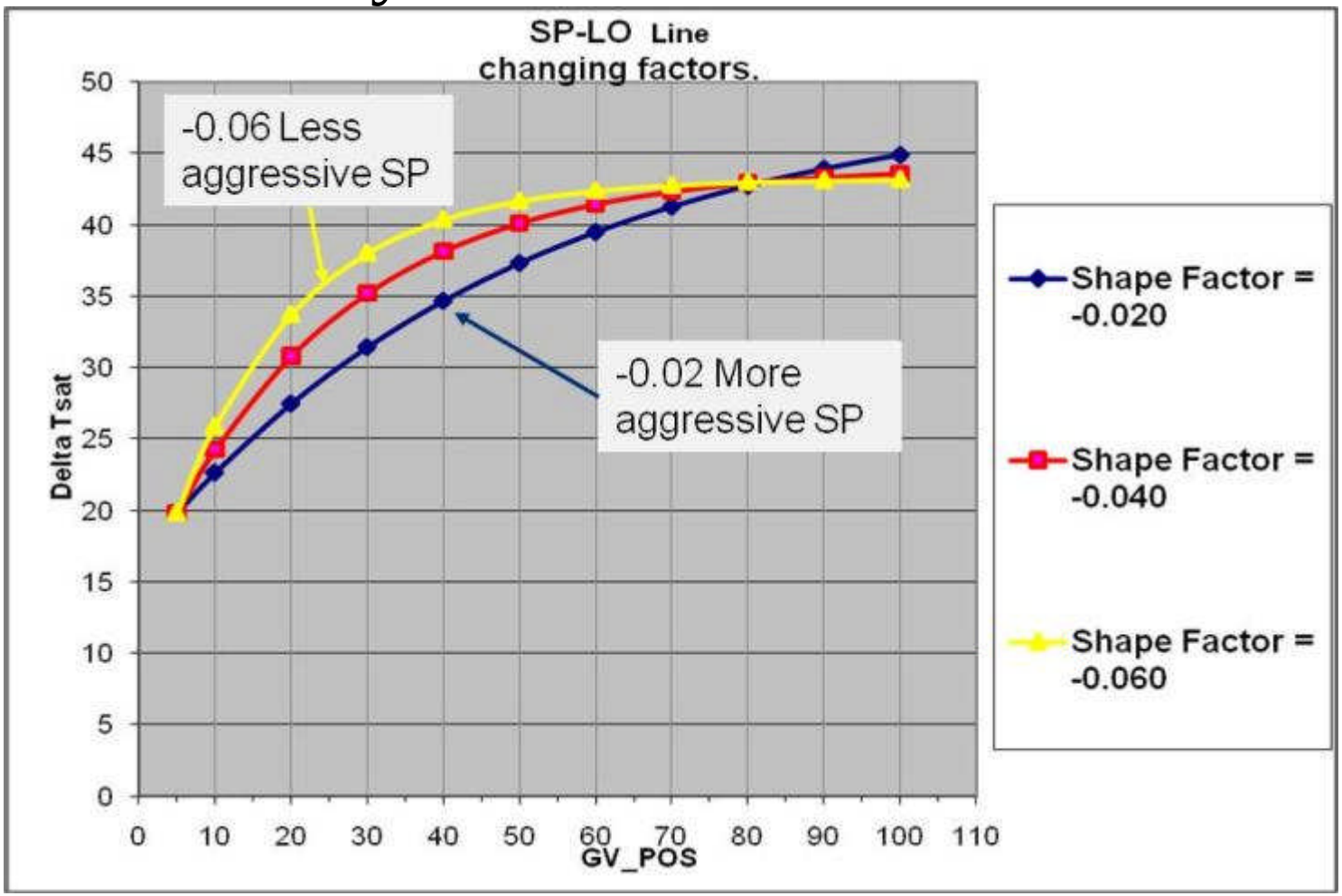
08/11/2010
05:05 PM

Control Parameters		
Surge/HGBP GVmin	5%	
Surge/HGBP Delta Tsmin	28.11 °F	
Surge Line Shape Factor	-0.04	
Surge/HGBP GVmax	100%	
Surge/HGBP Delta Tsmax	54.10 °F	
Cooler Min DP	2.4 psi	
Condenser Min DP	2.2 psi	
Heat Exchangers		
Condensing Temp	95.47 °F	94.31 °F
Cooler Wall Temp	43.64 °F	43.67 °F
Suction Temp	43.44 °F	43.48 °F
Cooler Freeze Temp	32.40 °F	
Cooler Tube Vel	3.24 ft/s	3.24 ft/s
Cond Tube Vel	5.84 ft/s	5.84 ft/s



XRV CAPACITY & SURGE PREV CONTROL

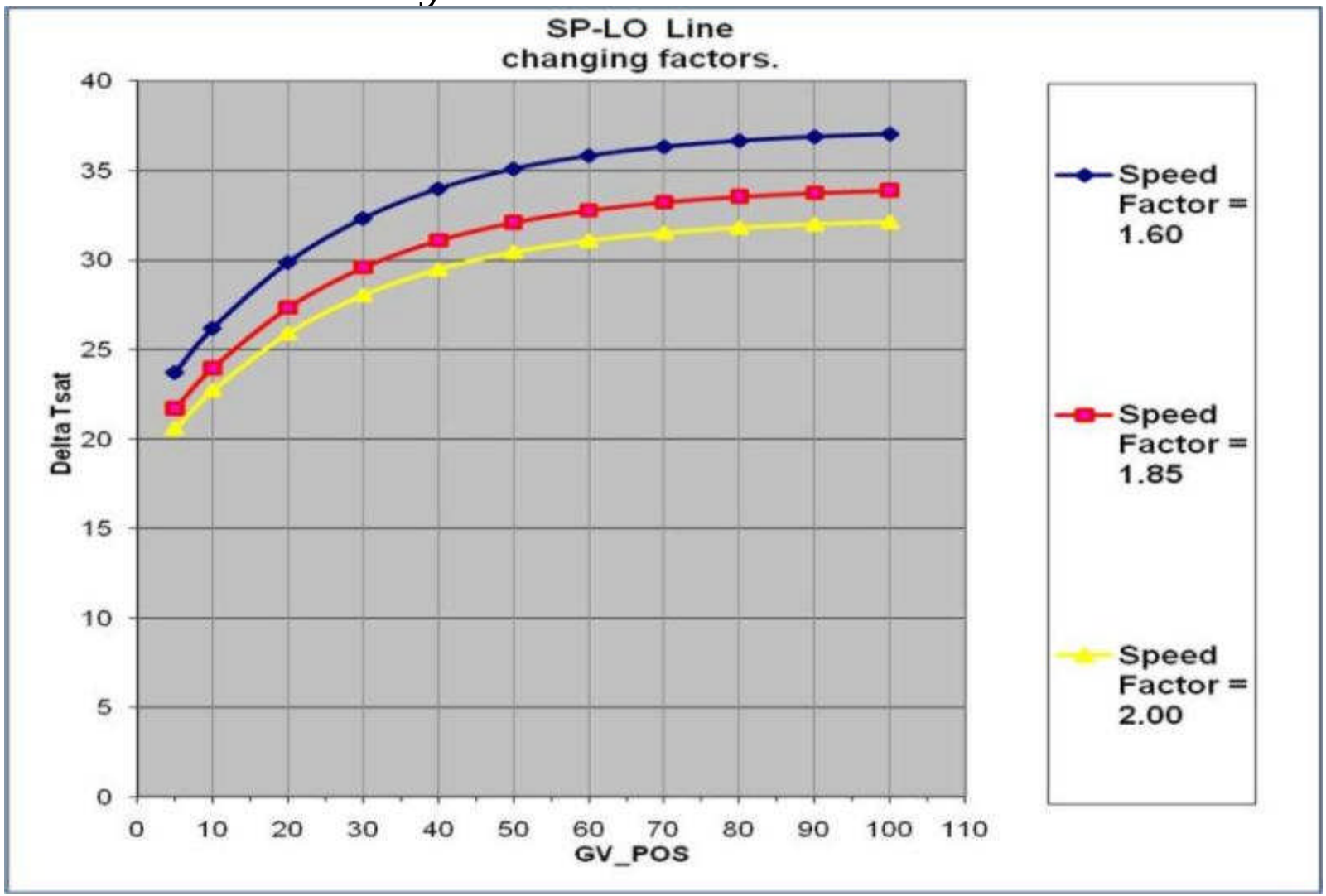
Variable Primary Flow Software



Lowering the shape factor from -0.020 to -0.060 will increase the bend of the surge line. Hence, higher shape factor (-0.020) means more aggressive surge protection.
Note: -0.020 is larger than -0.060

XRV CAPACITY & SURGE PREV CONTROL

Variable Primary Flow Software



Speed factor shifts the entire curve

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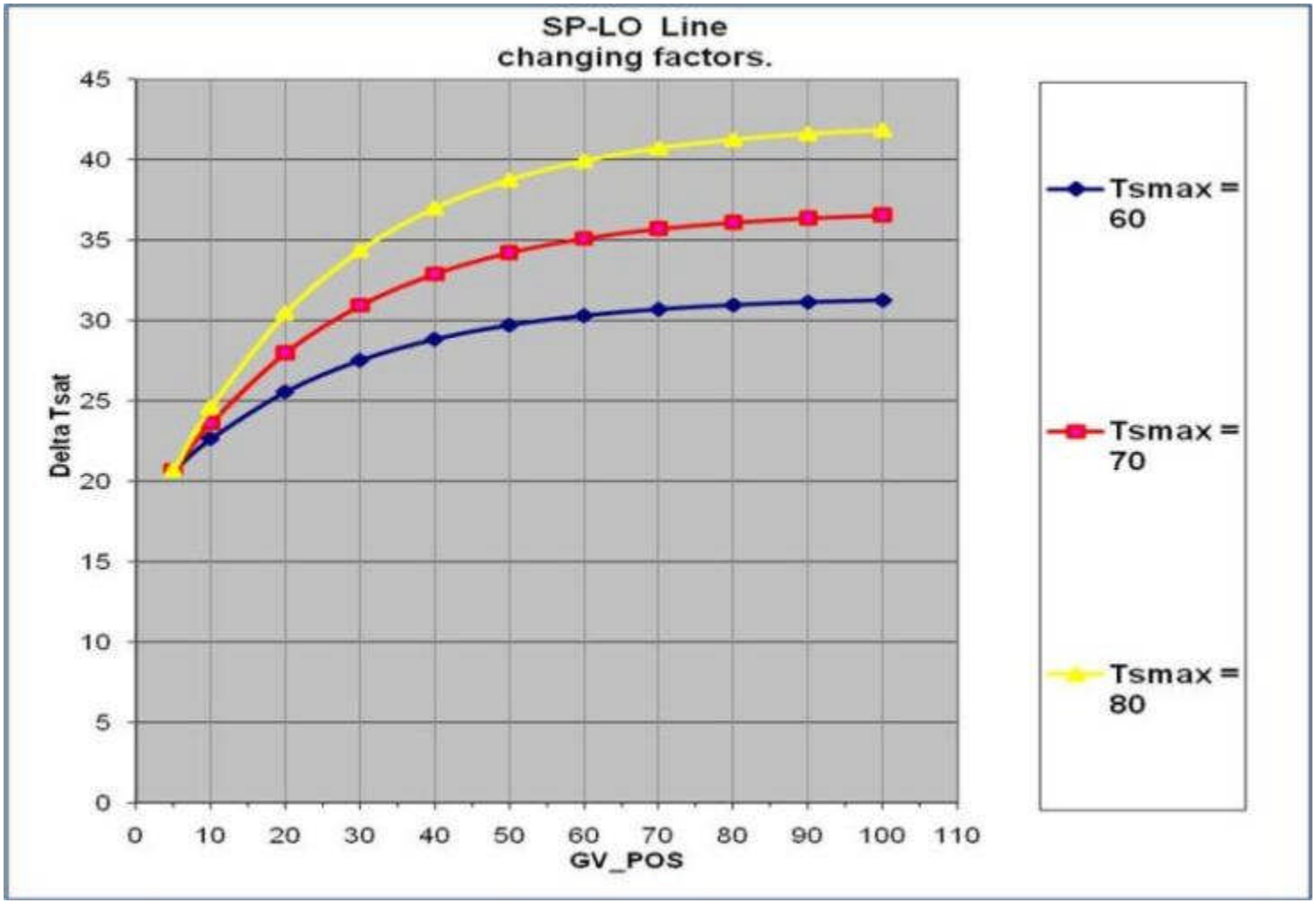
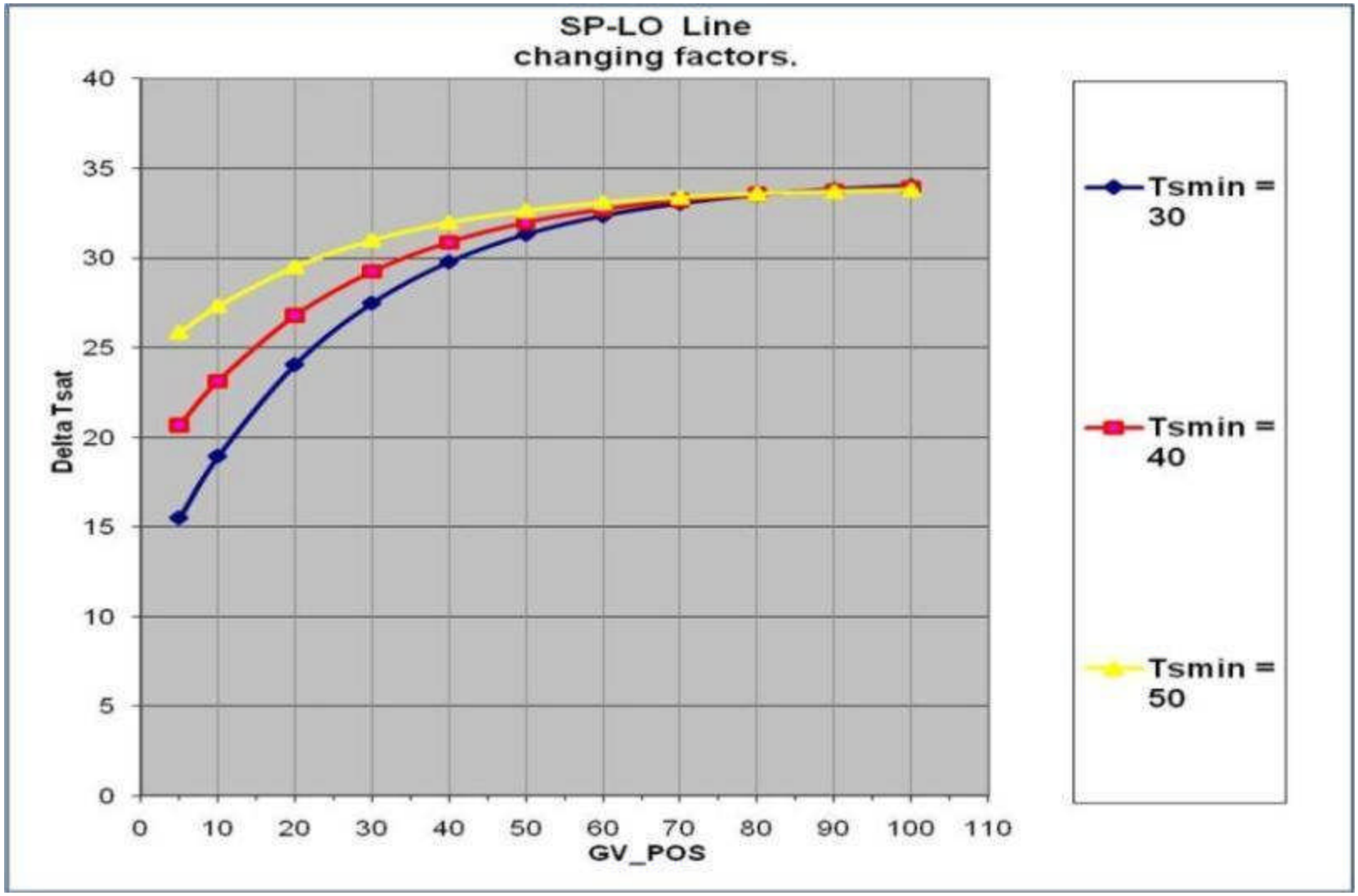
Variable Primary Flow Software



Changing the Tsmax value changes the points at full load

XRV CAPACITY & SURGE PREV CONTROL

Variable Primary Flow Software

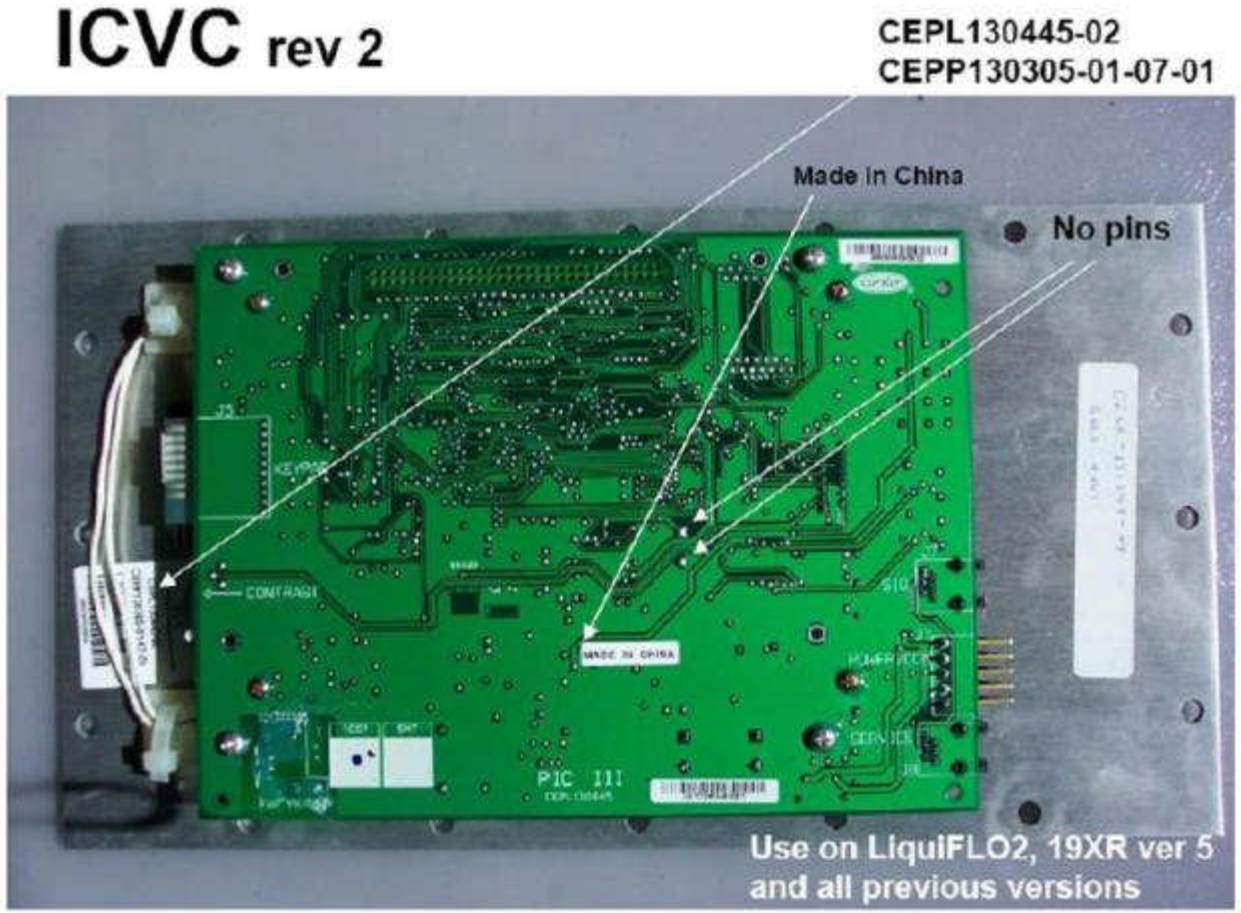


Changing the Tsmin value changes the points at low load

XRV CAPACITY & SURGE PREV CONTROL

Variable Primary Flow Software

Do not install 19XRV LF2 (131350-04) VPF software on ICVC hardware version #2, Made in China. Screen freezes and do not update
VPF software will work with ICVC hardware version #3R



XRV CAPACITY & SURGE PREV CONTROL

Variable Primary Flow Software

Table 19 — ICVC Hardware/Software Compatibility

ICVC HARDWARE PART NO.	VERSION	COMPATIBLE ICVC SOFTWARE
CEPL130445-01	1	19XR/XRV PIC II Versions 1-4*
CEPL130445-02	2	19XR/XRV PIC II Versions 1-9 19XRV PIC III Versions 1-3 23XRV PIC III Versions 1 and 2
CEPL130445-03	3	19XR/XRV PIC II Versions 8 and 9 19XRV PIC III Versions 3 and 4 23XRV PIC III Version 2

*Inadequate memory for Version 5 and higher.

NOTE: ICVC screen lockup reported on green ICVC with Made in China label while running version 4.

XRV CAPACITY & SURGE PREV CONTROL

Variable Primary Flow Software

Additional features for VPF software

- Surge Delta % Amps – 5~40%
- Added Thrust bearing temperature fault and settings (Service →Equipment service→Setup1)
- Daylight savings date changes
- Hot gas bypass relay will not energize during ramp loading