A FUNDAMENTAL PERSPECTIVE
on
CHILLED WATER SYSTEMS

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Fundamental Parameter

Performance

Examples of Other Parameters

- Financial
  - Cost (Investment)
  - Operating Cost
  - Maintenance & Repair
  - Energy
- Reliability
- Serviceability
- Energy Consumption
- Power consumption
- Environmental
  - Refrigerants
  - Water Use
  - Chemicals
- Flexibility
- Expandability
- Adaptability

Nature of Loads

1. Single Cooling Coil for Human Comfort (HC)
2. Multiple Coils (HC), Simultaneous Loading
3. Multiple Coils (HC), Non-simultaneous Loading
4. Multiple Coils, Some HC, Some Process Loads
5. Process Loads, Similar Requirements
6. Process Loads, Dissimilar Requirements
7. Any Combination of the Above

First Law

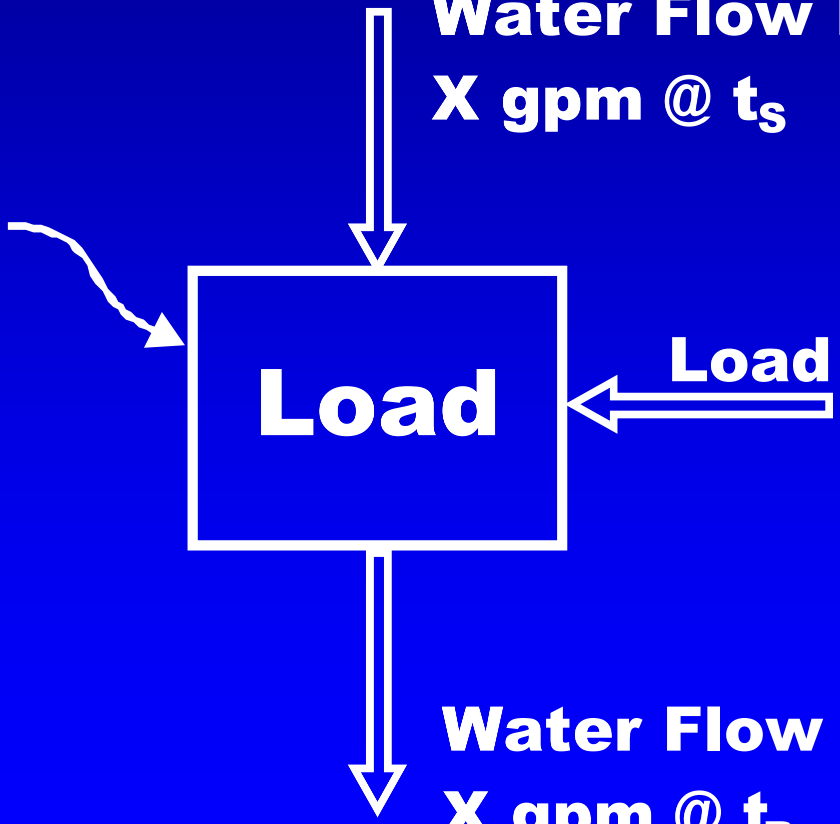
Heat Capacity Equation

$q = mC\,\Delta t$ Btu/hr

For Chilled Water

$Q = GPM\,(500)(t_r - t_s)$ Btu/hr

Energy Flow Diagram For Load System



Water Flow In

X gpm @ t_S

Boundary

Load

Load Heat In

q_L

Water Flow Out

X gpm @ t_R

Independent Variable q_L

Dependent Variables

GPM

t_S

t_R

$$q_L = GPM\ (500)\ (t_R - t_S)$$

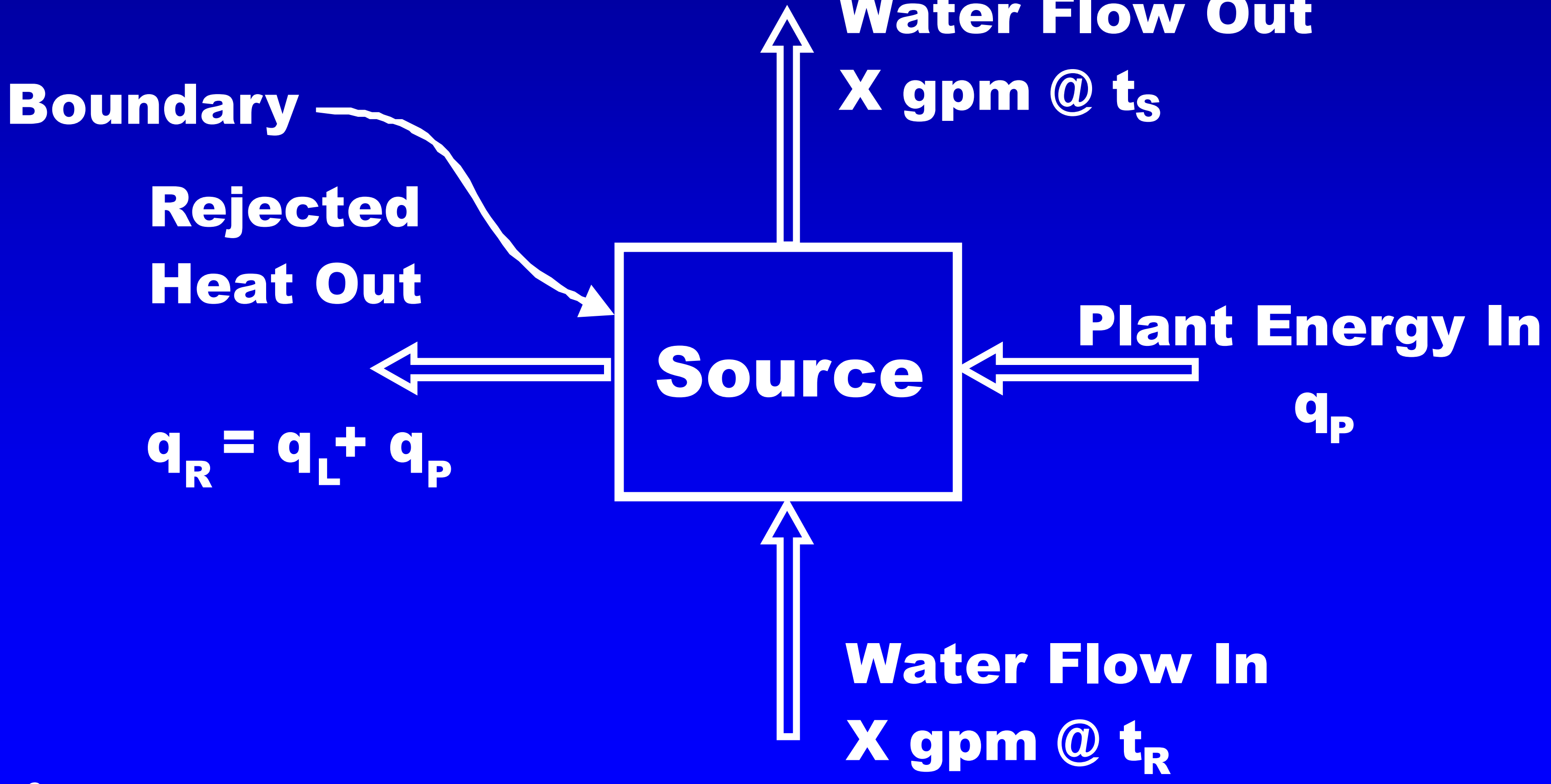
To Obtain Maximum Humidity Control

~ Constant t_S

To Obtain Maximum Chiller Benefit

~ Constant t_R

Energy Flow Diagram
For Source System



Water Flow Out

X gpm @ t_S

Boundary

Rejected

Heat Out

Source

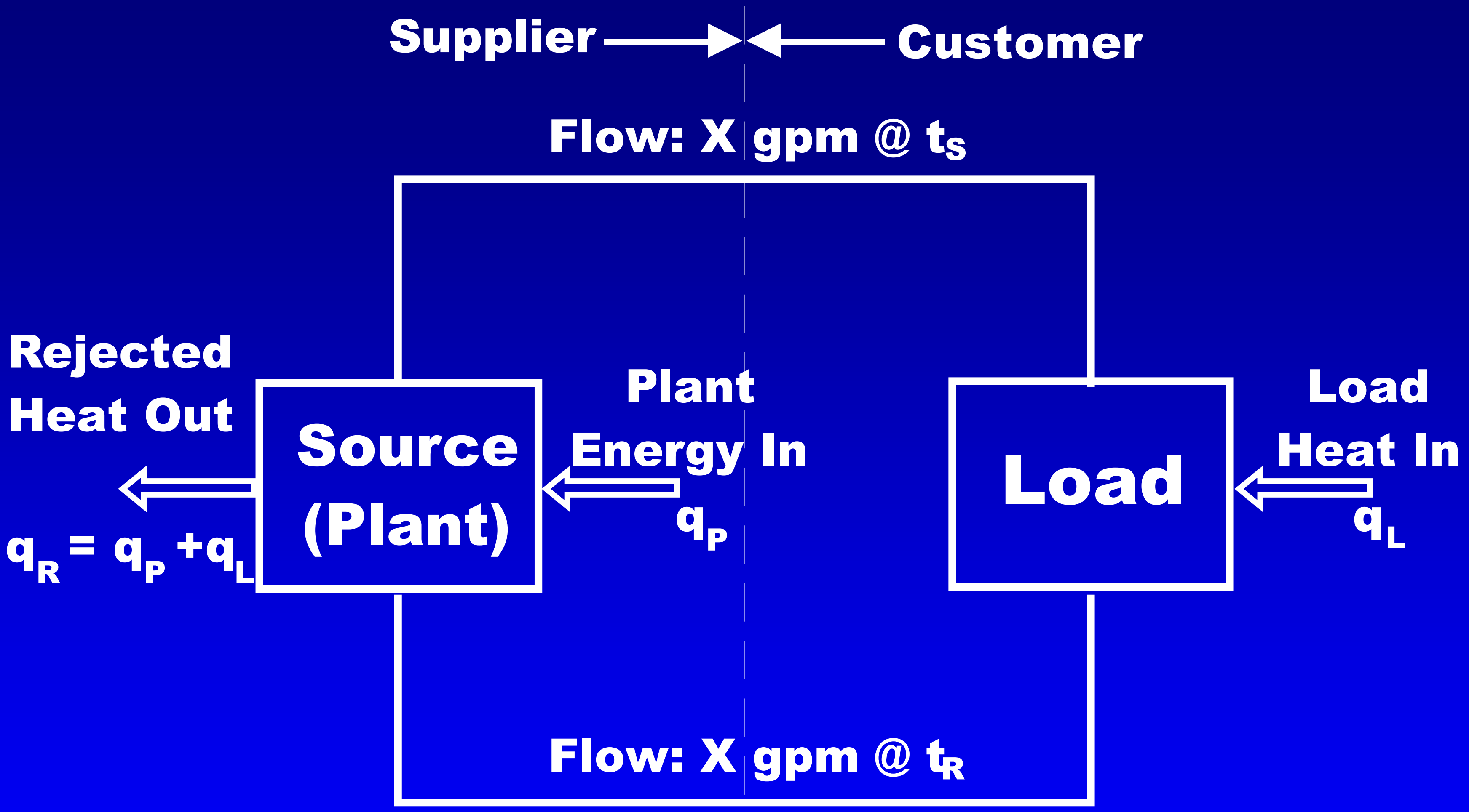
Plant Energy In

q_P

$q_R = q_L + q_P$

Water Flow In

X gpm @ t_R



Supplier → ← Customer

Flow: X gpm @ t_S

Rejected Heat Out

Source (Plant)

Plant Energy In q_P

Load

Load Heat In q_L

$q_R = q_P + q_L$

Flow: X gpm @ t_R

$t_R > t_S$

t_R is the highest temperature in the system

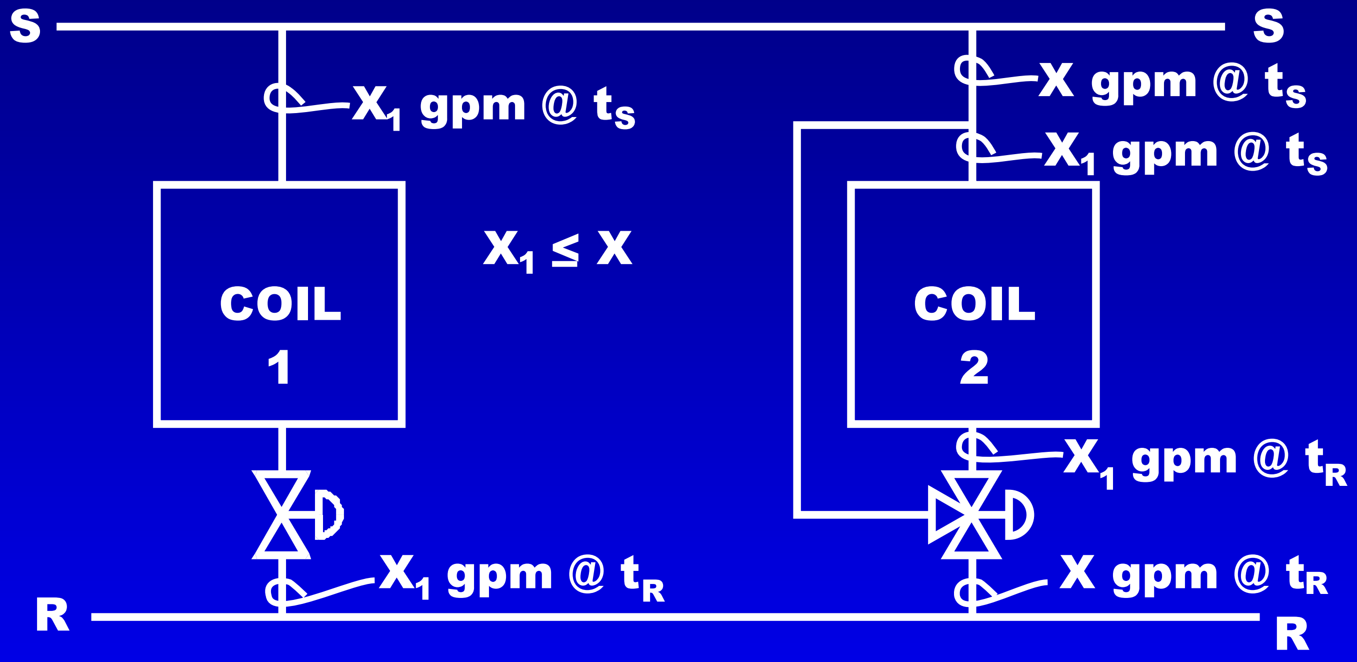
$$q_L = GPM\ (500)\ (t_R - t_S)$$

If Load wants constant t_S

Plant wants constant t_R

Only option is to vary the GPM

Load Control Options



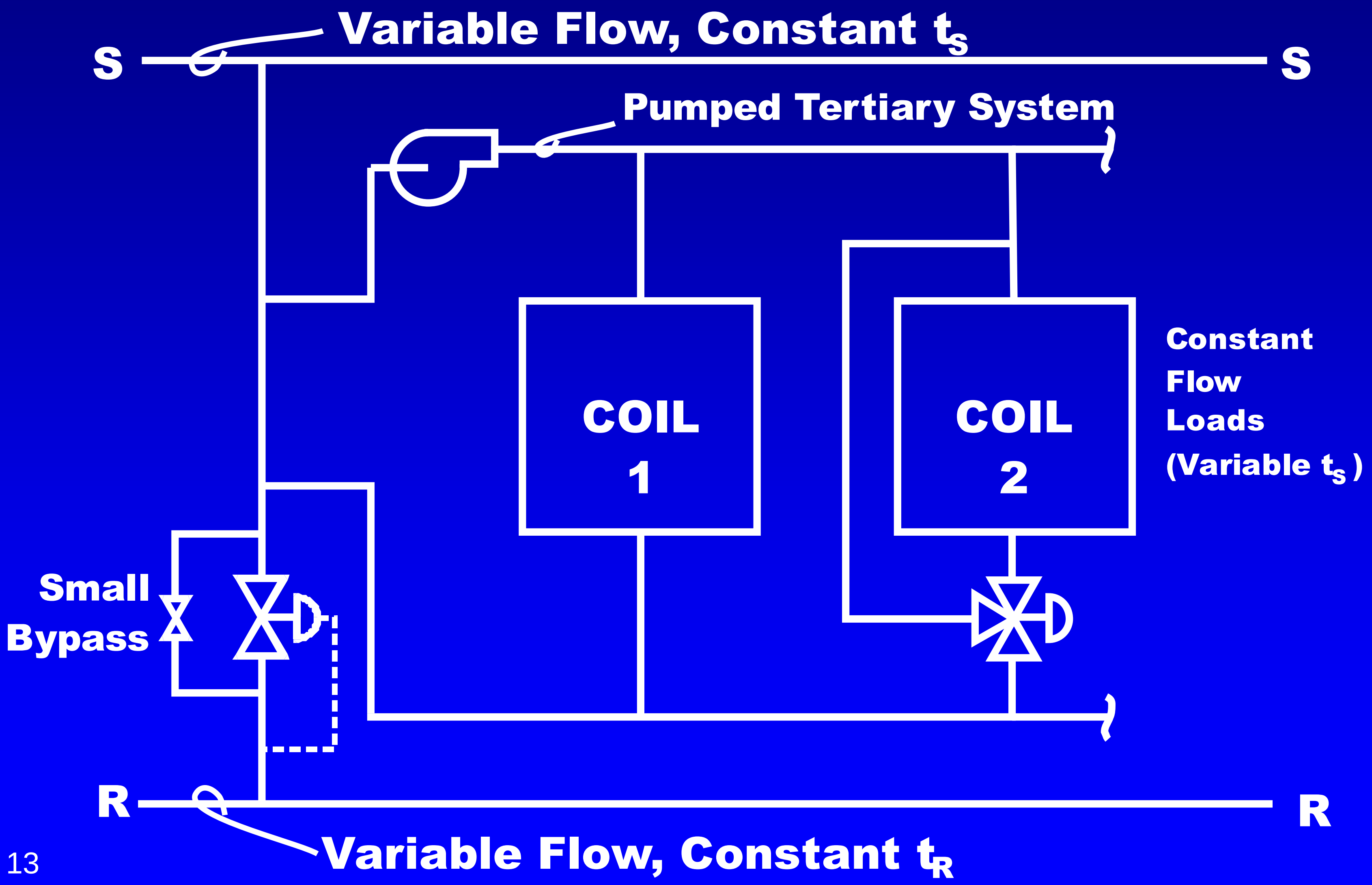
$$q = \underbrace{GPM}_{\text{variable}}\ 500\ (t_R - t_S)$$

$$q = GPM\ 500\ \underbrace{(t_R - t_S)}_{\text{variable}}$$

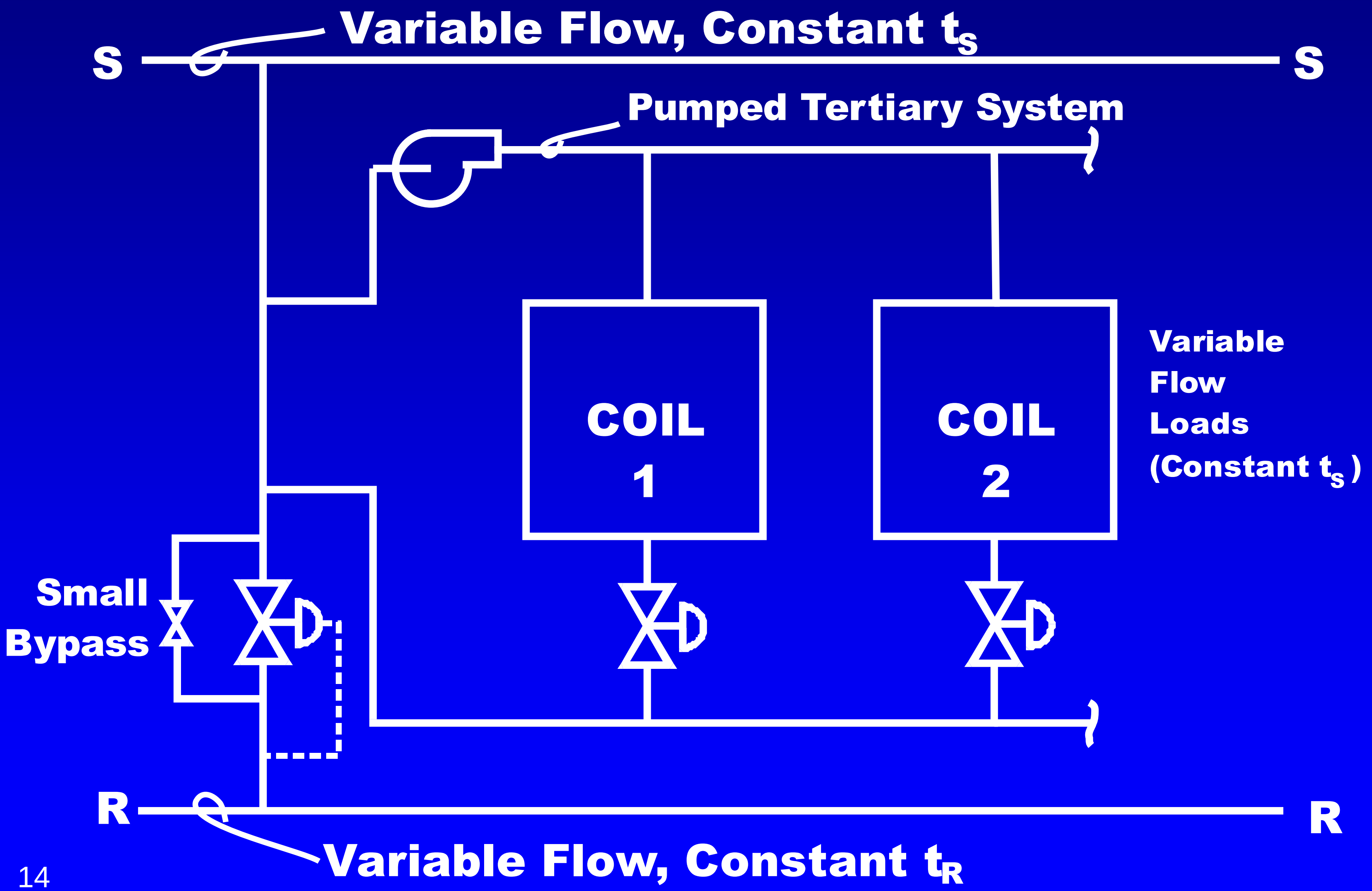
Variable Flow in Load
Variable Flow in System
Constant t_S and t_R

Variable Flow in Load
Constant Flow in System
Constant t_S
Variable t_R

Constant Flow Loads
Variable Flow System



Multiple Variable Flow Loads



S

Variable Flow, Constant t_S

S

Pumped Tertiary System

COIL 1

COIL 2

Variable Flow Loads (Constant t_S)

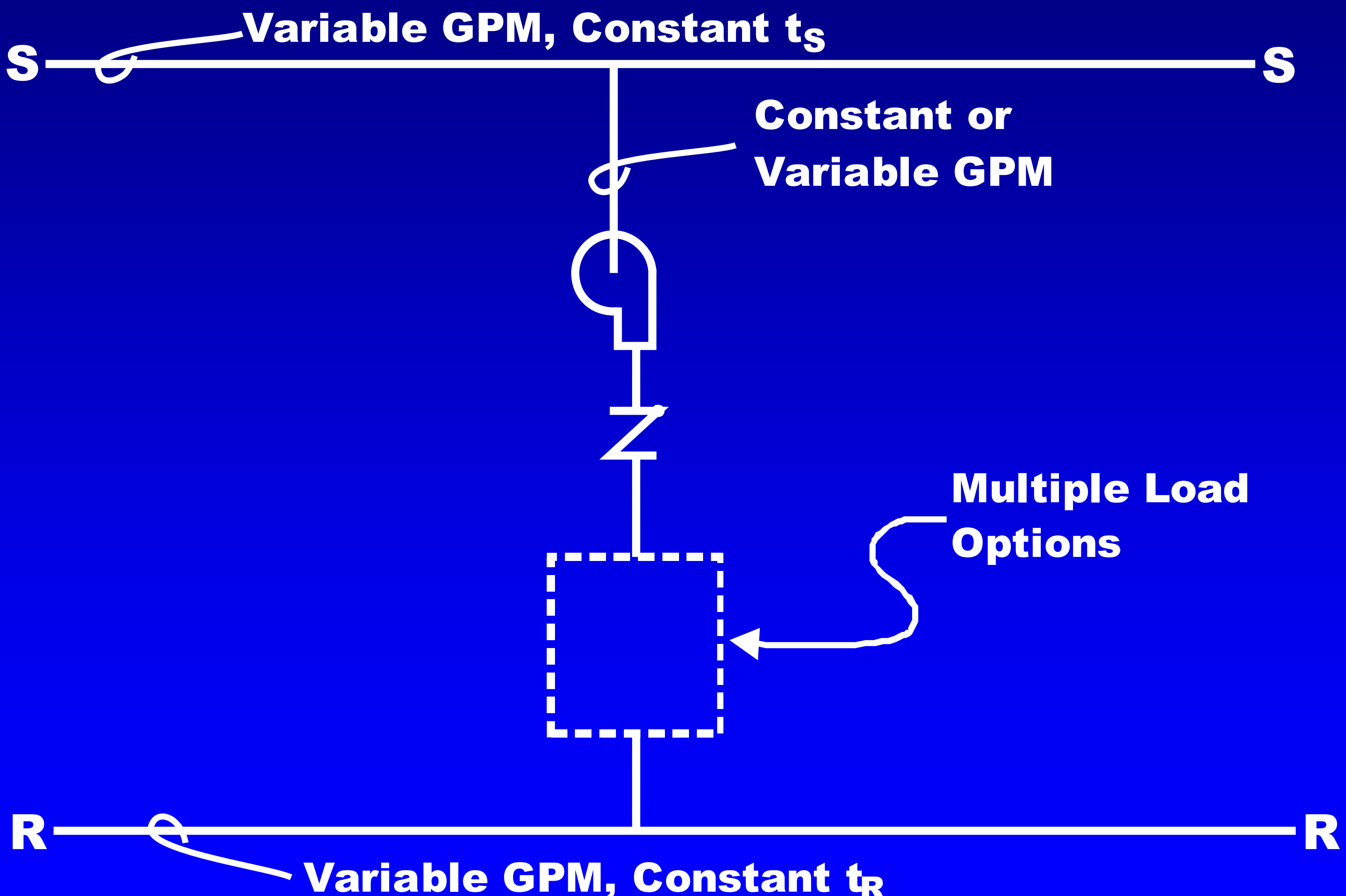
Small Bypass

R

R

Variable Flow, Constant t_R

Distributed Pumping



S

S

Variable GPM, Constant t_S

Constant or Variable GPM

Multiple Load Options

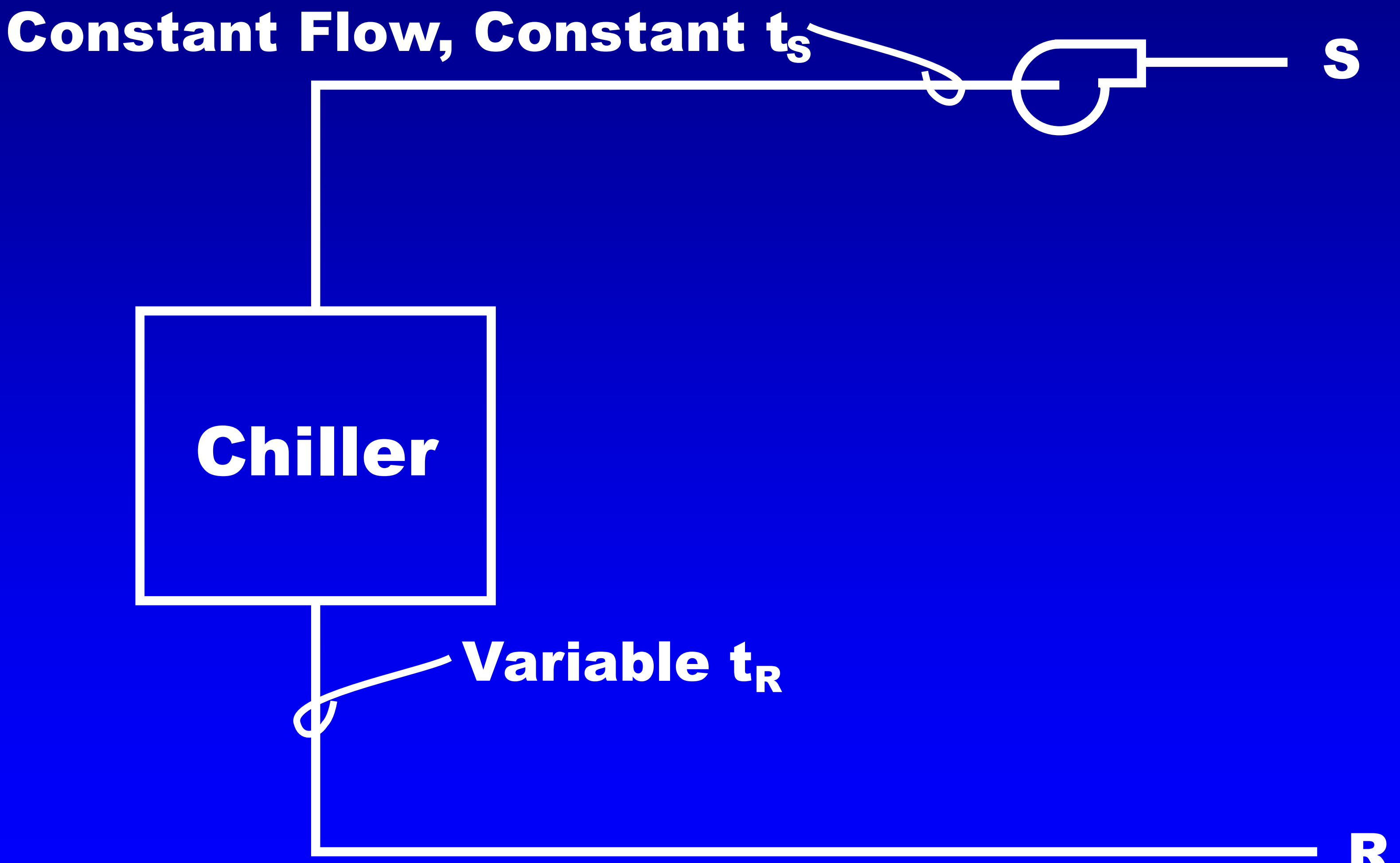
R

R

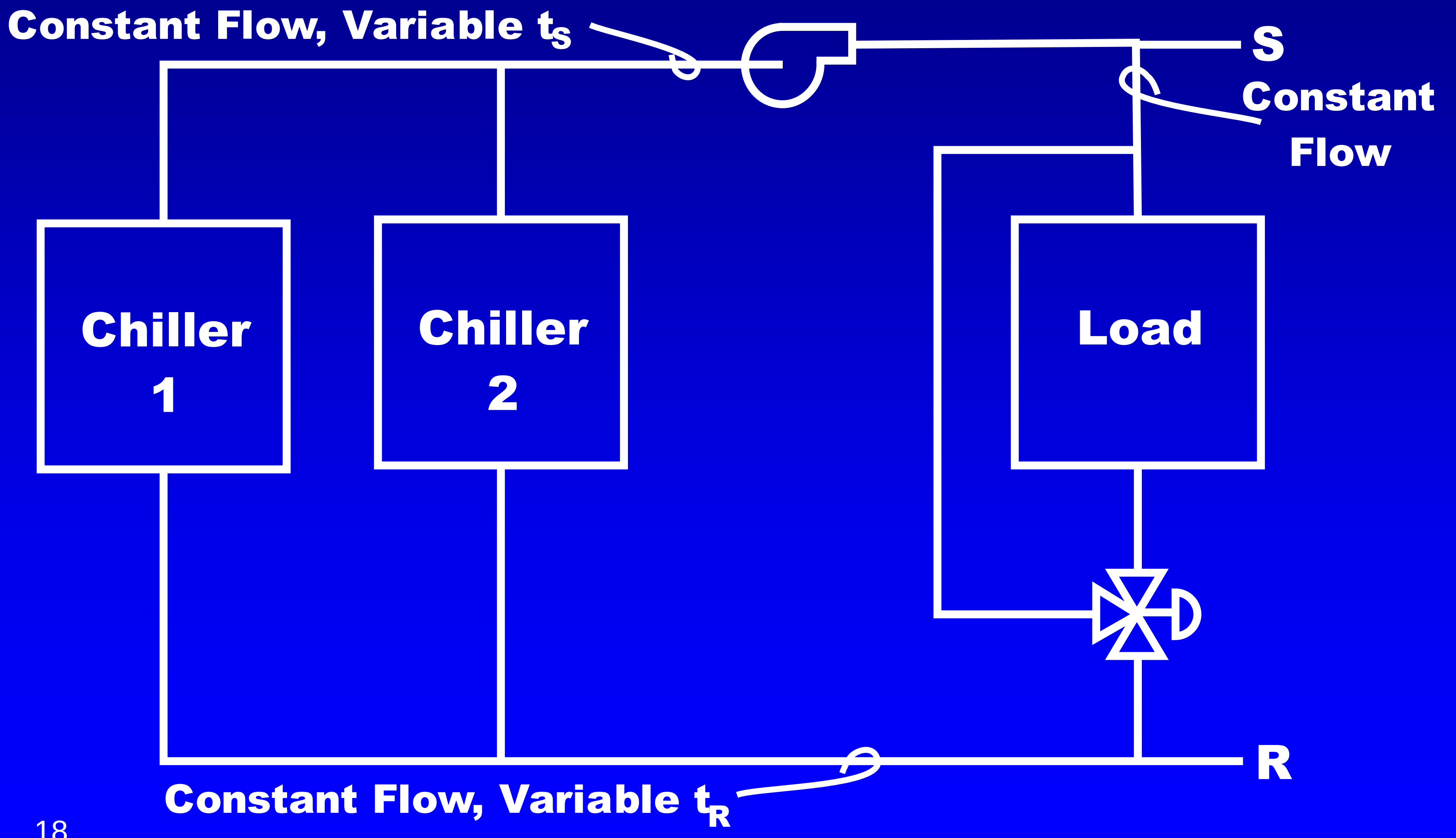
Variable GPM, Constant t_R

1. The water entering the chillers can never be warmer than the water entering the plant.
2. The water entering the plant can never be warmer than the weighted average leaving the loads.
3. The load on the plant is equal to the product of the flow leaving the plant, the Δt and the appropriate constant.

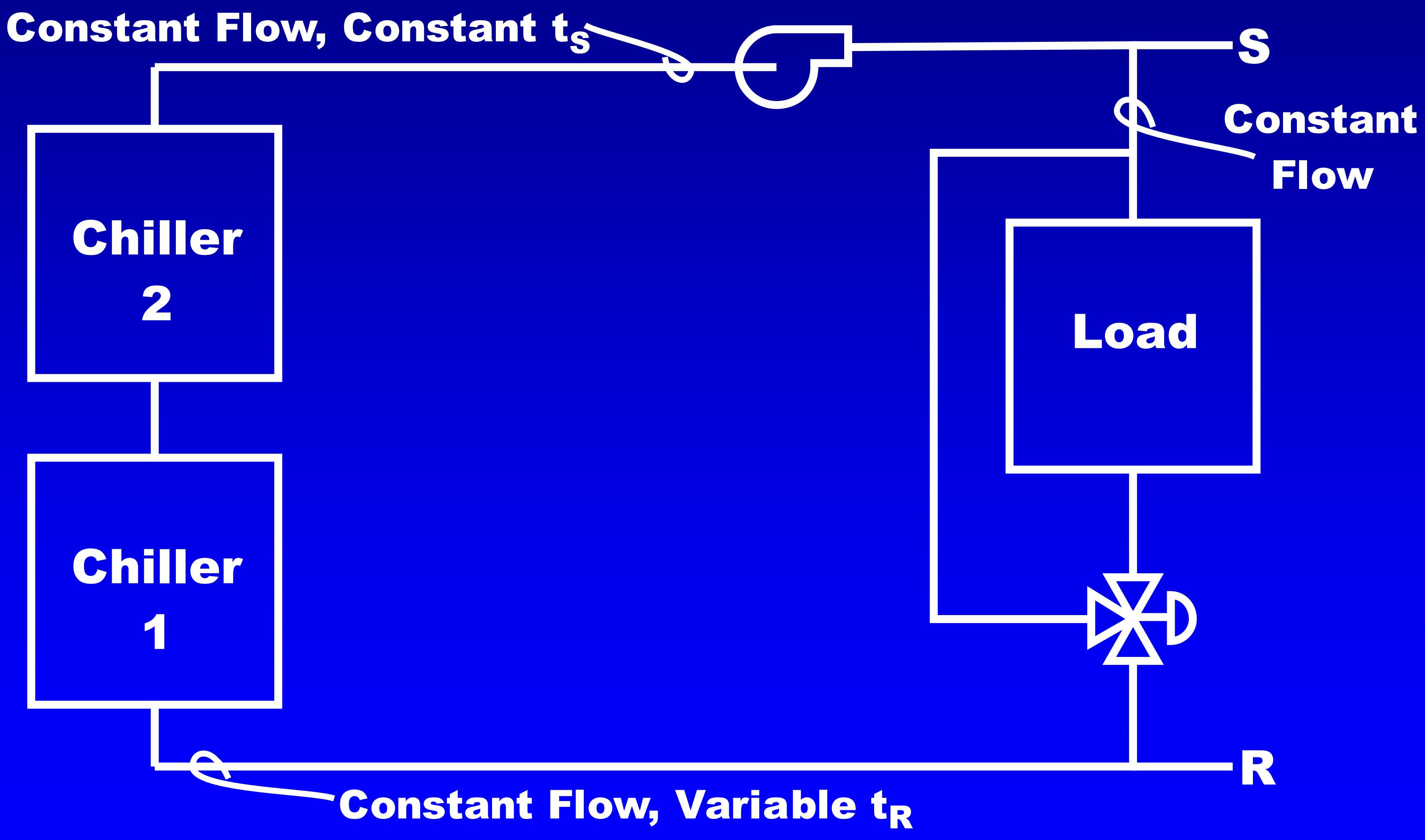
Single Chiller Plant



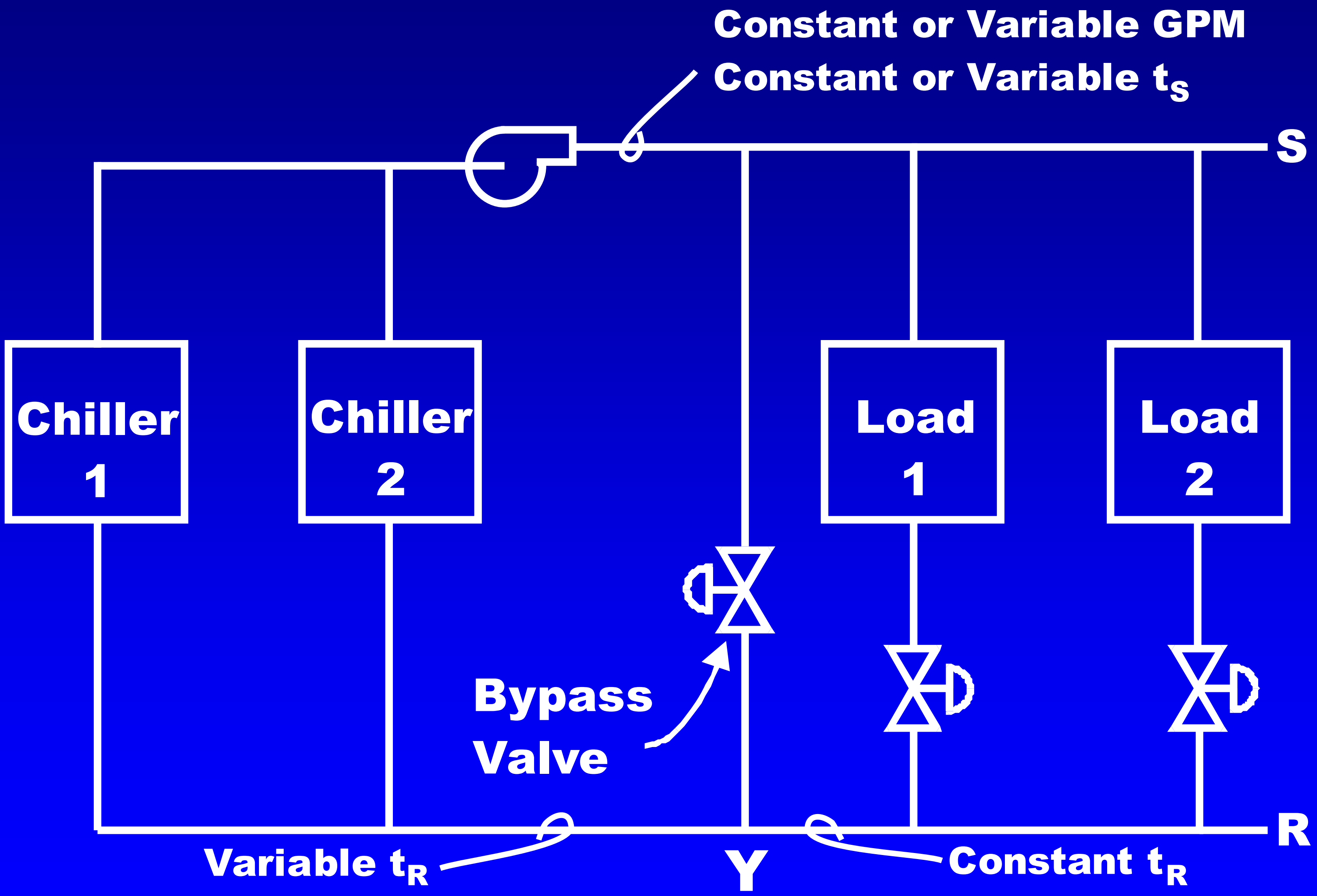
Multiple Chiller Plant
Parallel Chillers



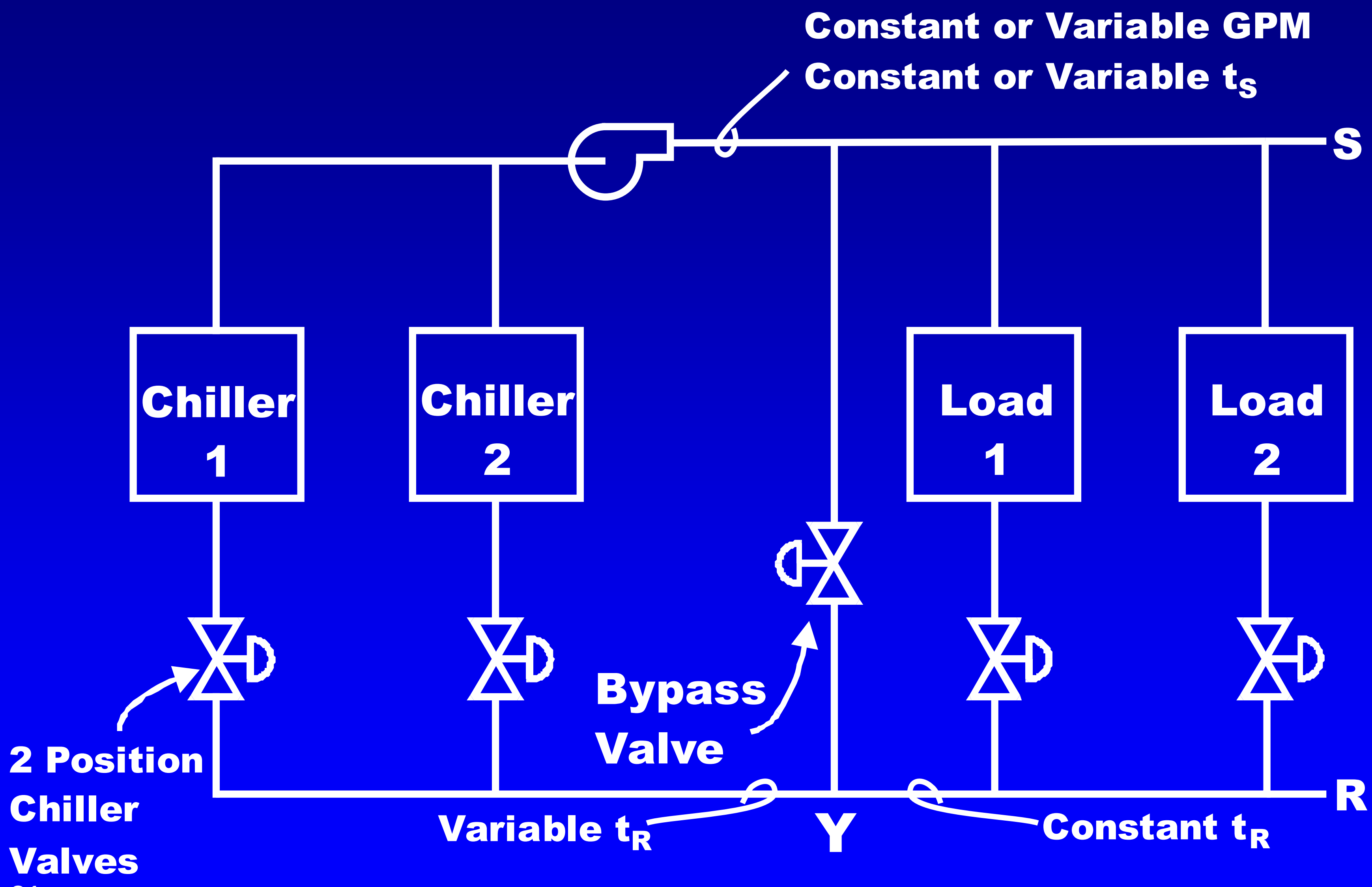
Multiple Chiller Plant
Series Chillers



Other Multiple Chiller Plants (1)



Other Multiple Chiller Plants (2)



Constant or Variable GPM

Constant or Variable t_S

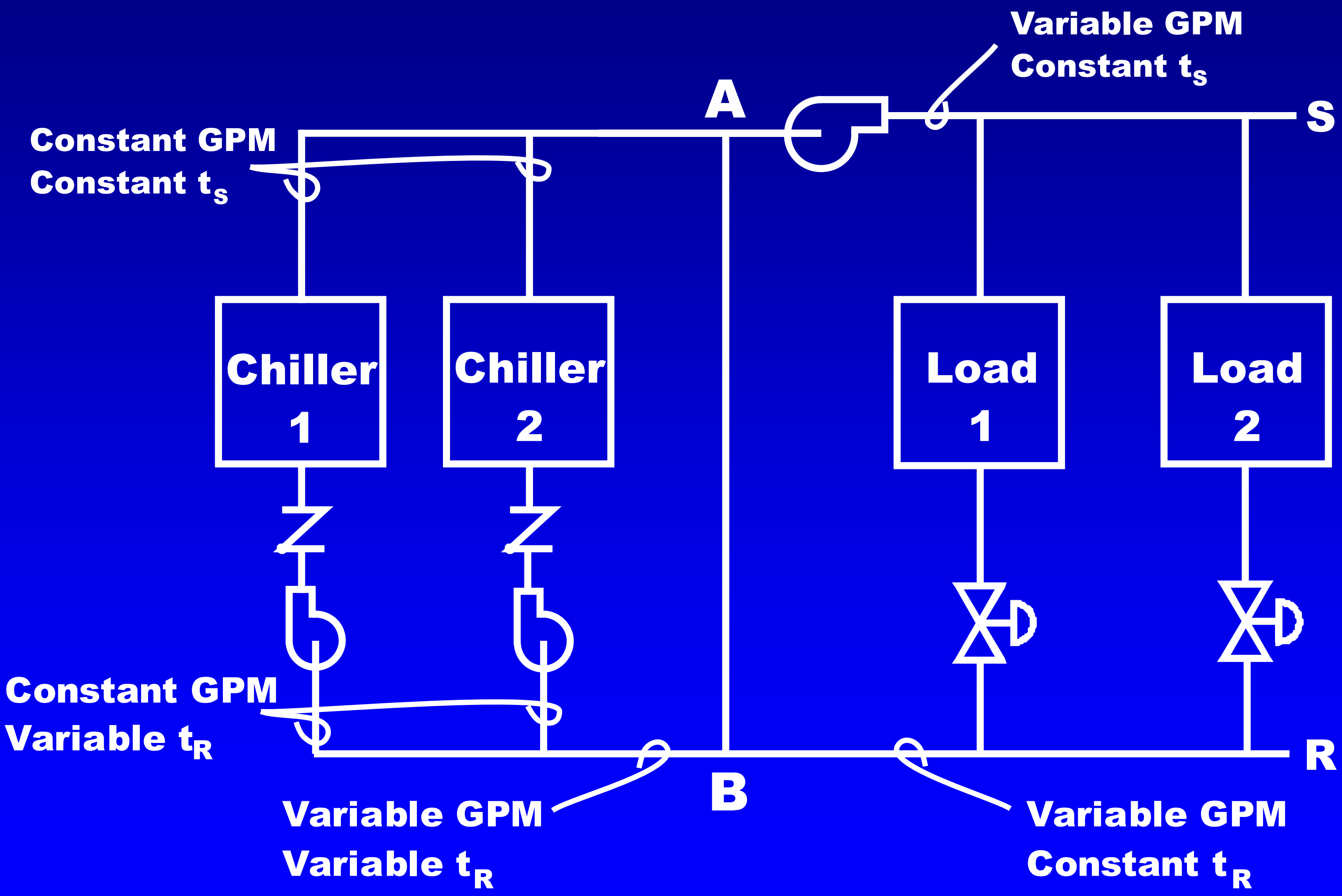
Bypass Valve

2 Position Chiller Valves

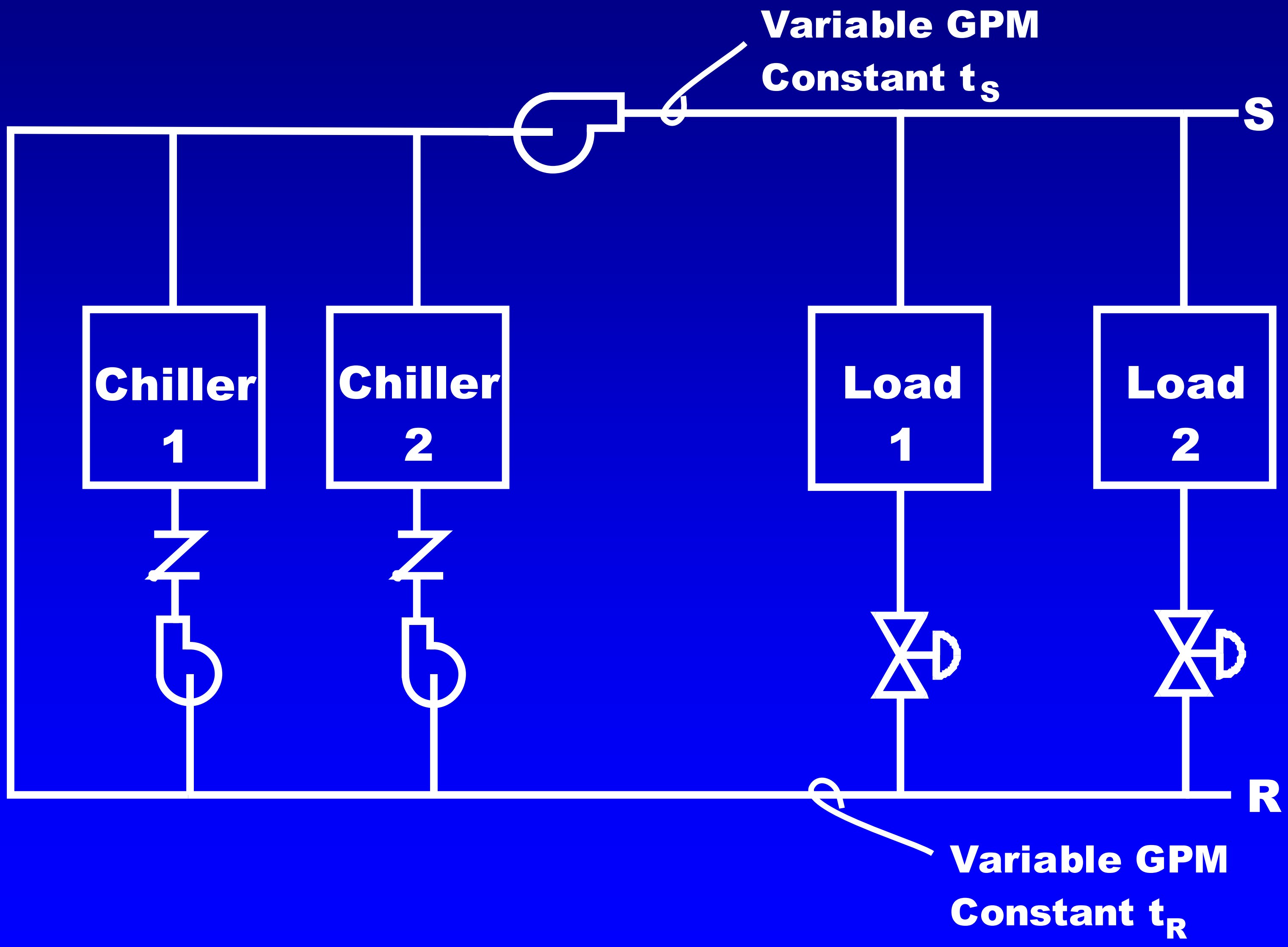
Variable t_R

Constant t_R

Multiple Chiller Plant
Compound Piping Equal Unloading



Multiple Chiller Plant
Compound Piping Sequence Unloading



1. Identify the types of loads to be served.
2. Design the load connections to receive water at the temperature(s) supplied from the plant and return water at the temperature required by the plant.
3. Design the plant to operate in harmony with the load requirements.
4. Keep all design concepts and algorithms as simple and understandable as possible.

The dynamics of the load and the source are intrinsically interdependent, thermally and hydraulically, and the failure of any component to perform as designed cannot be accommodated by adding complexity to the other components.