냉난방 수배관의
Energy ICT Solution

공학박사/대표 박동일

CONTENTS

- 세계 에너지소모 동향
- 온실가스 & 에너지 감축 제안
- Hydronic Engineering
- 에너지 ICT Solution
- Coil. Control V/V. BAS
- Control Valve의 Authority
- 적용 사례

Energy ICT Solution

Hydronic engineering for HVAC System

에너지 소모량

전세계 에너지 소비의 40%가 빌딩에서 사용

> USD 1.28 tri

그중 50%가 HVAC 시스템에서 사용

> USD 640 bil

HVAC 시스템 효율
30% 이상 향상

> USD 192 bil

(*) Sources: European Commission EPBD (point 6, pp1) & US Department of Energy's "Buildings Energy Data Book"

에너지 30% 절감 제안

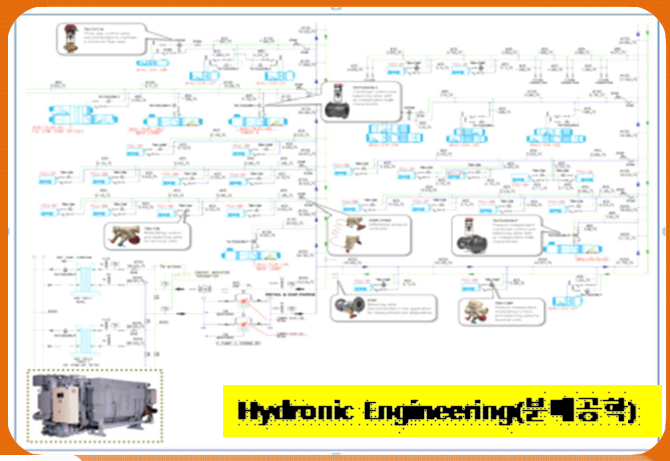
- 실내온도 편차를 ±0.5℃ 로 유지(Modulating Control)
- Max Pump Head를 20~30m 이내 유지
- 환수온도를 13~15 ℃ 이상으로 유지
- 과유량, 저유량 방지 (Any Load)
- 배관 최적화 설계를 위한 전산화 Program 사용
- 부분부하 운전시 수배관내 측정, 진단, 조정 T&C Report 제출 의무화

(*) ASHRAE Fundamental

Hydronic Engineering

열원을 설계 부하량으로 각 사용처에 공급

BEMS
측정,
분석,
지시,
기록



Hydronic Engineering(분배공학)

설계부하대로 부분부하시 최적의 유량을 제어
및 환수온도 △t 5℃ 이상 유지

EQM특성 Valve 사용
Control Valve Authority 0.25(Good) 이상
KVs 값을 조정 할 수 있는 Valve 적용
Control Valve Rangebility 100% 사용

열원 생산 : 냉수 7℃,

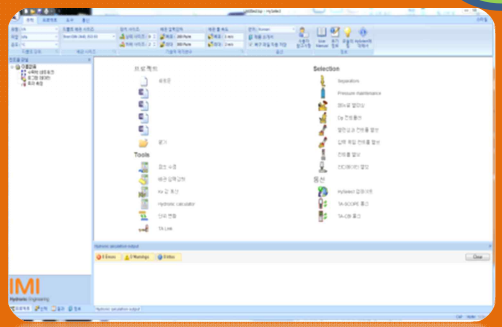
열원을 사용처까지 수송

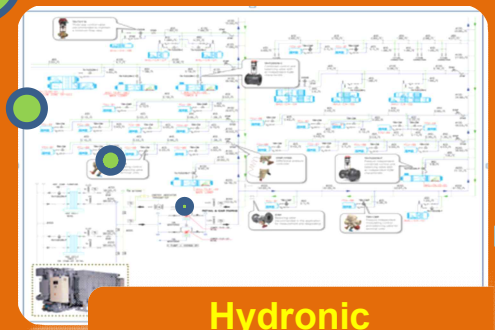
ICT Solution (B.M.W) 구성요소

Energy ICT Solution

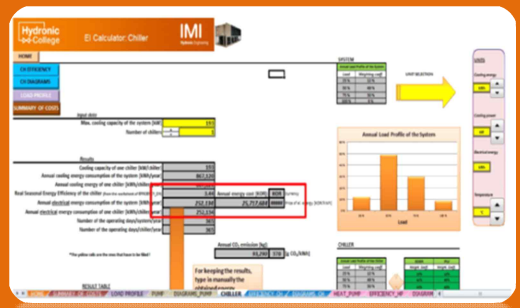
(B.M.W)

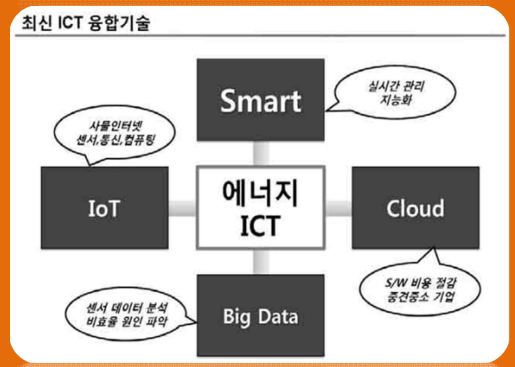
Why
ICT=B.M.W
Solution ?



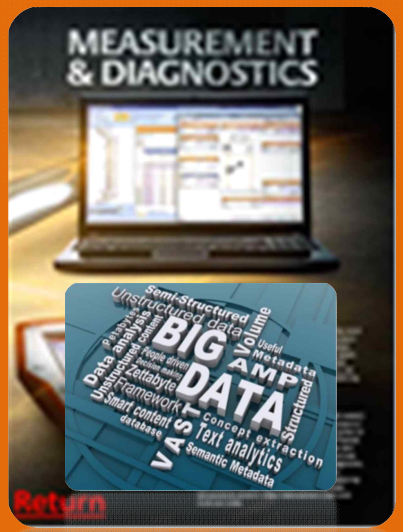


Hydronic engineering





Mobile

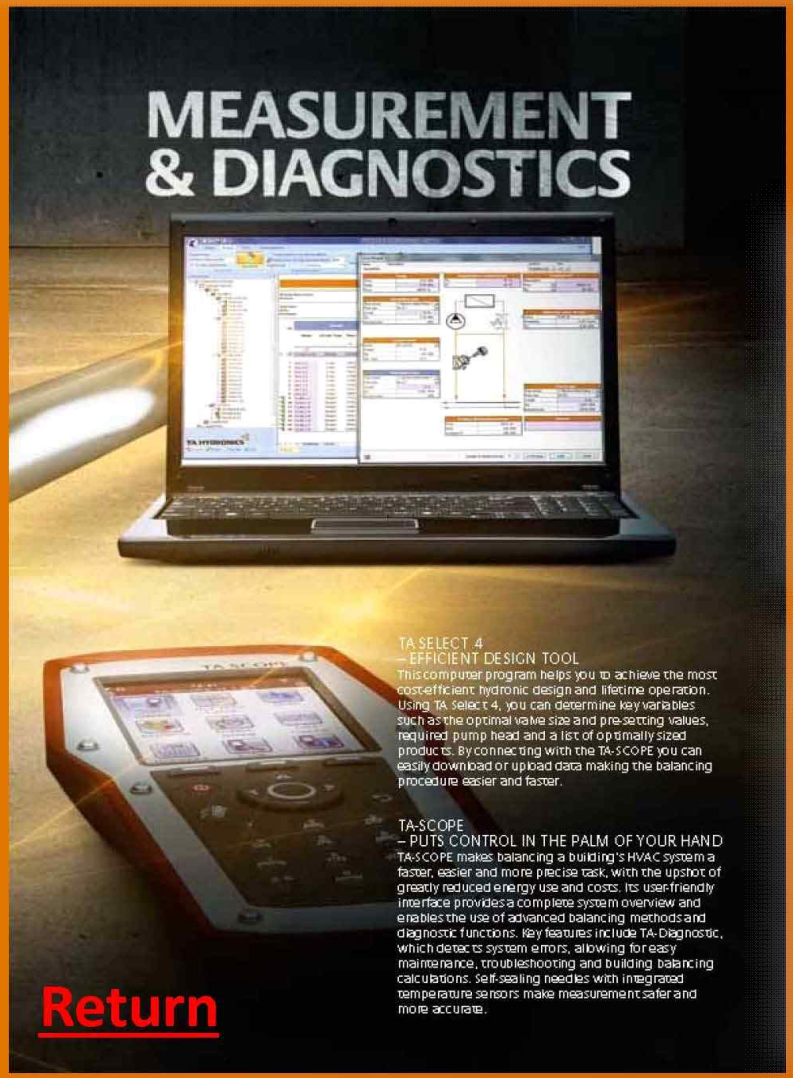


Big Data

Wareable

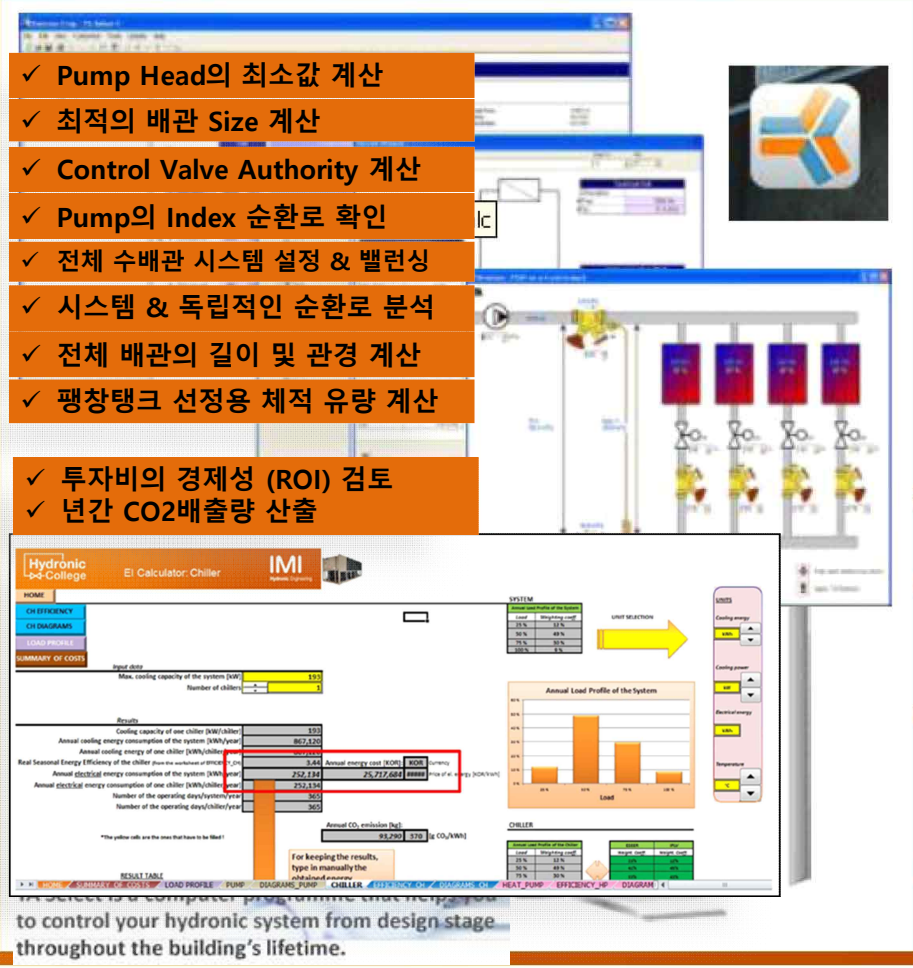
Hydronic Innovation Technology

Big Data-Program



- ✓ Pump Head의 최소값 계산
- ✓ 최적의 배관 Size 계산
- ✓ Control Valve Authority 계산
- ✓ Pump의 Index 순환로 확인
- ✓ 전체 수배관 시스템 설정 & 밸런싱
- ✓ 시스템 & 독립적인 순환로 분석
- ✓ 전체 배관의 길이 및 관경 계산
- ✓ 팽창탱크 선정용 체적 유량 계산

- ✓ 투자비의 경제성 (ROI) 검토
- ✓ 년간 CO2배출량 산출



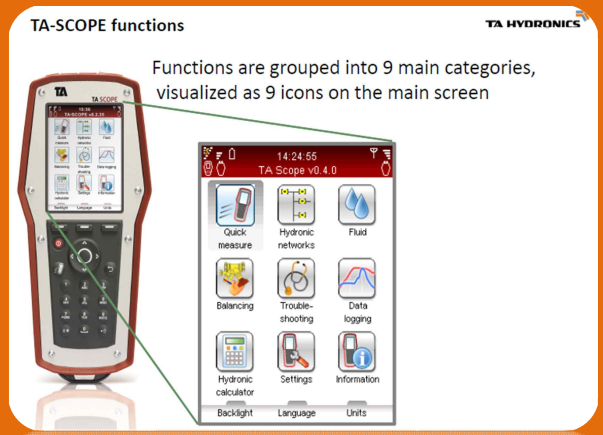
Hydronic Innovation Technology

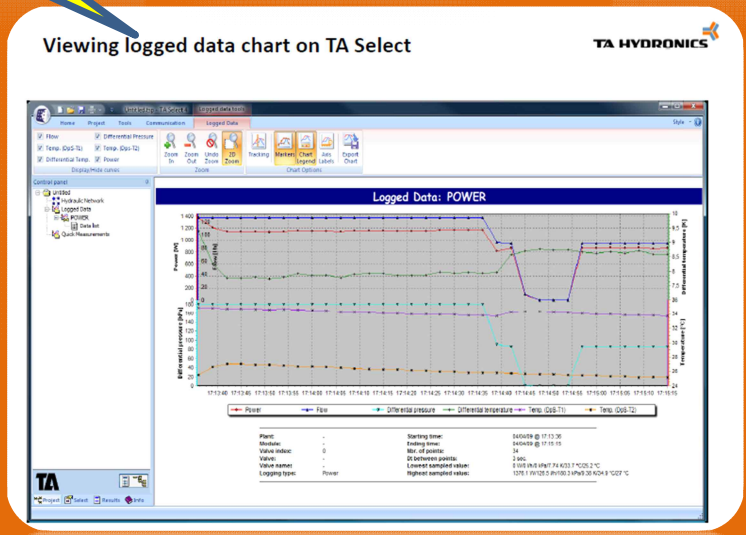
Mobile-Scope (측정, 진단, 조정, Data전송)

* T&C 검증 Tool

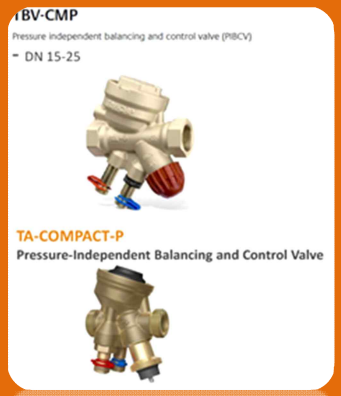
- ✓ 유량(q)
- ✓ 차압(Dp)
- ✓ 온도(T)
- ✓ 온도차(DT)
- ✓ 동력(P)

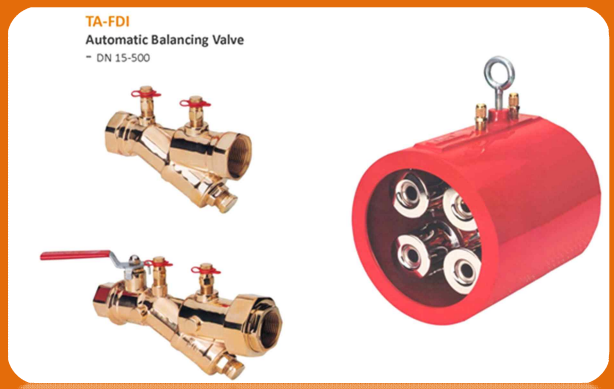
✓ DATA 통신

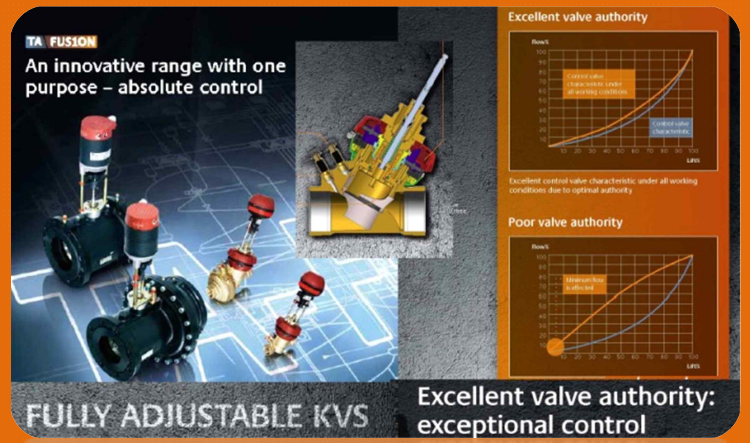




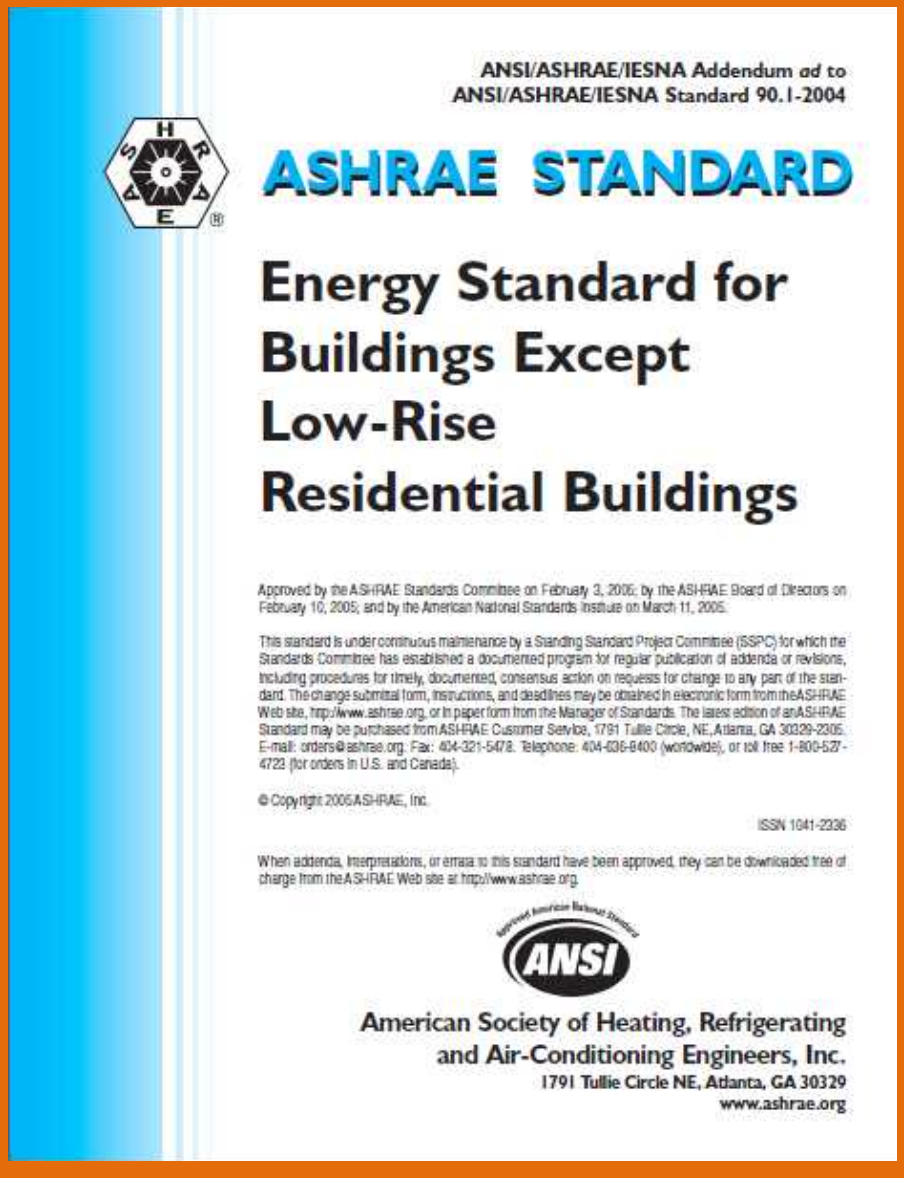
Hydronic Innovation Technology Wareable







BAS & Energy Saving



ANSI/ASHRAE/IESNA Addendum *ad* to
ANSI/ASHRAE/IESNA Standard 90.1-2004

ASHRAE STANDARD

Energy Standard for Buildings Except Low-Rise Residential Buildings

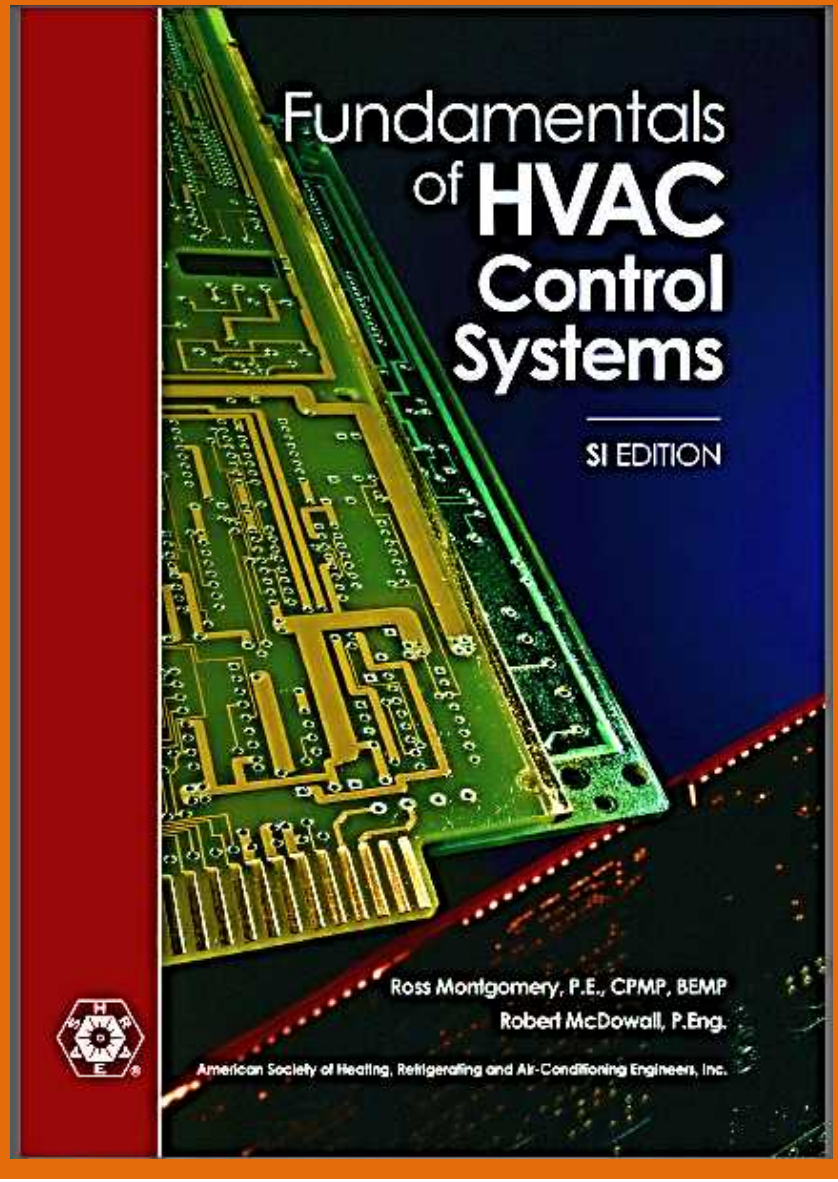
Approved by the ASHRAE Standards Committee on February 3, 2005; by the ASHRAE Board of Directors on February 10, 2005; and by the American National Standards Institute on March 11, 2005.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site, http://www.ashrae.org, or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in U.S. and Canada).

ISSN 1041-2336

When addenda, interpretations, or errata to this standard have been approved, they can be downloaded free of charge from the ASHRAE Web site at http://www.ashrae.org.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle NE, Atlanta, GA 30329
www.ashrae.org



Terminal. Control valve. BAS

- 유량과 차압 관계
- Coil 성능특성(ASHRAE 90.1)
- Valve 성능 특성
- Terminal 과 Valve의 관계
- Control Valve의 **Authority**
- PIBCV

Terminal. Control valve. BAS

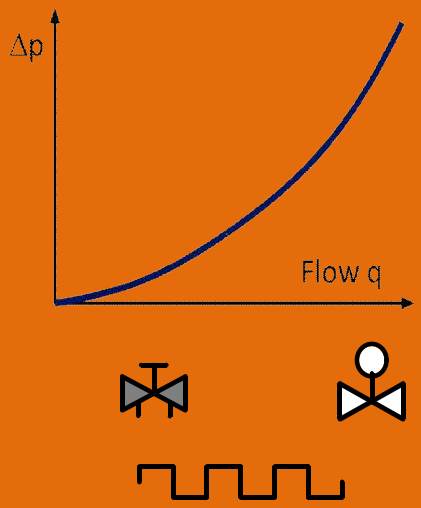
- **유량과 차압 관계**
- Coil 성능특성(ASHRAE 90.1)
- Valve 성능 특성
- Terminal 과 Valve의 관계
- Control Valve의 **Authority**
- PIBCV

유량 & 차압 관계

밸브, 배관, 코일, 냉동기, 열교환기 등등...

$$\Delta p \propto q^2$$

$$q \propto \sqrt{\Delta p}$$



만약 유량이 4배가 되면 (x4), 압력 강하는 2배가 된다. (x2).

Example :

- ✓ q increases 15%, Δp increase is $1.15^2-1 = 0.32$ (32%)
- ✓ Δp increases 20%, the flow increase is $1.2^{0.5}-1= 0.1$(10%)
- ✓ q reduces 40%, Δp reduced is $1-0.6^2= 0.64$ (64%)

Terminal. Control valve. BAS

- 유량과 차압 관계
- **Coil 성능특성(ASHRAE 90.1)**
- Valve 성능 특성
- Terminal 과 Valve의 관계
- Control Valve의 **Authority**
- PIBCV

Cooling Coil – Performance Characteristic

AHU/FCU Performance Characteristic

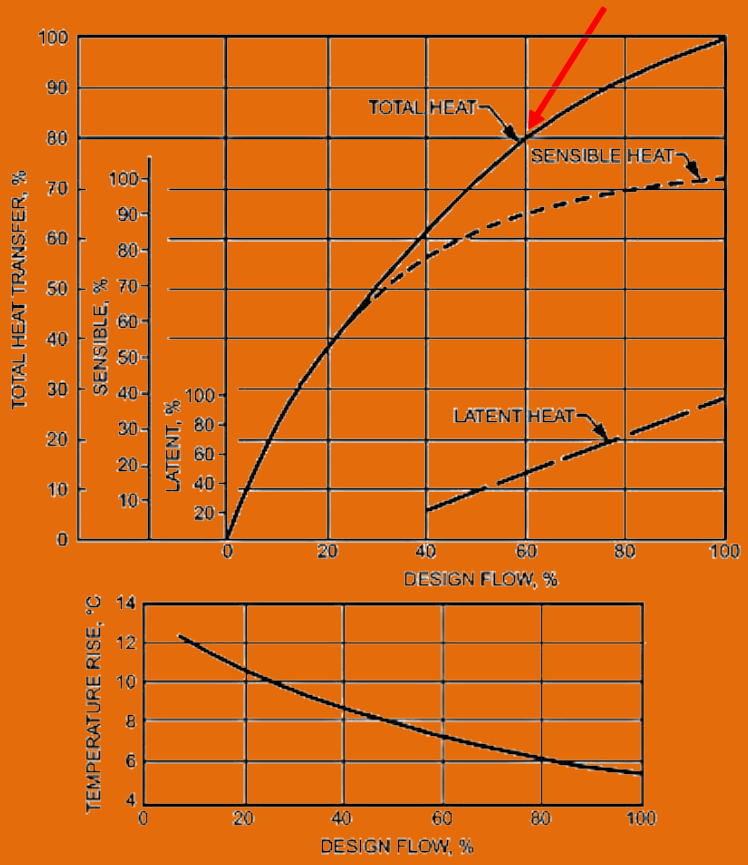


Fig. 4 Chilled Water Terminal Heat Transfer Versus Flow

2011 ASHRAE Handbook—HVAC Applications (SI)

- Dynamic balancing valves or flow-limiting valves (for prebalanced systems only); field adjustment of these devices is not normally required or possible (see Chapter 46)
- Pumps with factory-certified pump curves
- Components used as flowmeters (terminal coils, chillers, heat exchangers, or control valves if using manufacturer's factory-certified flow versus pressure drop curves)

Record Keeping

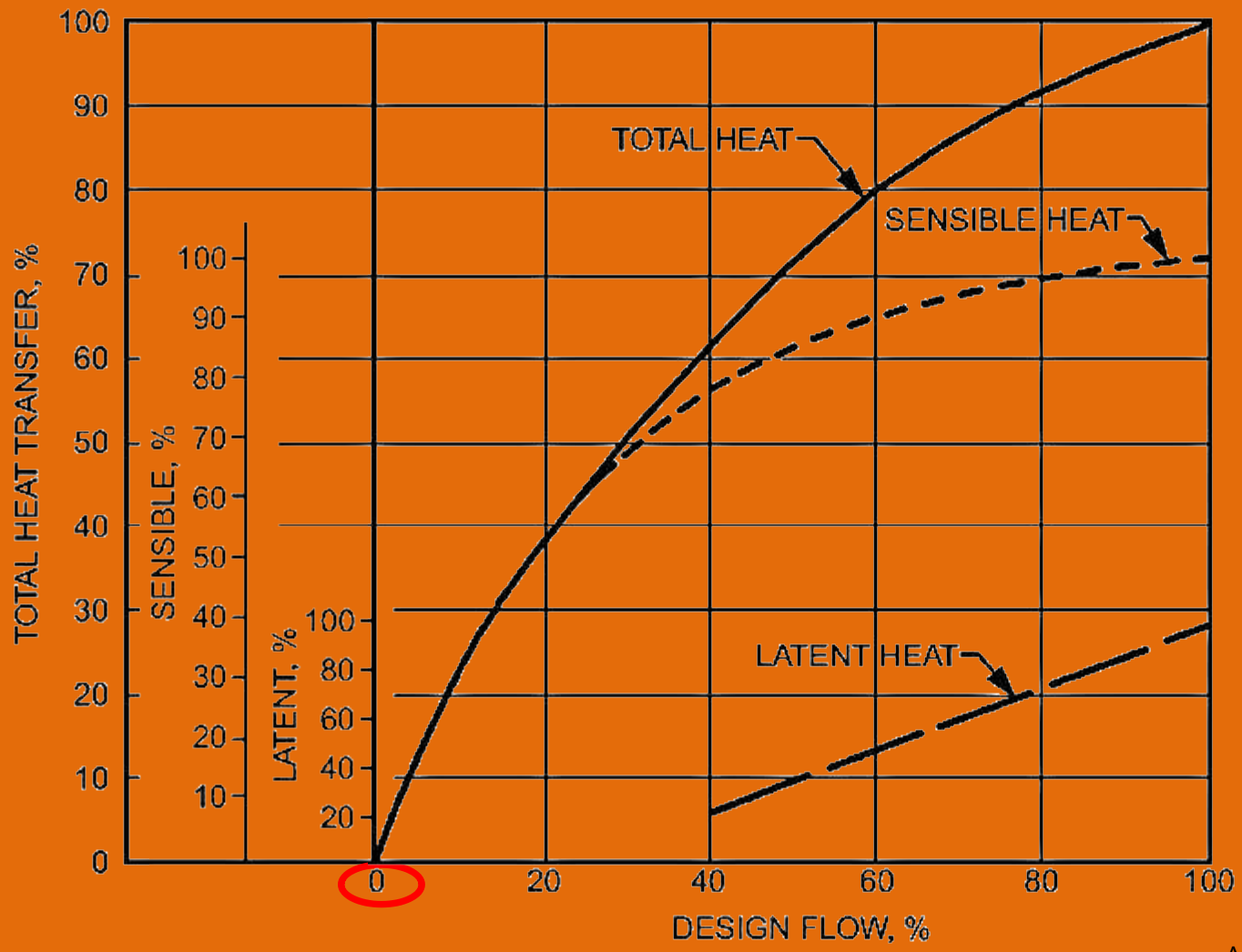
Balancing requires accurate record keeping while making field measurements. Dated and signed field test reports help the designer or customer in work approval, and the owner has a valuable reference when documenting future changes.

Sizing Balancing Valves

A balancing valve is placed in the system to adjust water flow to a terminal, branch, zone, riser, or main. It should be located on the leaving side of the hydronic branch. General branch layout is from takeoff to entering service valve, then to the coil, control valve, and balancing/service valve. Pressure is thereby left on the coil, helping keep dissolved air in solution and preventing false balance problems resulting from air bind.

A common valve sizing method is to select for line size; however, balancing valves should be selected to pass design flows when near or at their fully open position with 3 kPa minimum pressure drop. Larger Δp is recommended for accurate pressure readings. Many balancing valves and measuring meters give an accuracy of ±5% of range down to a pressure drop of 3 kPa with the balancing valve

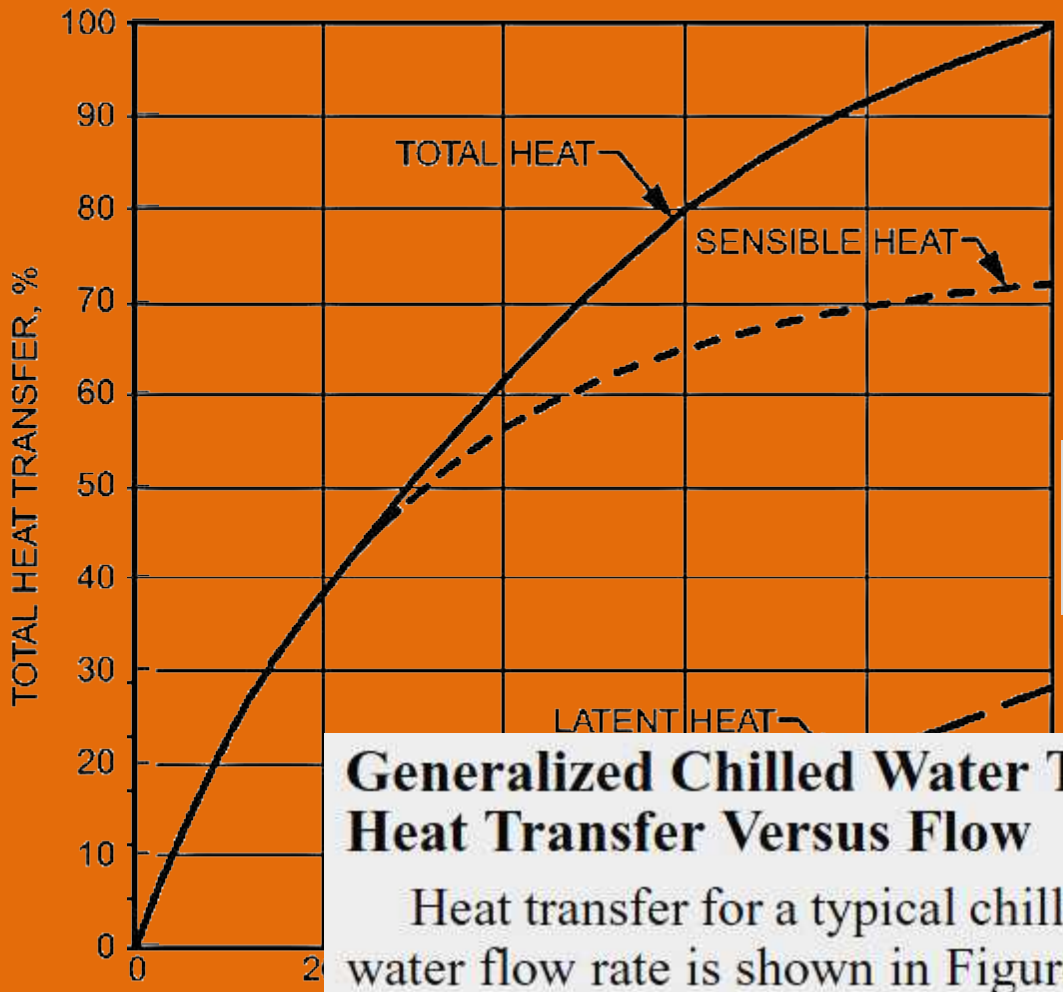
Cooling Coil – Performance Characteristic



ASHRAE Handbook Article 38.7

"Terminal unit" characteristic

Cooling Coil – Performance Characteristic



ASHRAE Handbook Article 38.7

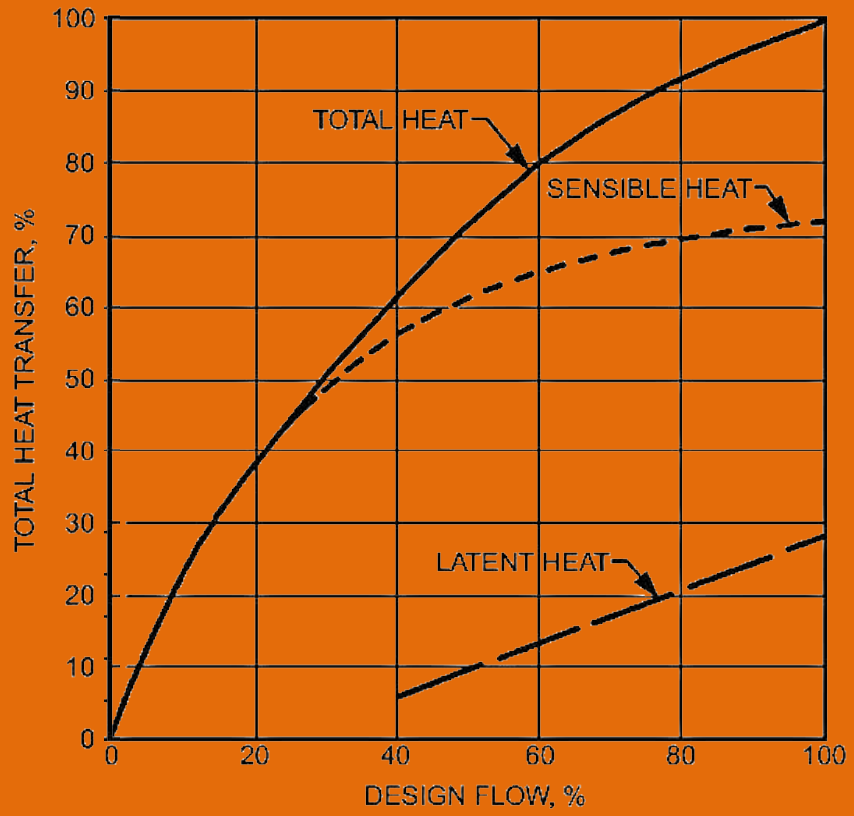
Outlet water is 12.8 degC
This coil characteristic is therefore based on
- Inlet water = 7.2 degc
- Outlet water = 12.8 degC

Generalized Chilled Water Terminal—Heat Transfer Versus Flow

Heat transfer for a typical chilled-water coil in an air duct versus water flow rate is shown in Figure 4. The curves are based on ARI rating points: 7.2°C inlet water at a 5.6 K rise with entering air at 26.7°C db and 19.4°C wb. The basic curve applies to catalog ratings

"Termin

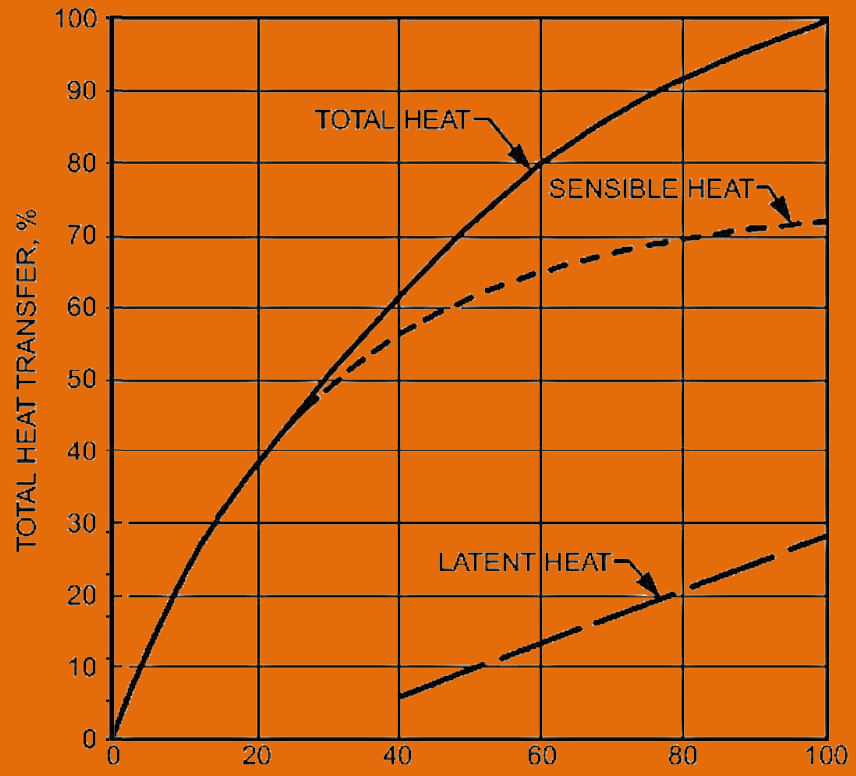
Cooling Coil – Performance Characteristic



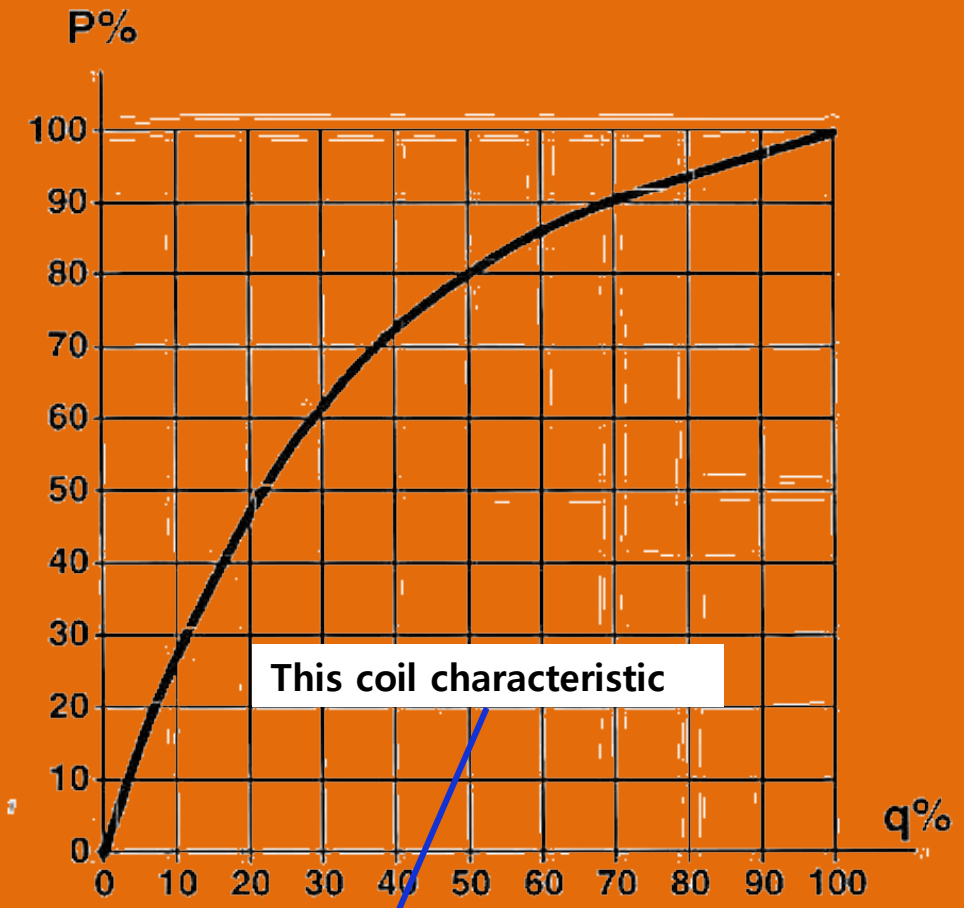
This coil characteristic is therefore based on

- Inlet water = 7.2 ºC
- Outlet water = 12.8 ºC

Cooling Coil – Performance Characteristic



more suited for USA



more suited for Our Region

This coil characteristic is therefore based on
- Inlet water = 7.2 ºC
- Outlet water = 12.8 ºC

Fig 1.4b. Cooling coil working under following condition:
Water: 6 °C inlet / 2 to 24 °C return
Air: 24 °C inlet/ 16 to 24 °C outlet

Terminal. Control valve. BAS

- 유량과 차압 관계
- Coil 성능특성(ASHRAE 90.1)
- **Valve 성능 특성**
- Terminal 과 Valve의 관계
- Control Valve의 **Authority**
- PIBCV

밸브의 특성(ASHRAE-Fundamentals)

ASHRAE – Fundamentals of HVAC Control

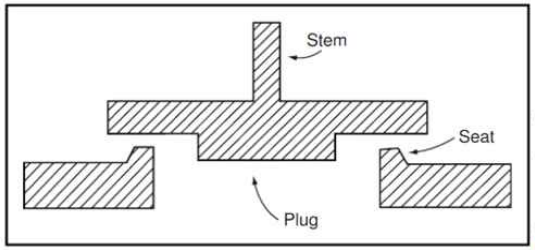


Figure 3-7 Quick-opening (Flat Plate) Valve Plug

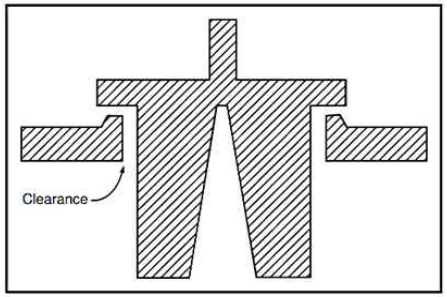


Figure 3-5 Linear (V-Port) Valve Plug

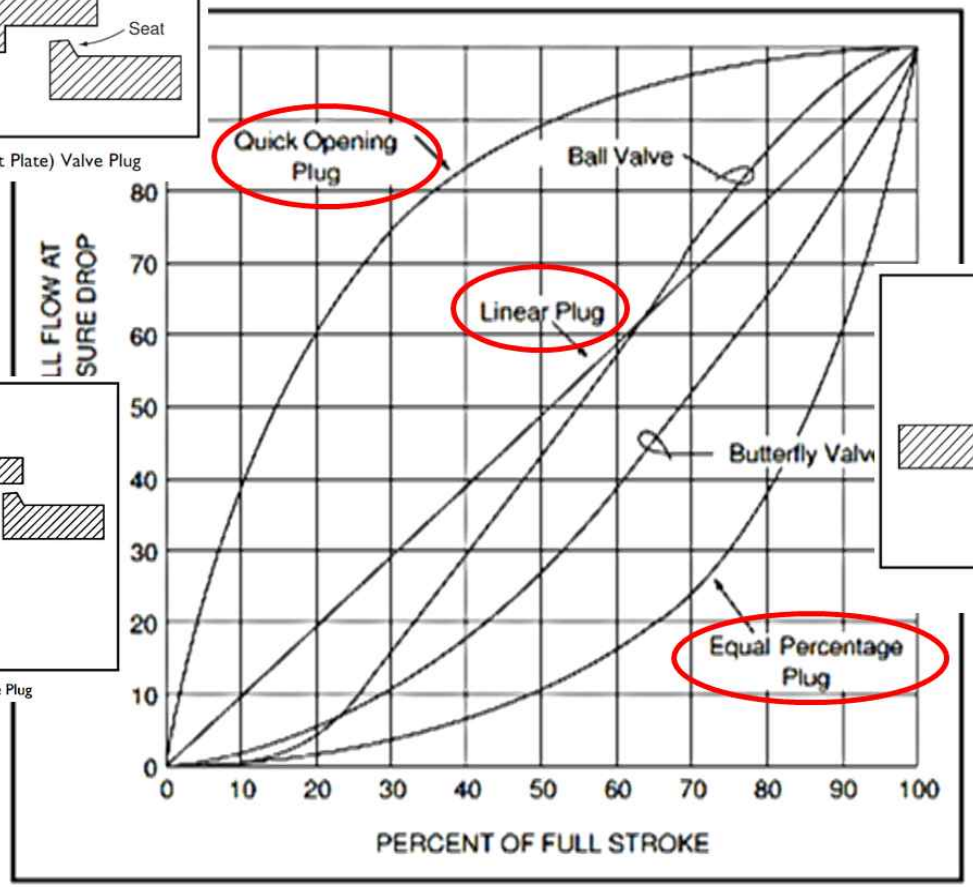


Figure 3-10 Typical Valve Characteristics at Constant Pressure Drop

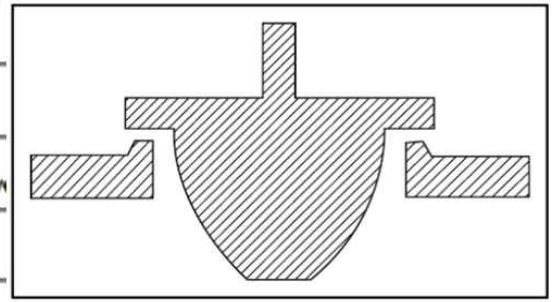


Figure 3-6 Equal Percentage Valve Plug

Terminal. Control valve. BAS

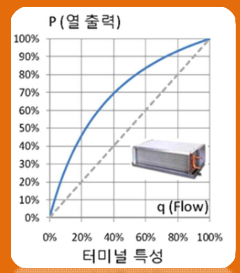
- 유량과 차압 관계
- Coil 성능특성(ASHRAE 90.1)
- Valve 성능 특성

  Terminal 과 Valve의 관계
- Control Valve의 **Authority**
- PIBCV

Terminal과 Valve의 관계 (Energy)

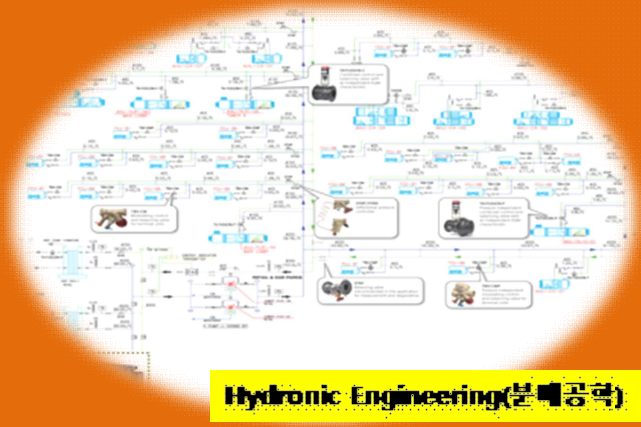
열원을 설계 부하량으로 각 사용처에 공급

BEMS

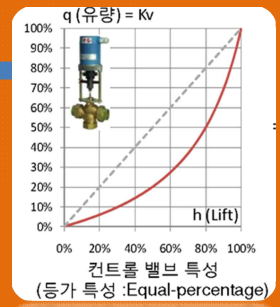


터미널 특성

순환로 특성



Hydronic Engineering(분배공학)



컨트롤 밸브 특성
(등가 특성 :Equal-percentage)

설계부하대로 부분부하시 최적의 유량을 제어 및 환수온도 Δt 5℃ 예상 유지

EQM특성 Valve 사용
Control Valve Authority 0.25(Good) 이상
KVs 값을 조정 할 수 있는 Valve 적용
Control Valve Rangebility 100% 사용

$$\Delta p \propto q^2$$

열원 생산 : 냉수 7℃, 온수 70℃

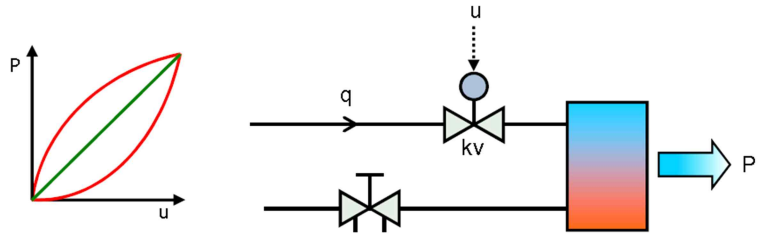
열원을 사용처까지 수송

터미날. 컨트롤 Valve. BAS의 연관 관계 (ASHRAE 90.1)

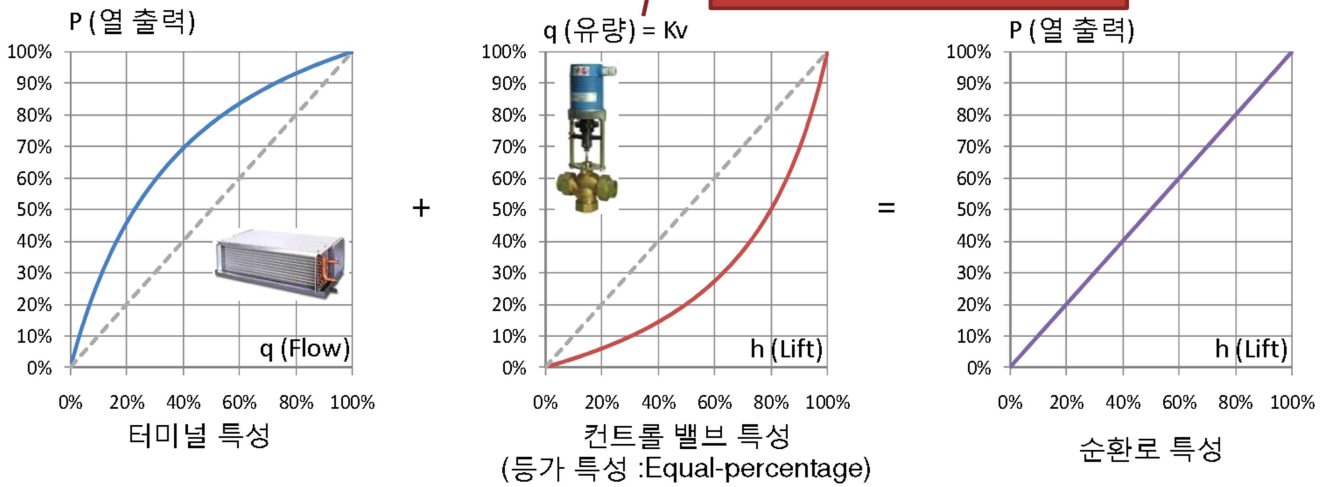
- 안정적이고 정확한 BAS 제어를 얻기 위해서는, 제어 시스템이 비례적인 움직임(선형 특성)이여야 한다.
- 냉난방 코일 성능 특성은 결코 선형적이지 않다
- 안정적이고 정확한 제어를 위해 터미널 유닛 특성의 비선형은 모든 선형 순환로 특성을 보장 하기 위해 컨트롤 밸브의 수정 등가특성(EQM)에 의해 보상되어진다.

비례 제어 터미널 특성과 컨트롤 밸브 특성

가능한 선형적인 순환로 특성을 얻기 위해, **터미널 특성의 비선형성은 컨트롤 밸브의 등가 특성으로 보상되어 진다.**



Δp가 일정한 경우에만:
$q = Kv \sqrt{(\Delta p)}$



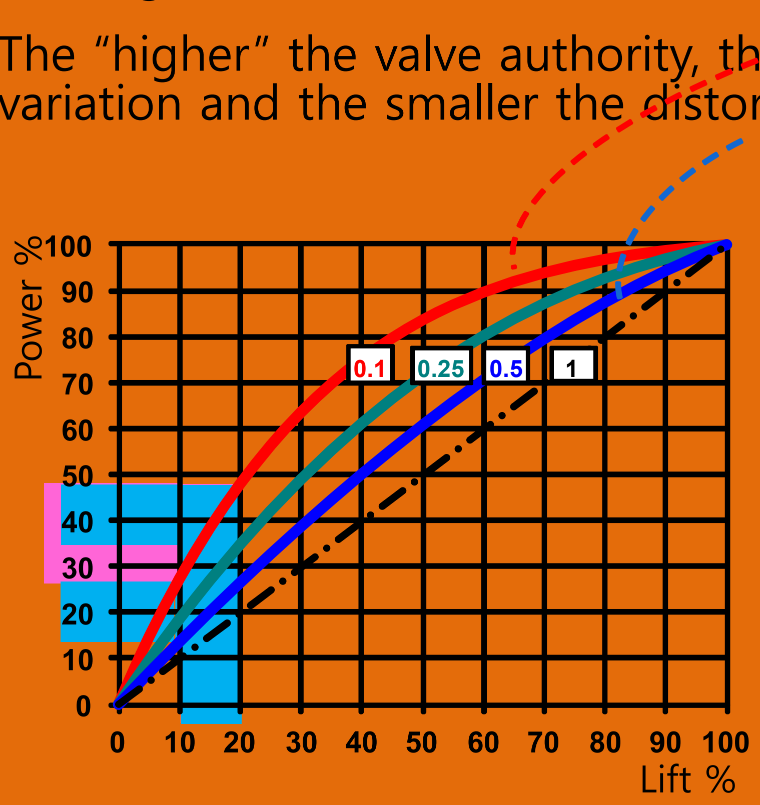
Terminal. Control valve. BAS

- 유량과 차압 관계
- Coil 성능특성(ASHRAE 90.1)
- Valve 성능 특성
- Terminal 과 Valve의 관계
- Control Valve의 **Authority**
- PIBCV

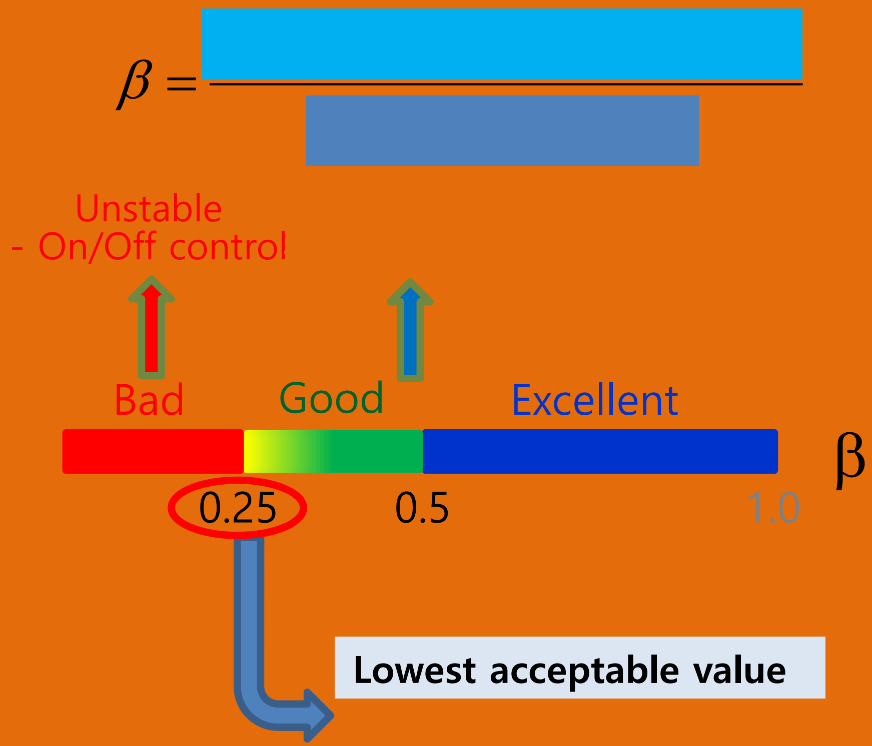
Control Valve Authority Guidelines

The "lower" the valve authority,
the larger the dP variation on the control valve.
the larger the distortion on the valve characteristic.

The "higher" the valve authority, the smaller the Dp variation and the smaller the distortion



Control valve with EQM Characteristic

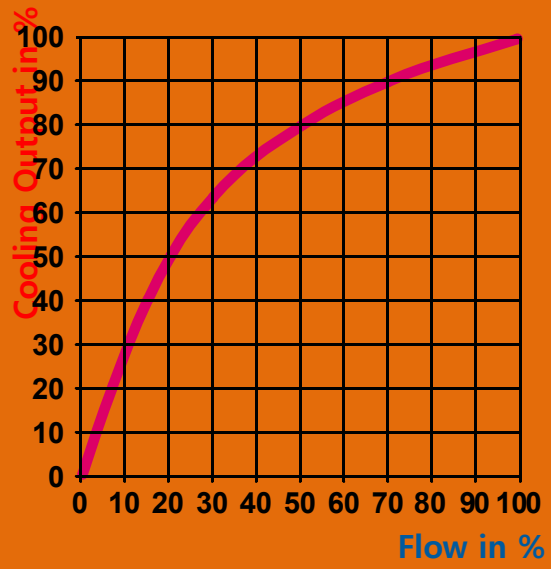


Hydronic design(Terminal과 Valve의 관계)

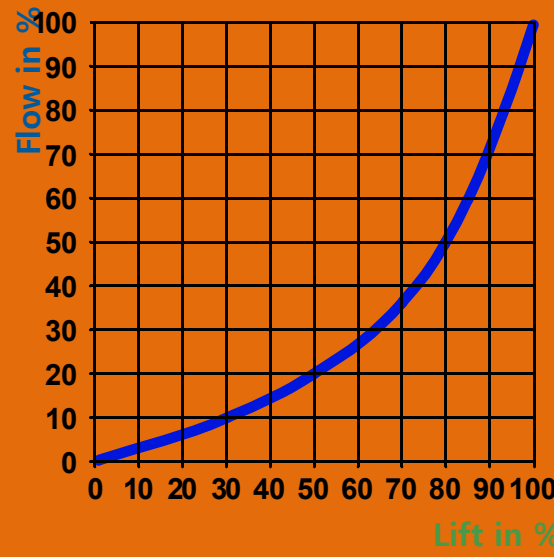
What is this?

- "Combined" performance of 2 characteristics:

1. **"AHU/FCU"** performance characteristic (cooling output vs flow)
2. **"Control valve"** performance characteristic (flow vs valve lift)



"AHU/FCU" characteristic



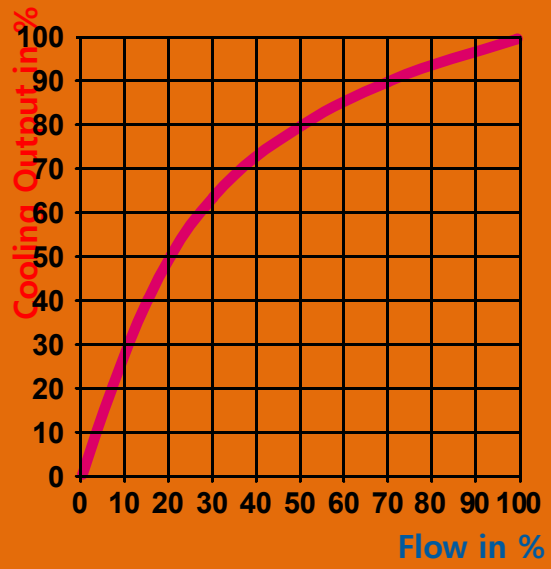
"Control valve" characteristic

Global Circuit Characteristic

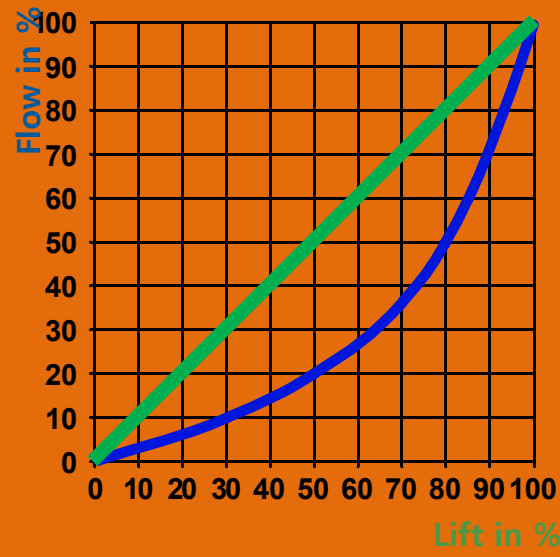
What is this?

- "Combined" performance of 2 characteristics:

1. **"AHU/FCU"** performance characteristic (cooling output vs flow)
2. **"Control valve"** performance characteristic (flow vs valve lift)



"AHU/FCU" characteristic



"Control valve" characteristic

Global Circuit Characteristic

- What is the “ideal” global characteristic?
  - Linear
- Why?

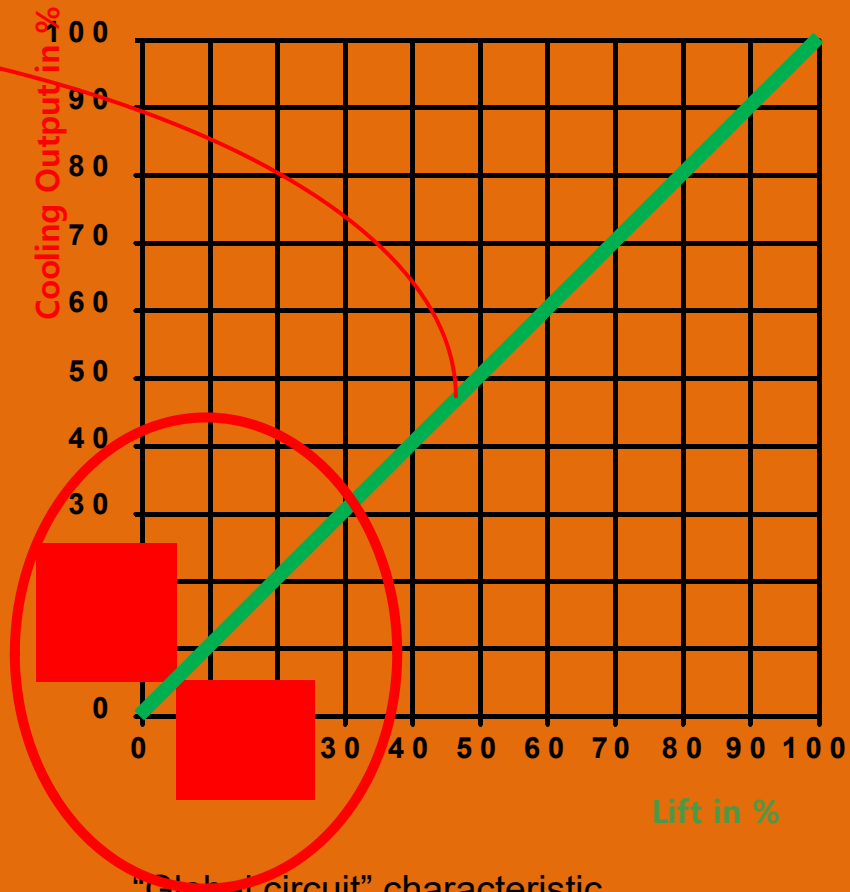
Cooling Power

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

Lift

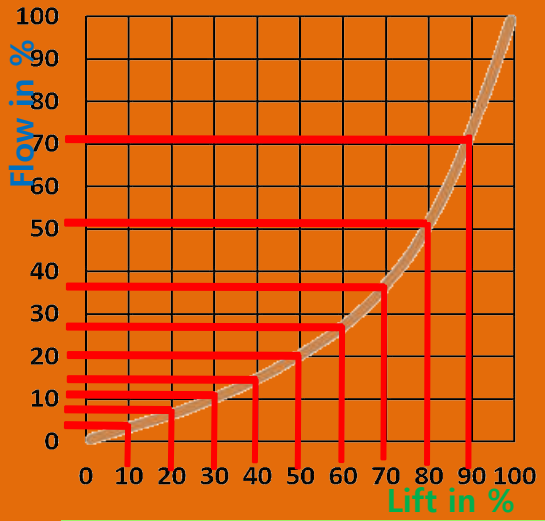
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

Stable control of temperature
No overflow
No underflow
Best for BAS

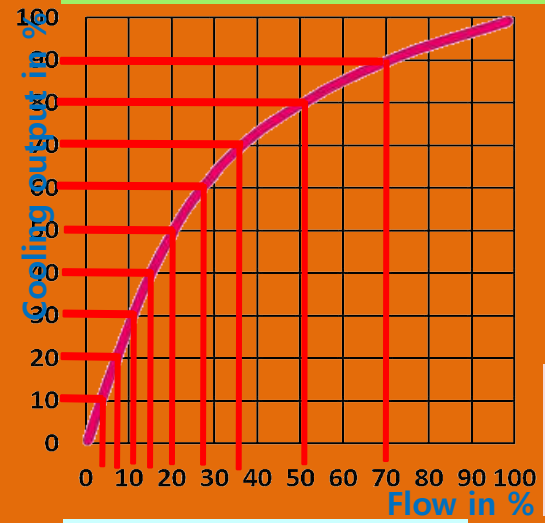


“Global circuit” characteristic

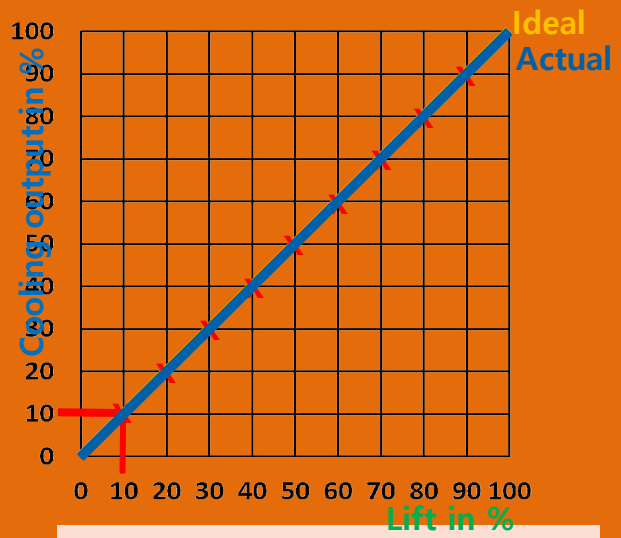
Good Valve Authority



Control Valve (EQM) Characteristic



AHU/FCU Characteristic



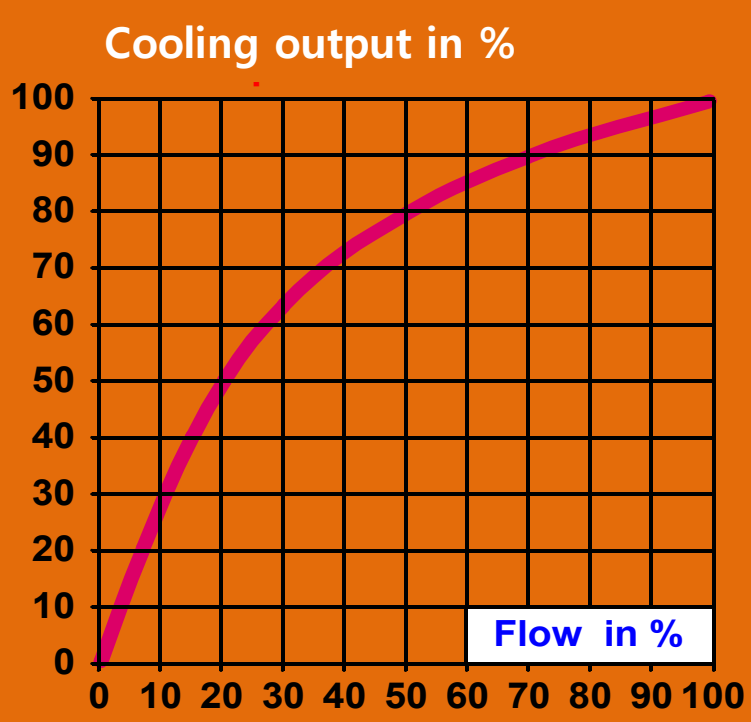
Global Characteristic – EQM Valve

EQM valve is exact match and therefore gives the “ideal” Global Characteristic suitable for HVAC control

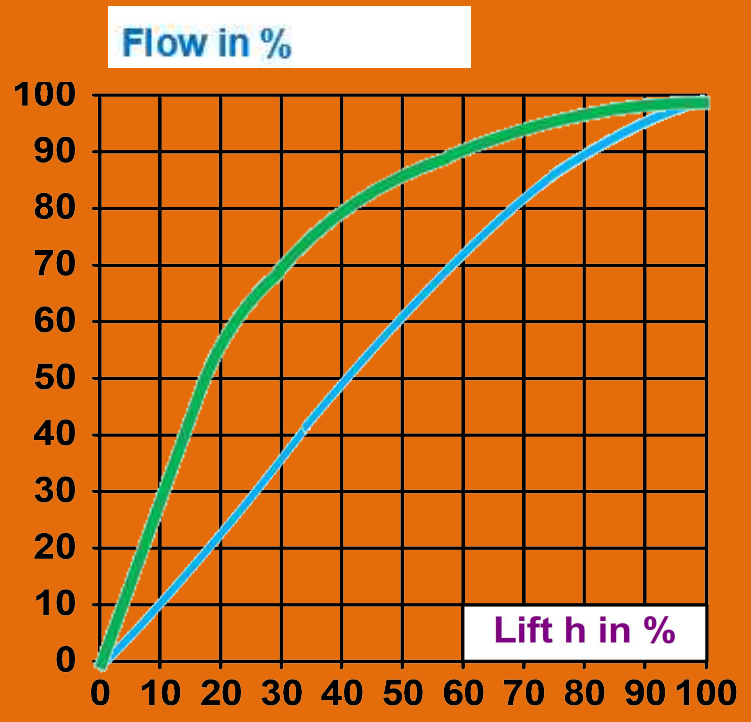
2 options available to achieve close to 100% authority

- Independent ‘differential pressure controllers” on each circuit
- Adjustable KVs control valve with fixed EQM characteristic

Bad Valve Authority

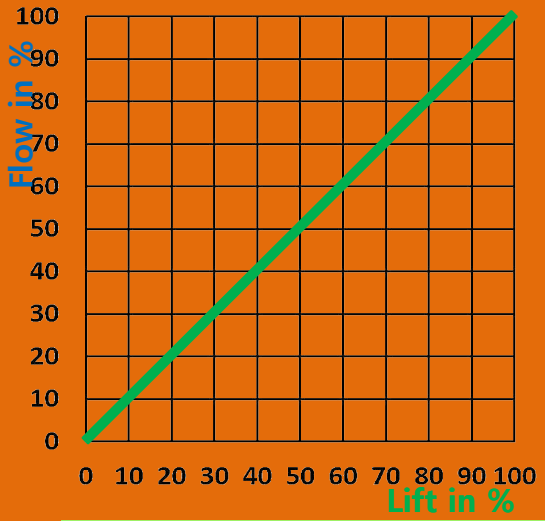


Terminal unit characteristic

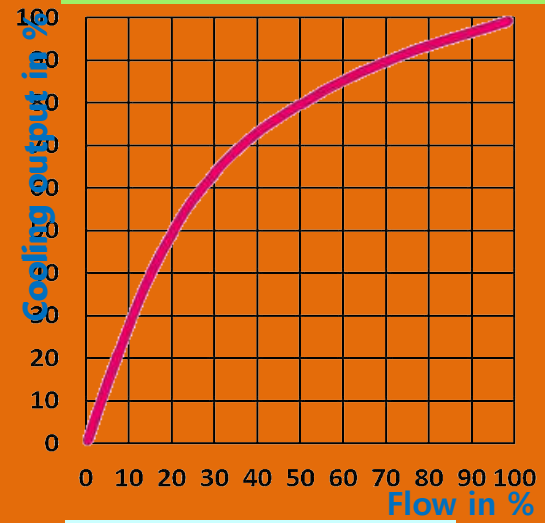


Resultant characteristic

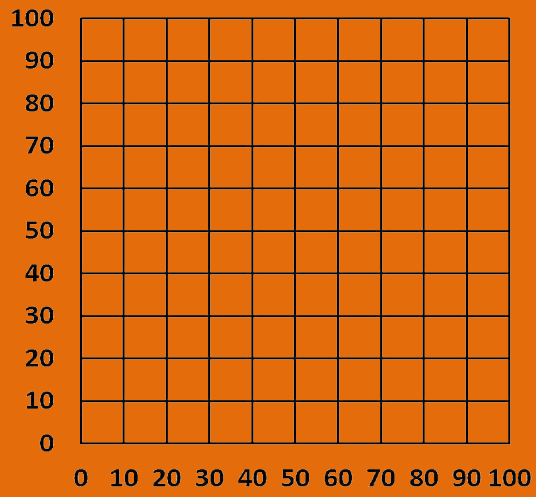
Linear Valve with 100% Authority



Control Valve (Linear) Characteristic



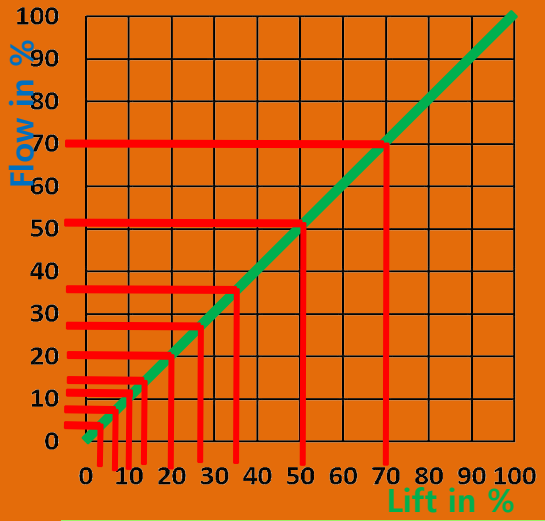
AHU/FCU Characteristic



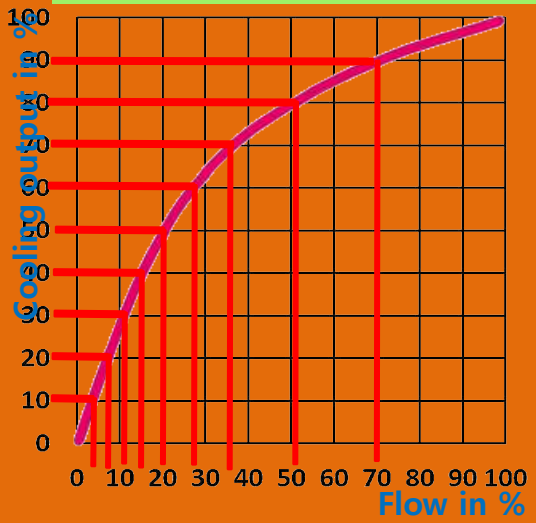
Global Characteristic – Linear Valve

ASHRAE – Fundamentals of HVAC Control

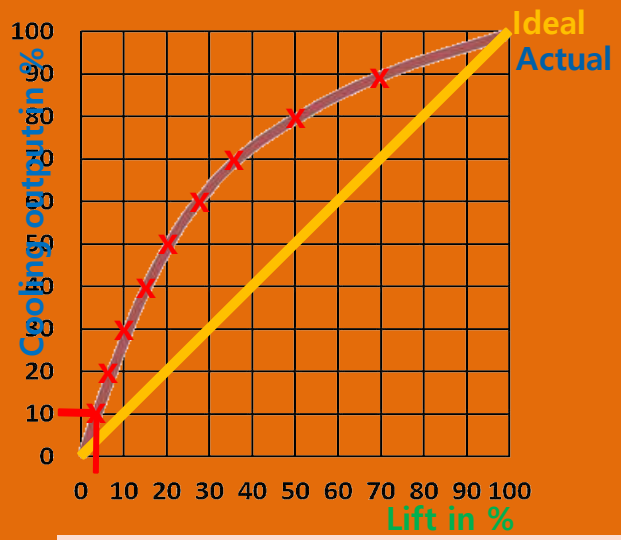
Linear Valve with 100% Authority



Control Valve (Linear) Characteristic



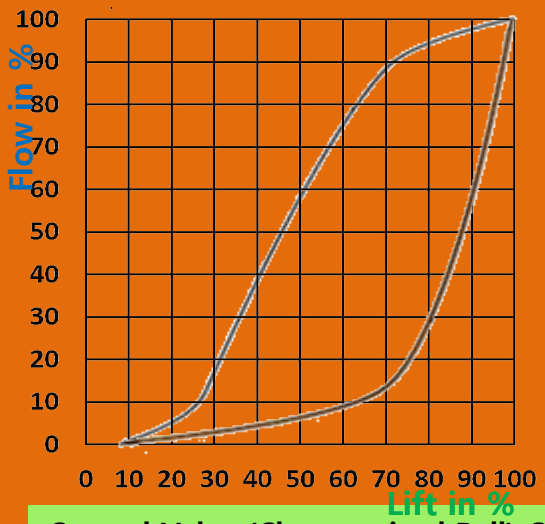
AHU/FCU Characteristic



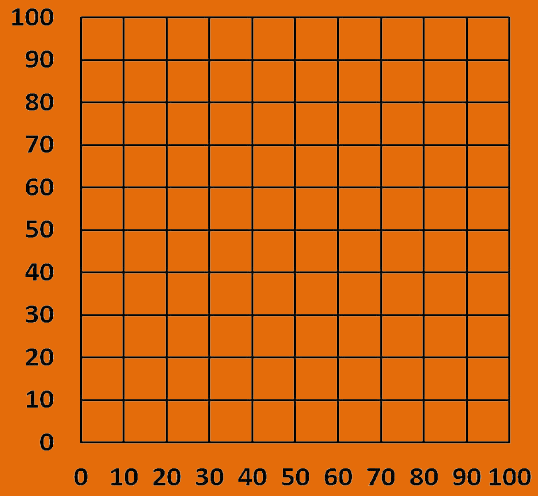
Global Characteristic – Linear Valve

Linear valve only suitable for ON/OFF moderate response systems (HVAC control)

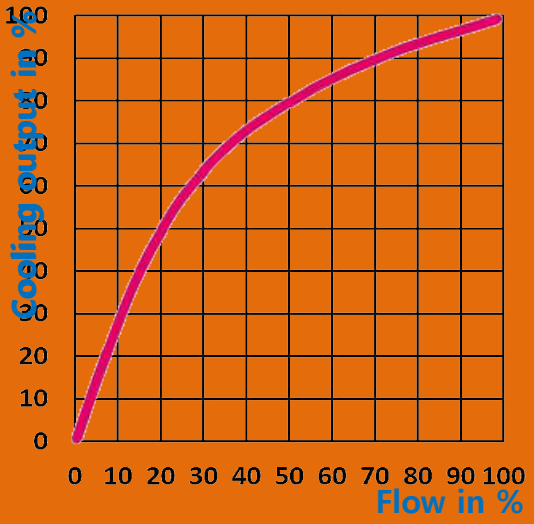
Characterised Ball Valve with 100% Authority



Control Valve (Characterised Ball) Characteristic



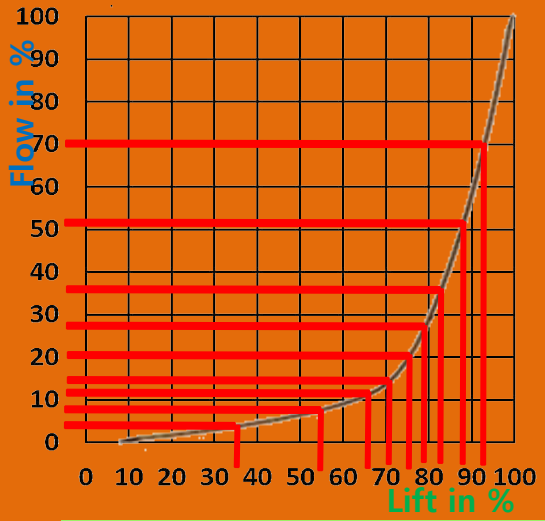
Global Characteristic – Characterised Ball Valve



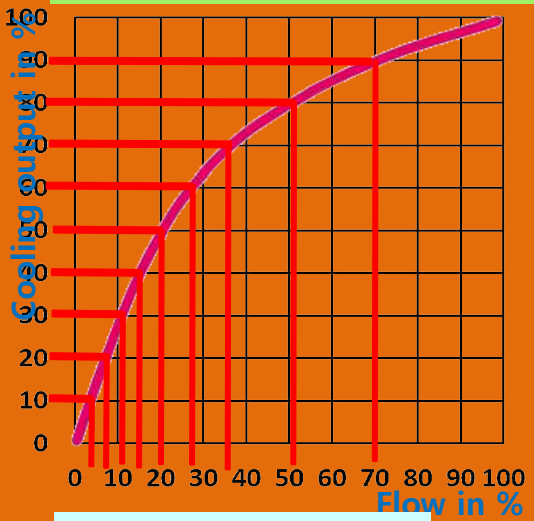
AHU/FCU Characteristic

ASHRAE – Fundamentals of HVAC Control

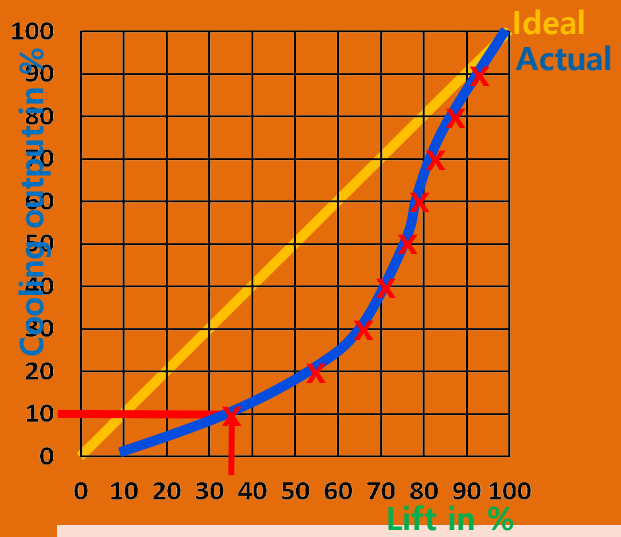
Characterised Ball Valve with 100% Authority



Control Valve (Characterised Ball) Characteristic



AHU/FCU Characteristic



Global Characteristic – Characterised Ball Valve

i.e. if □□P is constant
But ePIV does not keep □□P constant

Energy Valve - ePIV

Extract from write-up:

- *Characterized Control Valve (CCV) Technology*
- *2-way characterized control valve*

What does this mean?

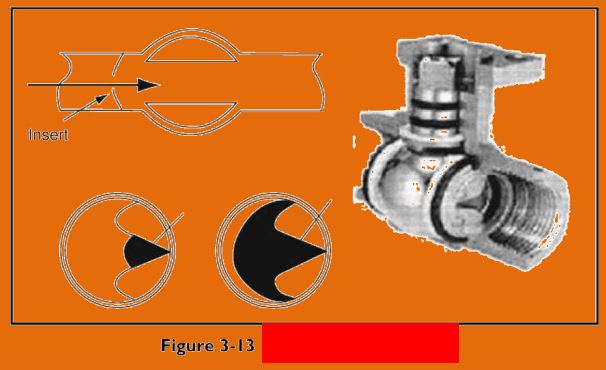


Figure 3-13

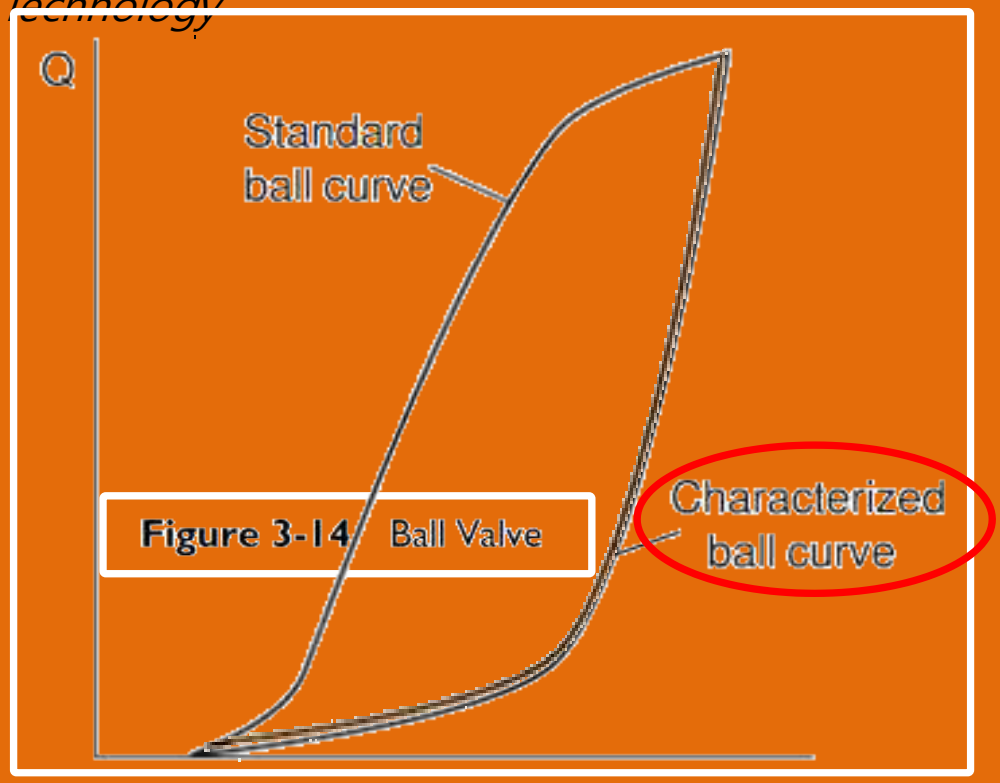
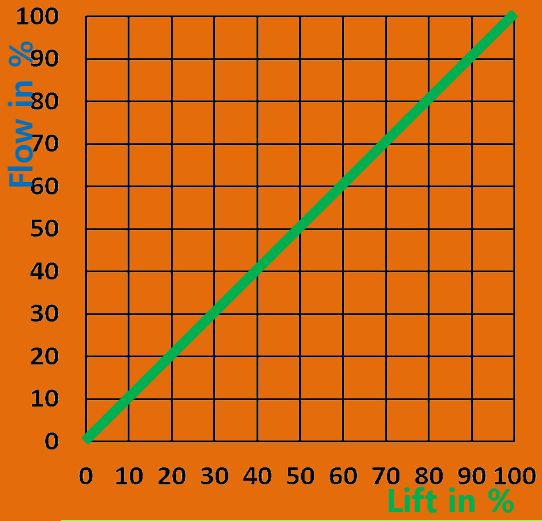
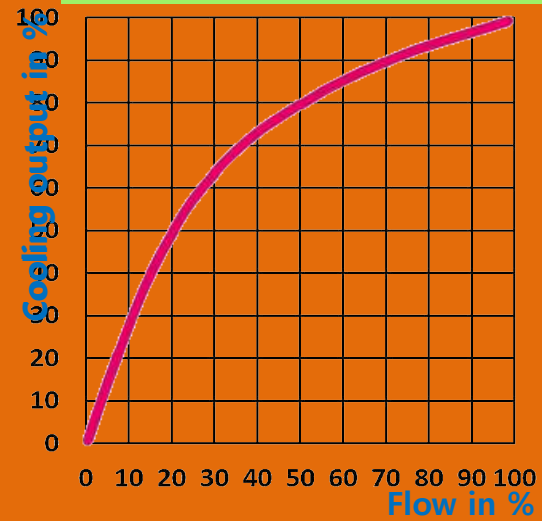


Figure 3-14 Ball Valve

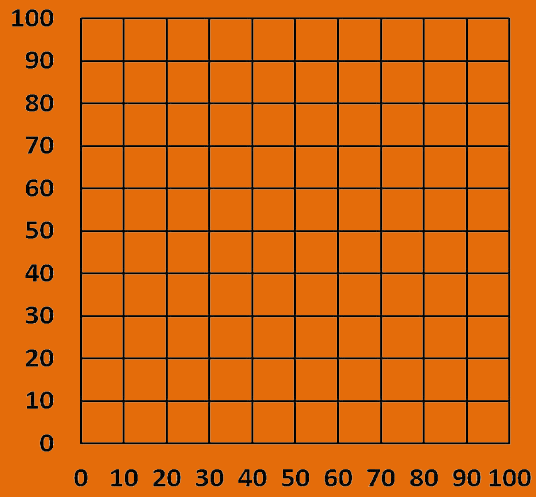
Linear Valve with 100% Authority



Control Valve (Linear) Characteristic



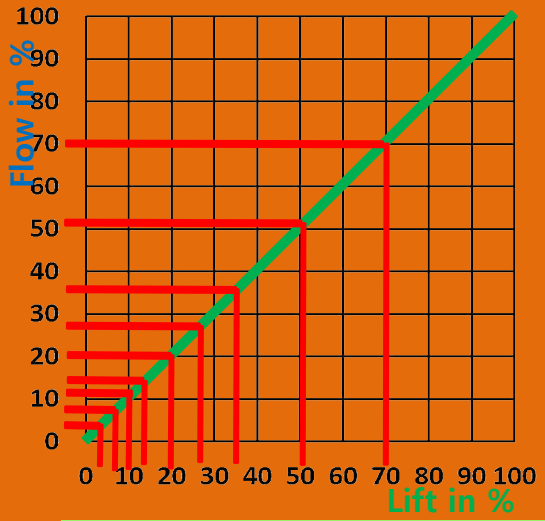
AHU/FCU Characteristic



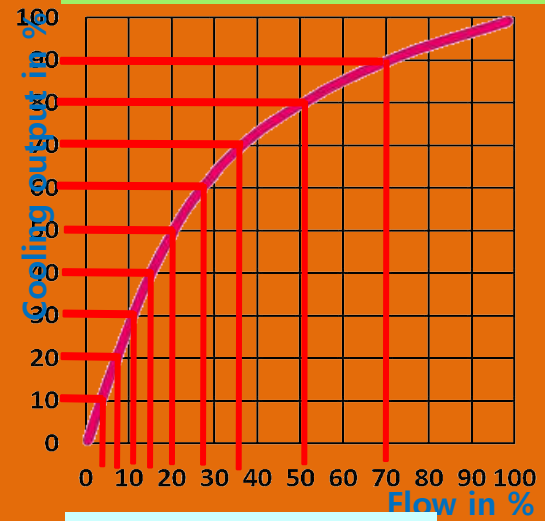
Global Characteristic – Linear Valve

ASHRAE – Fundamentals of HVAC Control

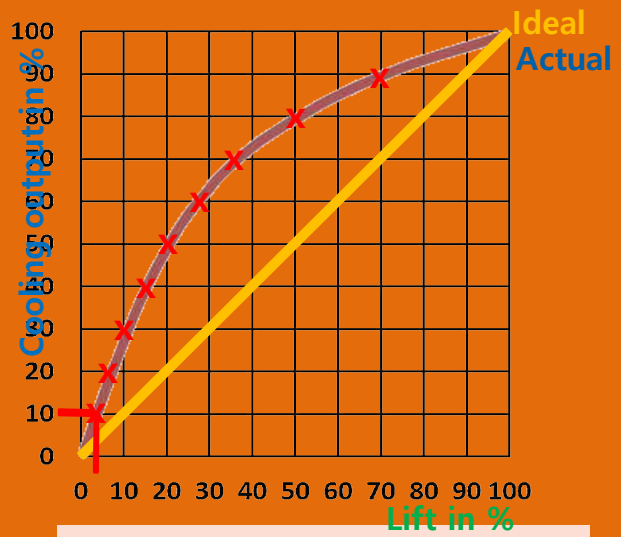
Linear Valve with 100% Authority



Control Valve (Linear) Characteristic



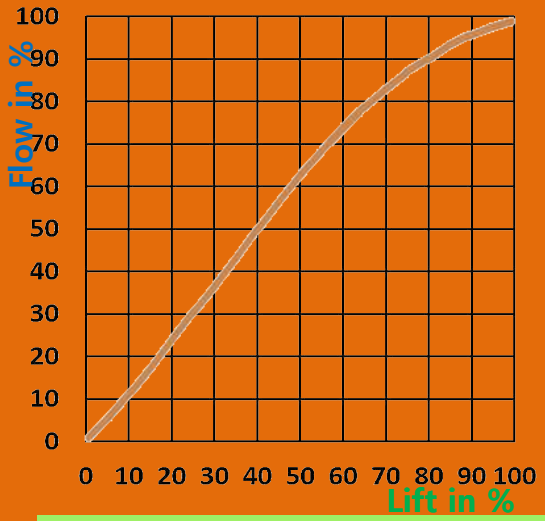
AHU/FCU Characteristic



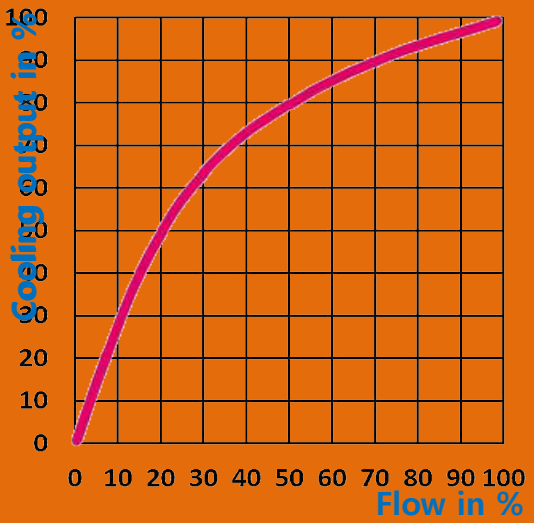
Global Characteristic – Linear Valve

Linear valve only suitable for ON/OFF moderate response systems (HVAC control)

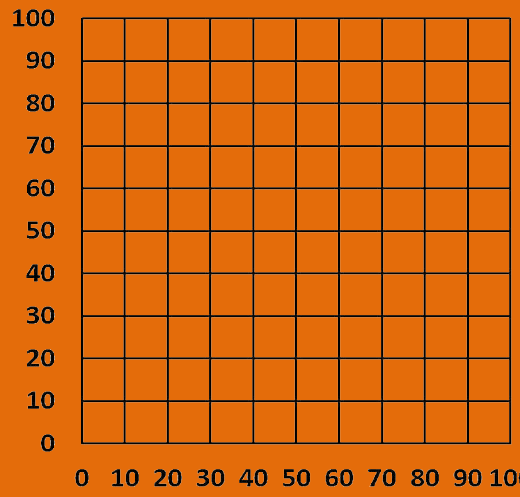
EQM Valve with Poor Authority



Control Valve (EQM – 0.1 Authority) Characteristic



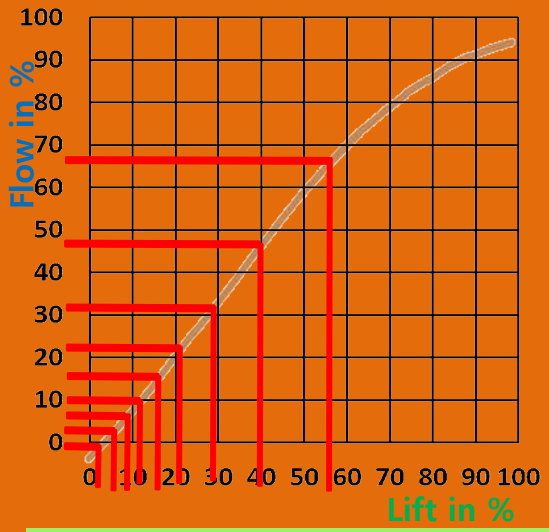
AHU/FCU Characteristic



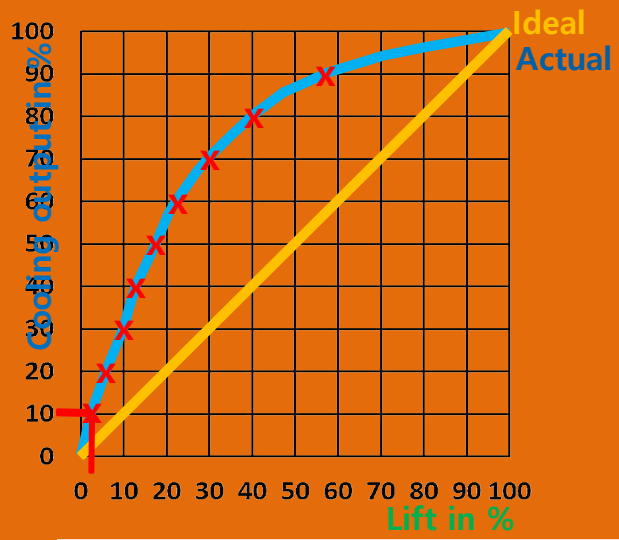
Global Characteristic – EQM Valve with 0.1 Authority

ASHRAE – Fundamentals of HVAC Control

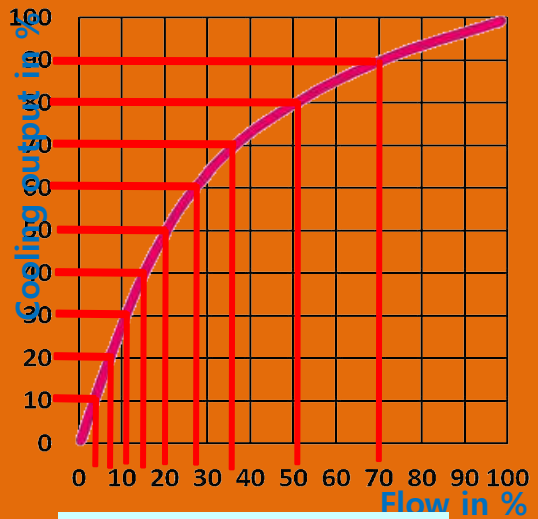
EQM Valve with Poor Authority



Control Valve (EQM – 0.1 Authority) Characteristic



Global Characteristic – EQM Valve with 0.1 Authority

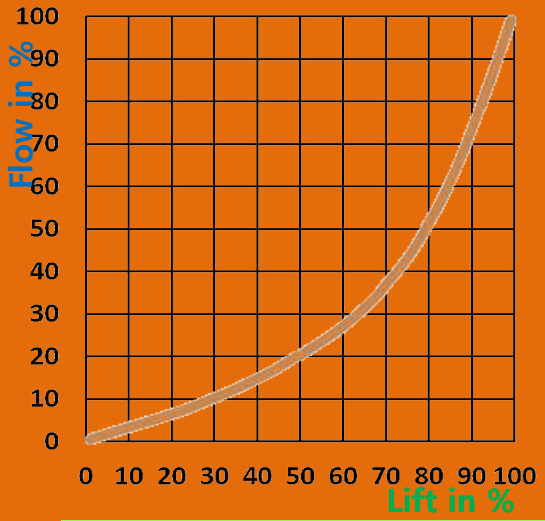


AHU/FCU Characteristic

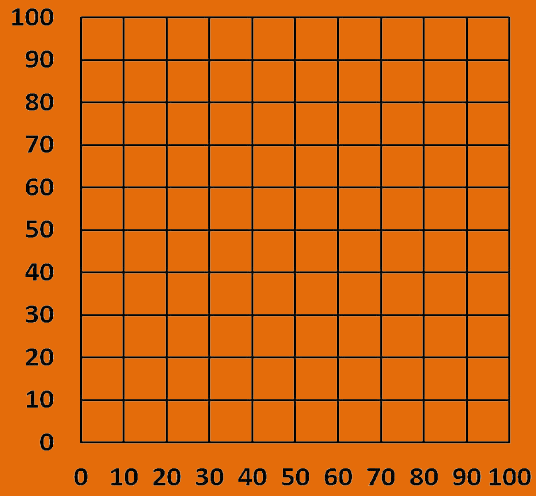
EQM valve with 0.1 Authority due to:

- Control valve is oversized, not calculated but uses a factor based on pipe size
- No differential pressure controller installed
- Pump head higher than required, no hydronic calculation

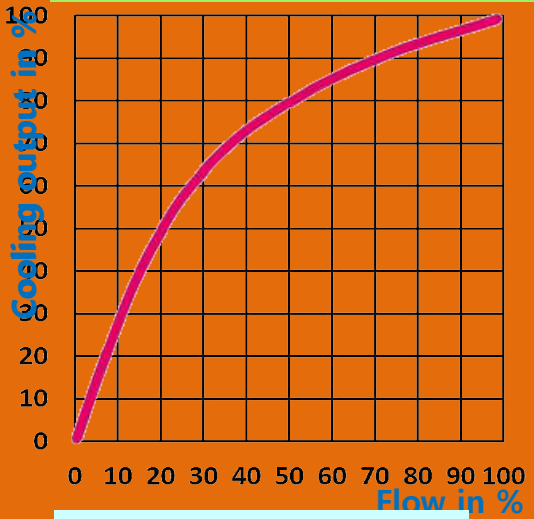
EQM Valve with 100% Authority



Control Valve (EQM) Characteristic



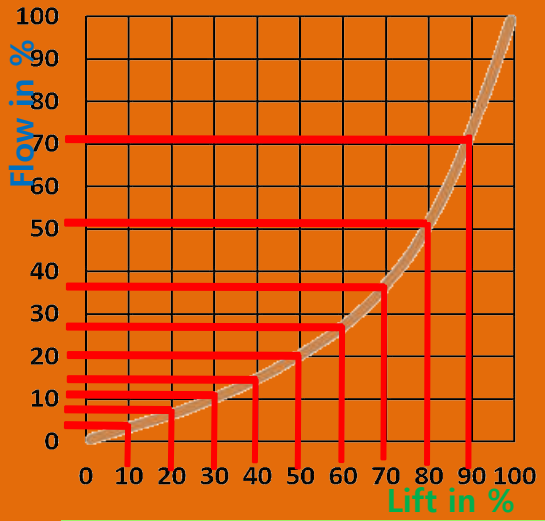
Global Characteristic – EQM Valve



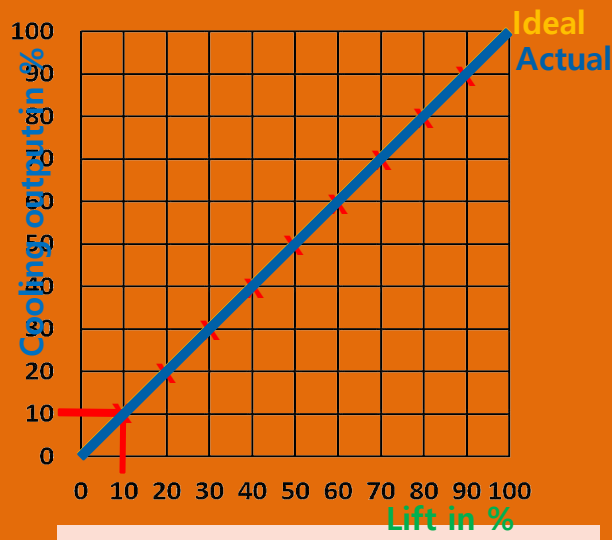
AHU/FCU Characteristic

ASHRAE – Fundamentals of HVAC Control

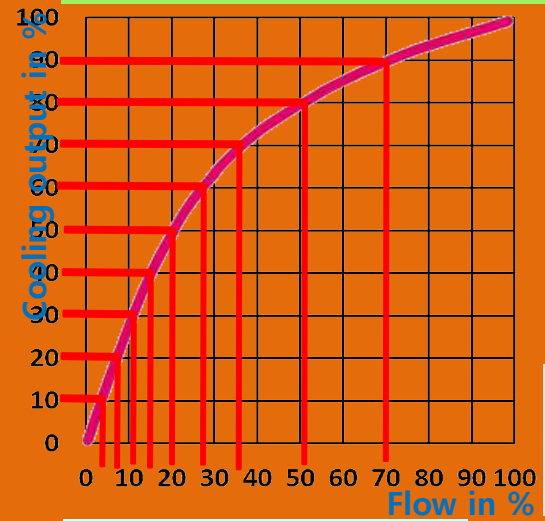
EQM Valve with 100% Authority



Control Valve (EQM) Characteristic



Global Characteristic – EQM Valve



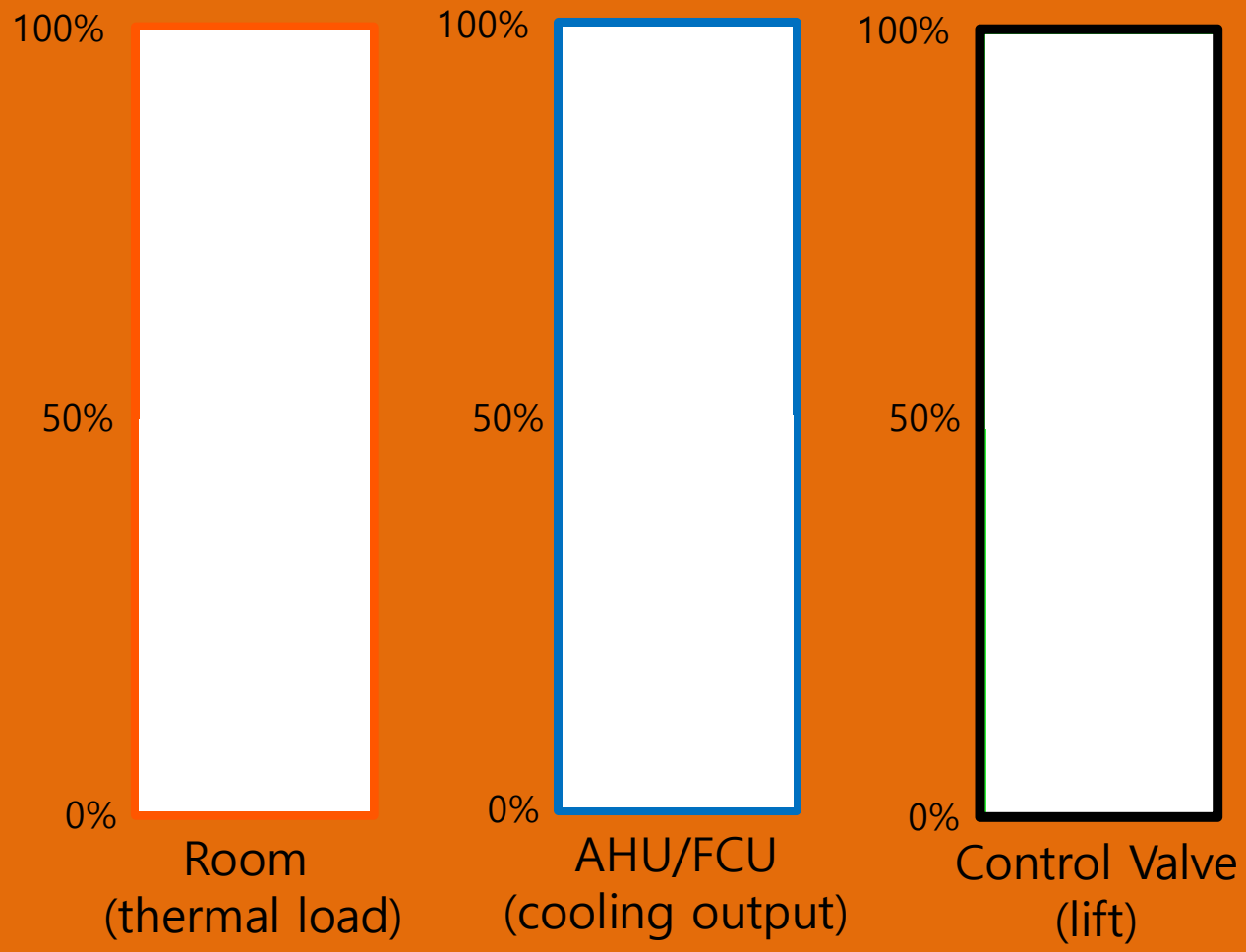
AHU/FCU Characteristic

EQM valve is exact match and therefore gives the “ideal” Global Characteristic suitable for HVAC control

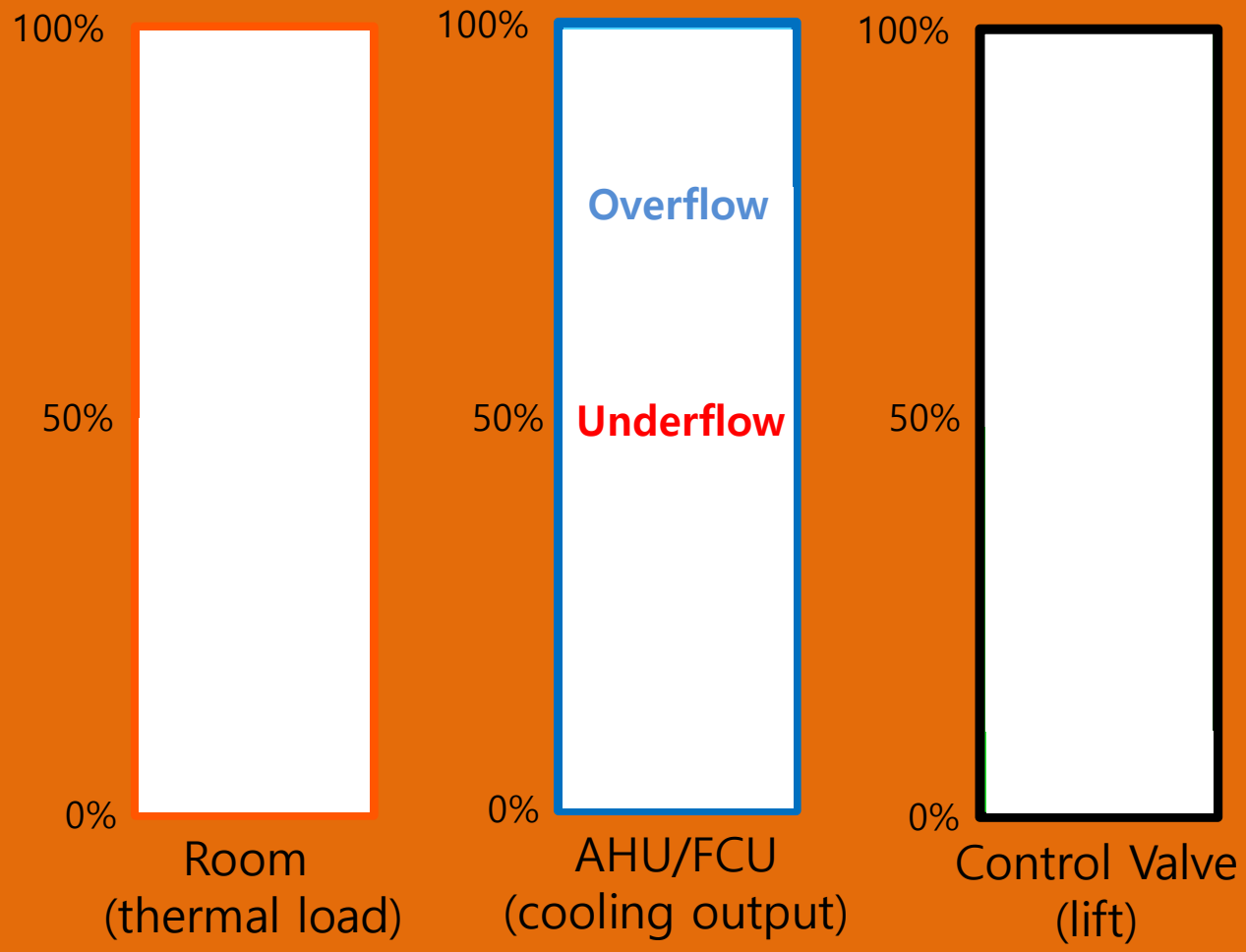
2 options available to achieve close to 100% authority

- Independent ‘differential pressure controllers” on each circuit
- Adjustable KVs control valve with fixed EQM characteristic

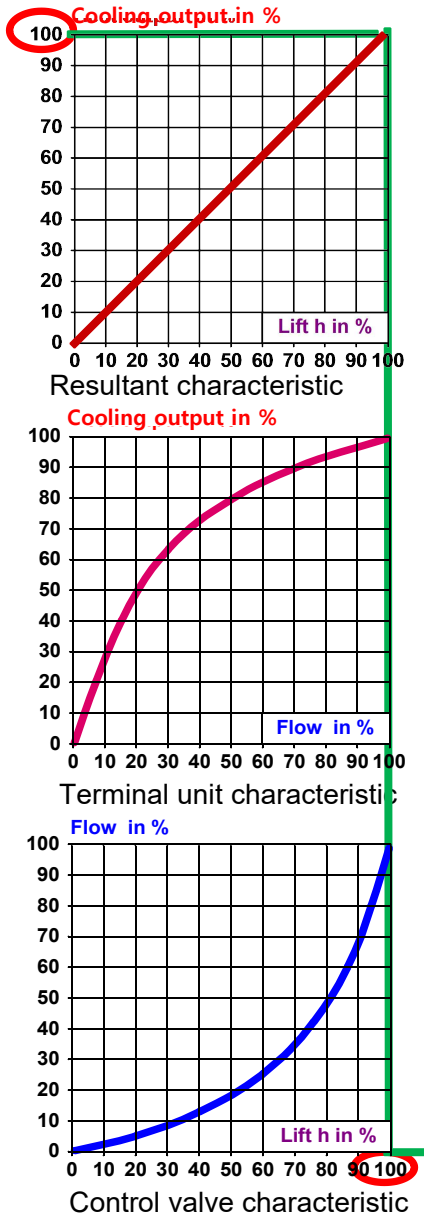
"Good" Authority Valve



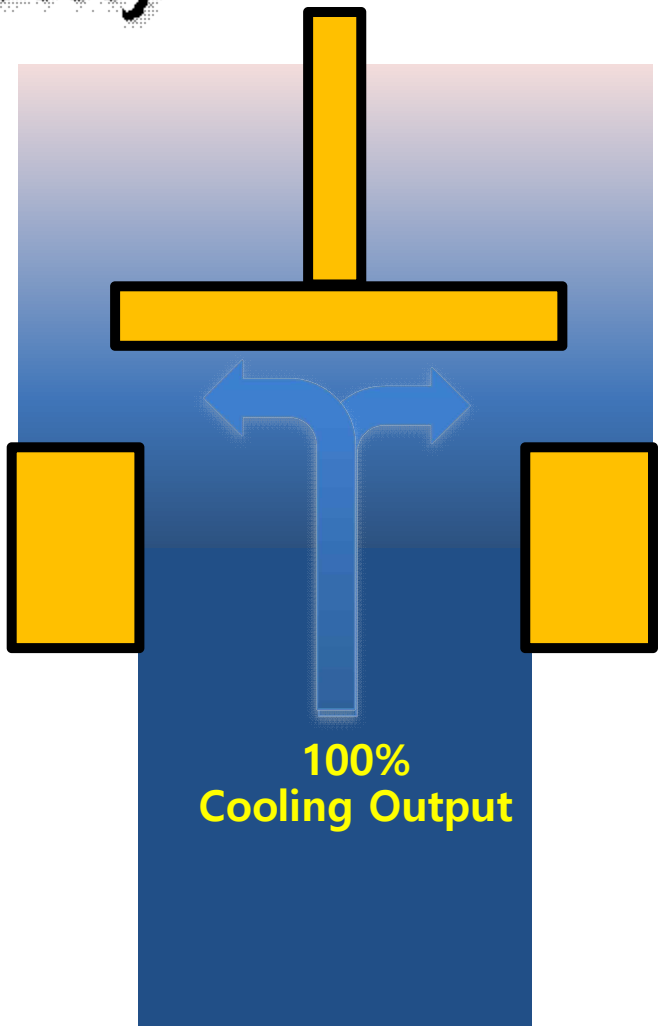
"Bad" Authority Valve



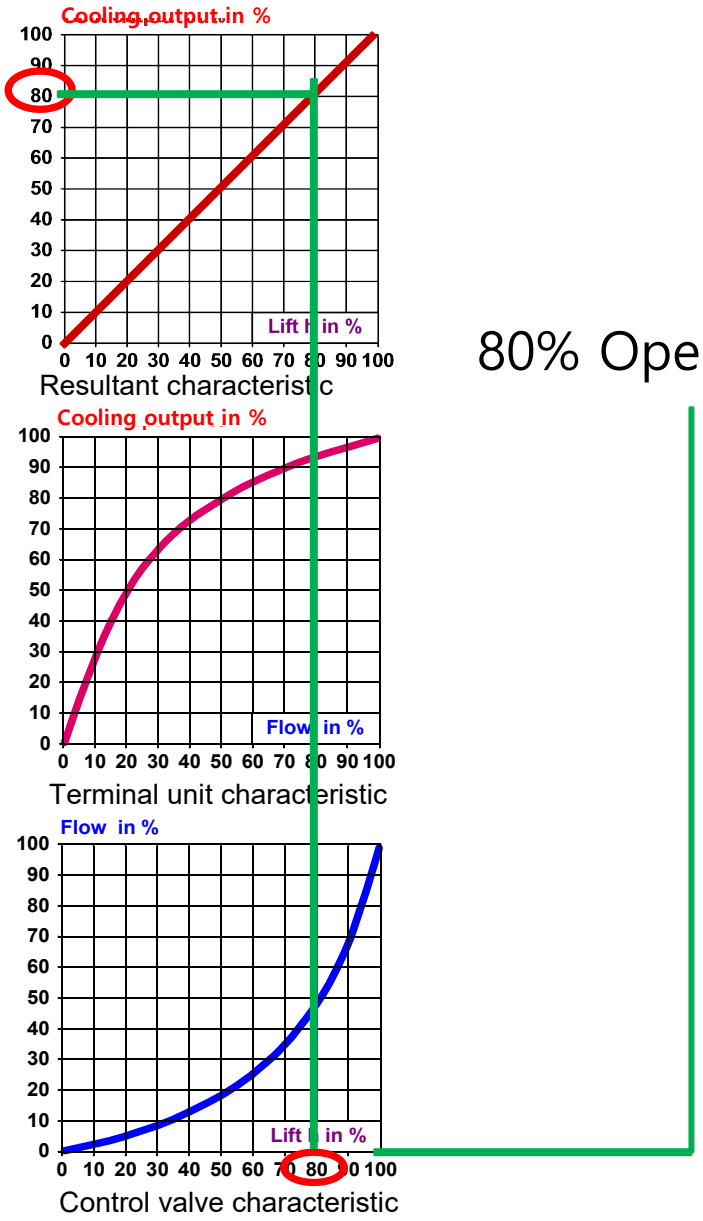
Good Valve Authority



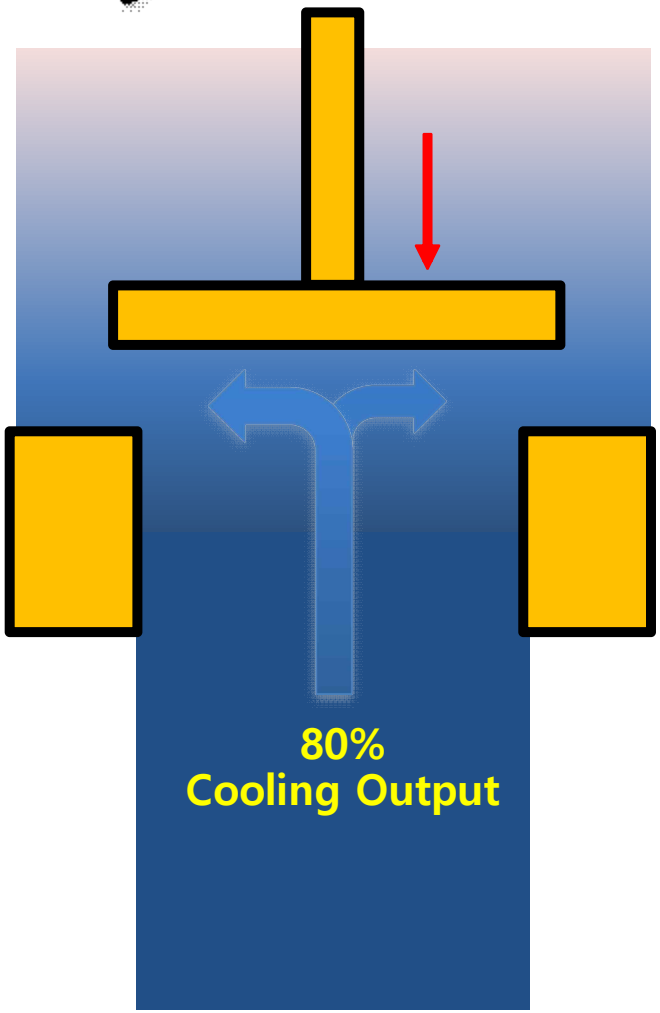
100% Opening



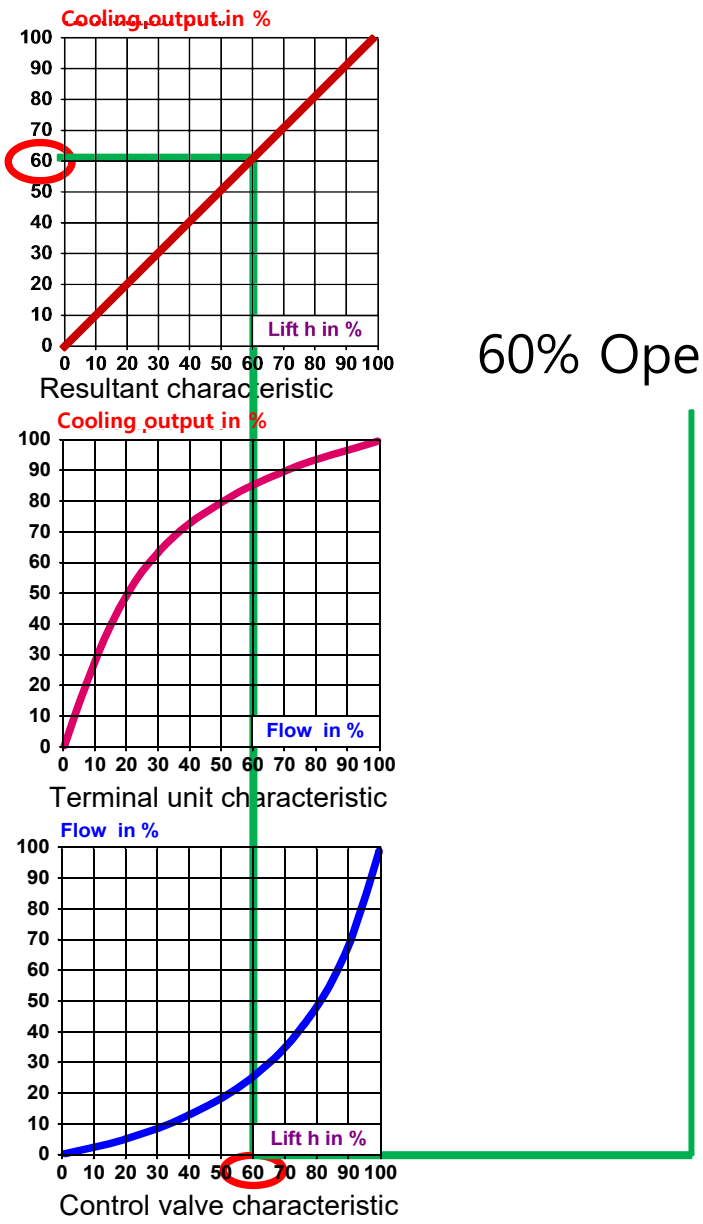
Good Valve Authority



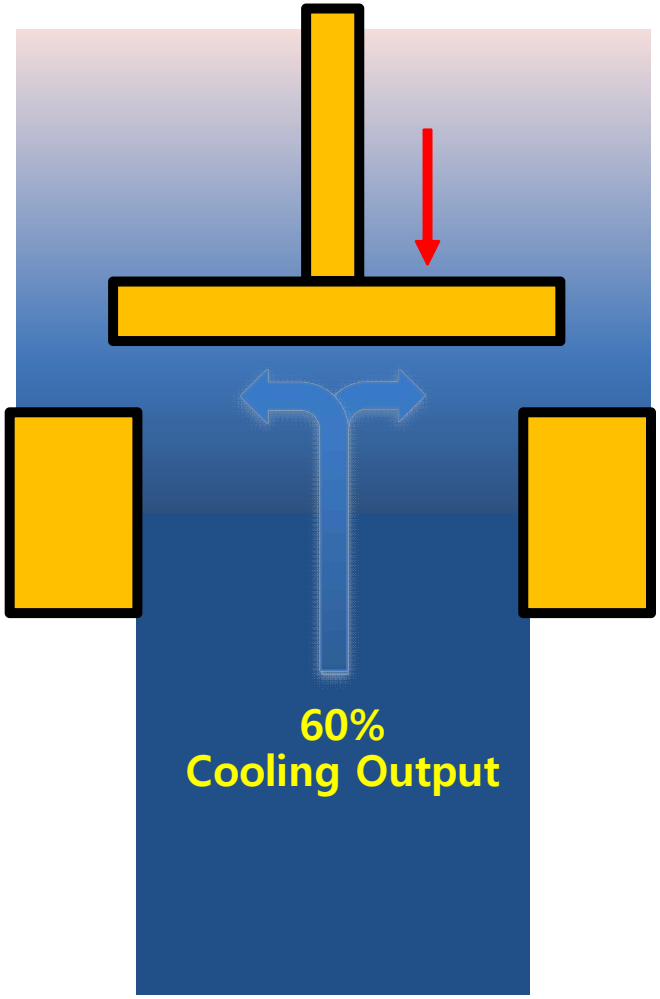
80% Opening



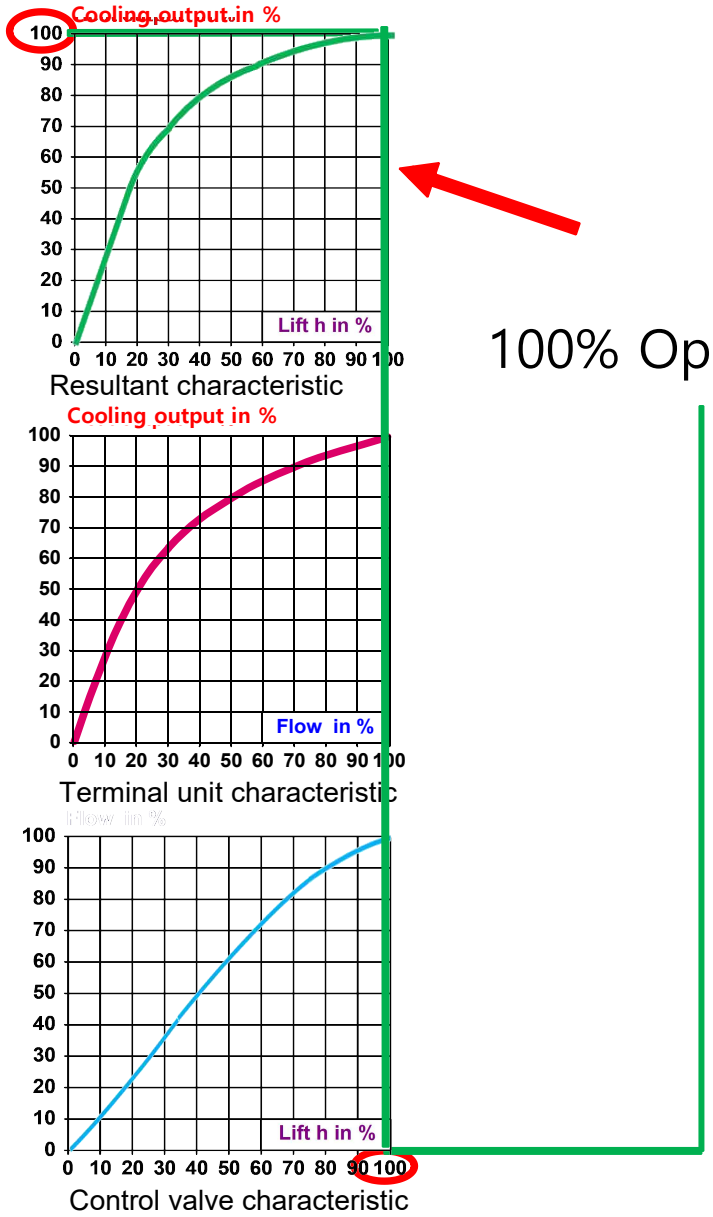
Good Valve Authority



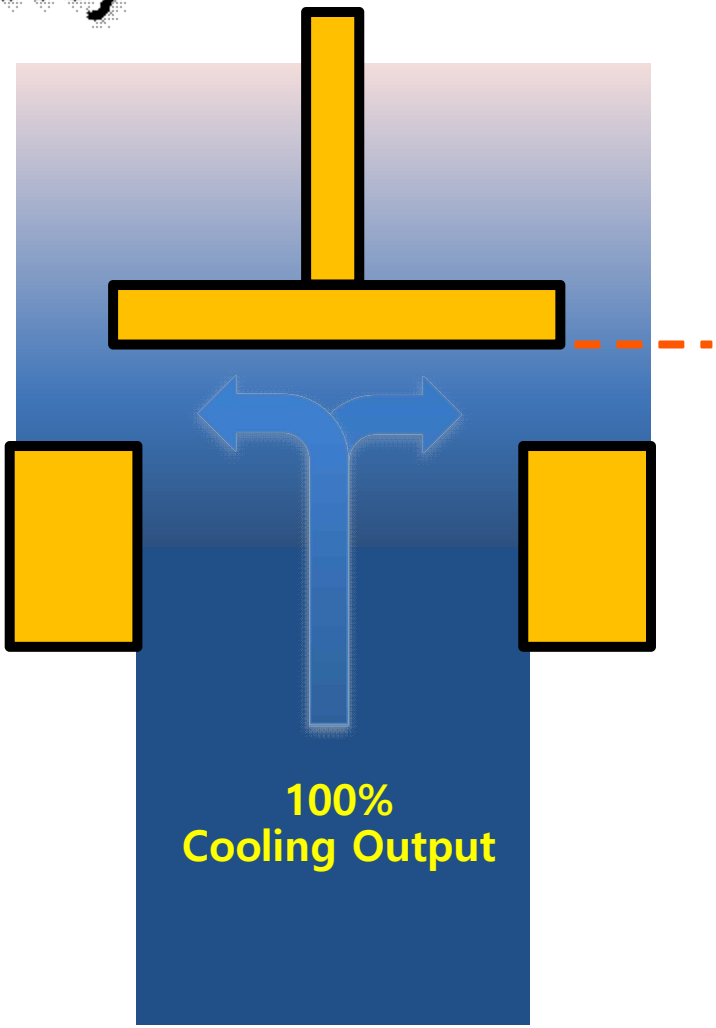
60% Opening



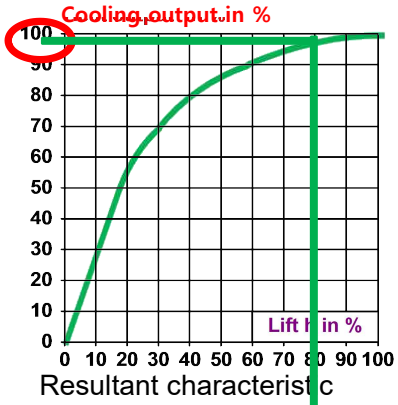
Bad Valve Authority



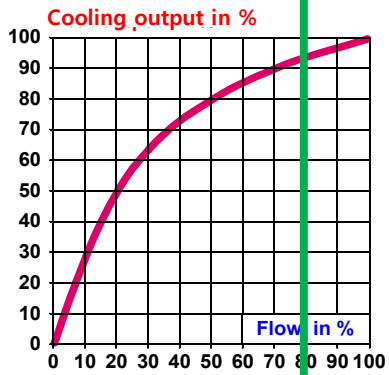
100% Opening



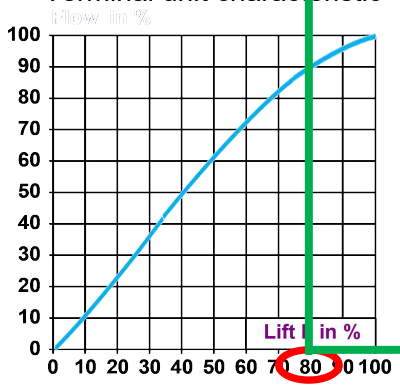
Bad Valve Authority



Resultant characteristic

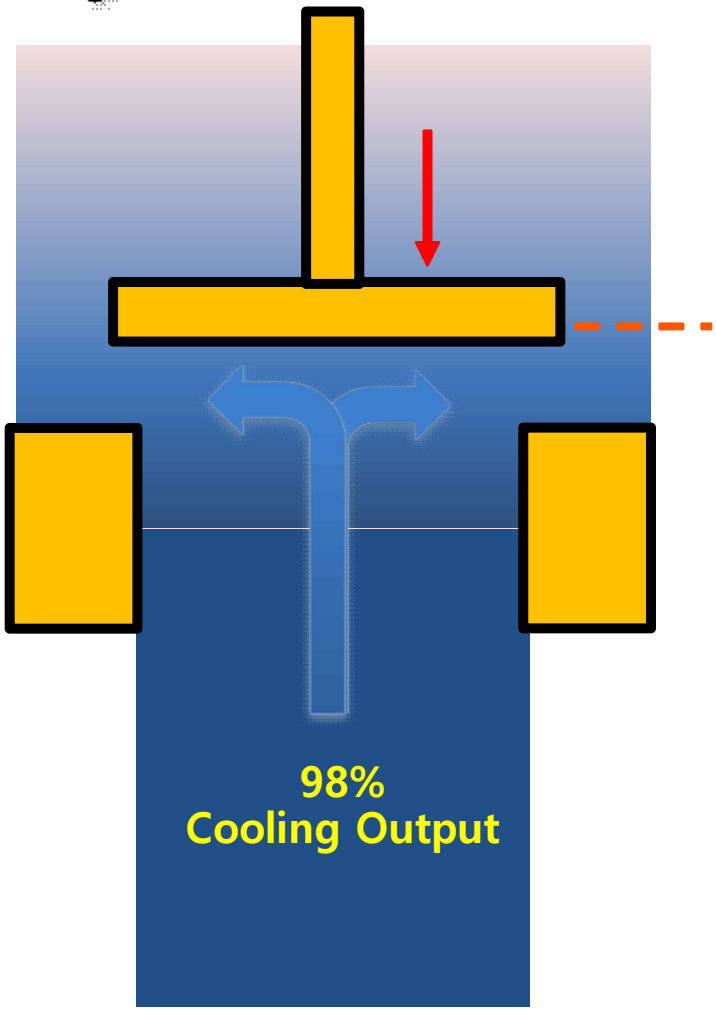


Terminal unit characteristic

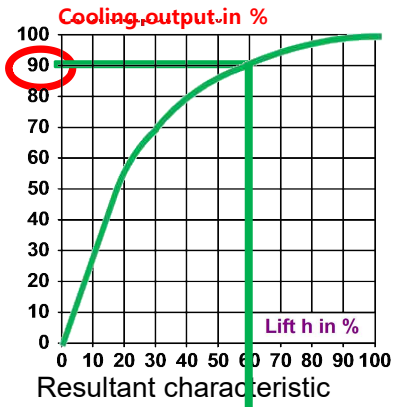


Control valve characteristic

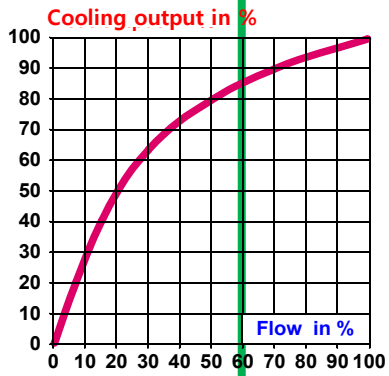
80% Opening



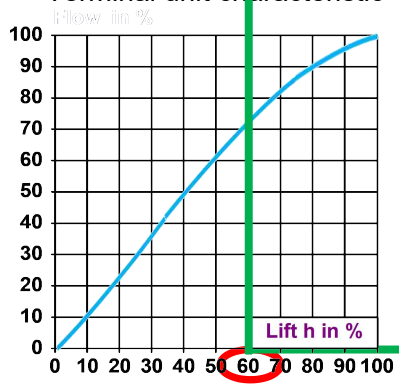
Bad Valve Authority



Resultant characteristic

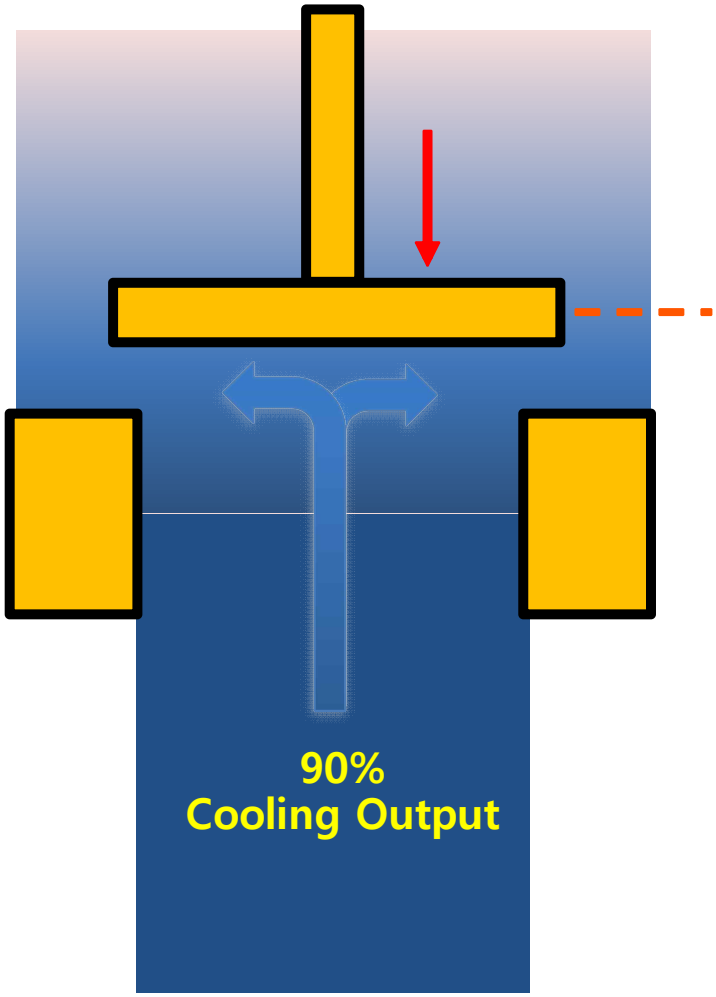


Terminal unit characteristic

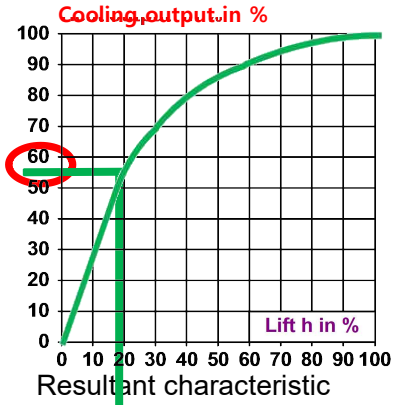


Control valve characteristic

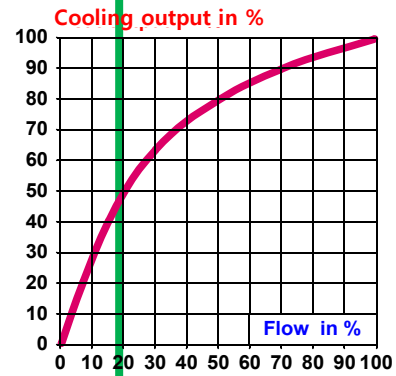
60% Opening



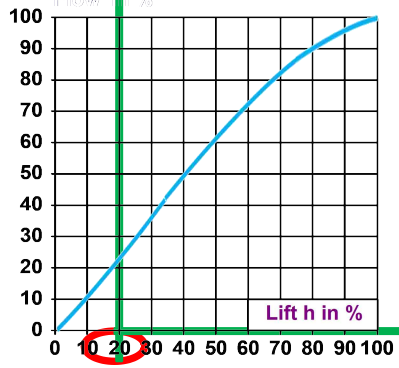
Bad Valve Authority



Resultant characteristic

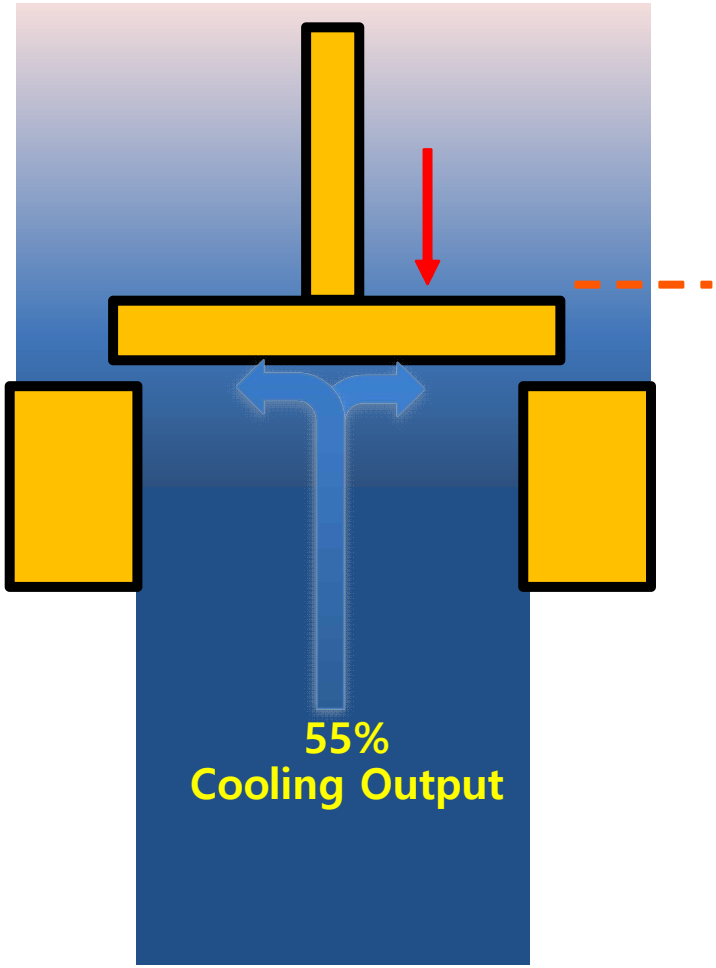


Terminal unit characteristic



Control valve characteristic

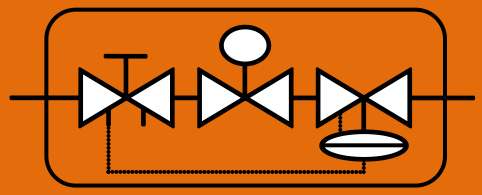
20% Opening

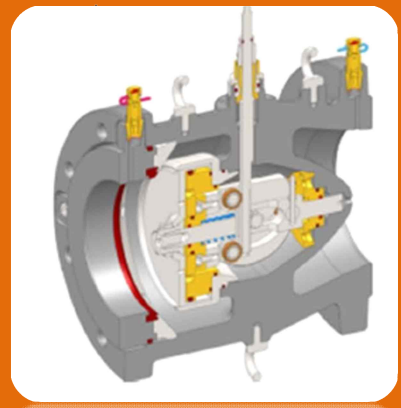


Terminal. Control valve. BAS

- 유량과 차압 관계
- Coil 성능특성(ASHRAE 90.1)
- Valve 성능 특성
- Authority
- **PIBCV**

압력 독립 밸런싱 컨트롤 밸브
(Pressure Independent Balancing Control valve)





✓ 조정 가능한 Kvs

✓ 독립적인 EQM 특성

✓ 탁월한 부하 조정비 (Rangebility)

- 3가지 기능(밸런싱, 컨트롤, 차압 컨트롤)이 한개 밸브에 모두 포함되어 있다.
- 이러한 밸브 종류에 대해서, 여러 명칭이 사용된다 :
  - **압력 독립 밸런싱 컨트롤 밸브 (PIBCV)**
  - **(P**ressure **I**ndependent **B**alancing and **C**ontrol **V**alve)
  - (이 기능의 제품에 대한 TA의 공식적인 명칭)
  - … 그러나 또한 다음의 여러 명칭의 이름을 보게 된다.

    복합 밸브
    유량과 온도 컨트롤러
    컨트롤과 밸런싱 밸브…